

Global Memory Tech

BofA memory indicator exceeded 2H21 peak

Industry Overview

December results led to V-shaped recovery in 2023

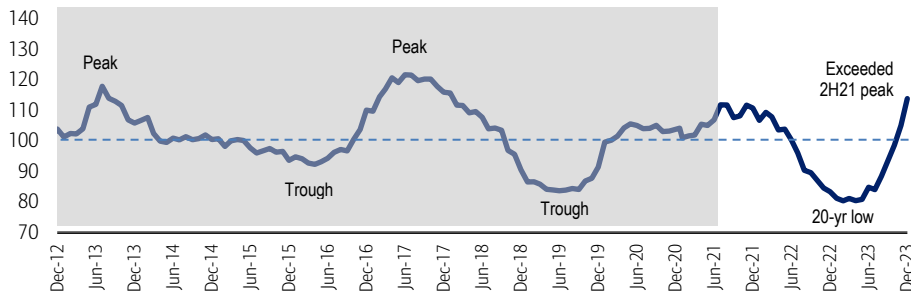
Our memory indicator, which measures YoY change among seven components (DRAM and NAND spot/ASP/billings and Korea's semis exports), improved further in Dec 2023 (114; above mid-cycle of 100) from 99/105 in Oct/Nov. This is even slightly higher than the 2H21 peak (112). Key contributors should be a strong recovery in NAND spot price (up more than 50% YoY) and billings (DRAM: +78% YoY, NAND: +48%). This is consistent with Korean chipmakers' 4Q23 robust bit growth (Samsung Electronics: mid-35% QoQ for both DRAM and NAND) and even NAND ASP (SK Hynix: 40%+ QoQ). We also note almost V-shaped turnaround in the memory indicator after a 20-year low trough (80-81 in Jan-May) and then more meaningful recovery through Aug/Sept (88/94). Of course, Dec indicator is still lower than previous upcycle levels (120-130+ in 2019-10/2017).

Jan-Feb prices/exports also up strongly YoY

Jan spot price rebounded further (+5% MoM for both DRAM/NAND) even after Nov-Dec strength. Korea's Jan semis export growth (mostly memory chips) also hit a 6-year high at 56% YoY. Three factors seem to have led to strong YTD growth – ASP hike, volume increase and mix improvement (with HBM). We also see spot-price strengths ahead of Lunar New Year holiday (10 Feb), which is a typical trend during memory upcycle period. Of course, we acknowledge potentially decelerating growth rates in Korea semis exports and NAND spot price after Jan-Feb peak, but too early to see a downturn signal.

Exhibit 2: BofA Memory Indicator – V-shaped recovery through 2023

Above mid-cycle through Nov-Dec vs 20-year low in 1H23



Source: DRAMeXchange, WSTS, MoTIE Korea, BofA Global Research

The shaded area represents backtested results from January 1991 to March 2021. The unshaded area represents actual performance since April 2021. This performance is backtested up to March 2021, and does not represent the actual performance of any account or fund. Back-tested performance depicts the theoretical (not actual) performance of a particular strategy over the time period indicated. No representation is being made that any actual portfolio is likely to have achieved returns similar to those shown herein.

Disclaimer: The BofA Memory Indicator is intended to be an indicative metric only and may not be used for reference purposes or as a measure of performance for any financial instrument or contract, or otherwise relied upon by third parties for any other purpose, without the prior written consent of BofA Global Research. This indicator was not created to act as a benchmark

BofA GLOBAL RESEARCH

>> Employed by a non-US affiliate of BofAS and is not registered/qualified as a research analyst under the FINRA rules.

Refer to "Other Important Disclosures" for information on certain BofA Securities entities that take responsibility for the information herein in particular jurisdictions.

BofA Securities does and seeks to do business with issuers covered in its research reports. As a result, investors should be aware that the firm may have a conflict of interest that could affect the objectivity of this report. Investors should consider this report as only a single factor in making their investment decision.

Refer to important disclosures on page 10 to 12.

12655216

Timestamp: 05 February 2024 06:38AM EST

05 February 2024

Equity
Global
Technology

Simon Woo, CFA >>
Research Analyst
Merrill Lynch (Seoul)
+82 2 3707 0554
simon.woo@bofa.com

Dai Shen >>
Research Analyst
Merrill Lynch (Hong Kong)
dai.shen@bofa.com

Vivek Arya
Research Analyst
BofAS
vivek.arya@bofa.com

Mikio Hirakawa >>
Research Analyst
BofAS Japan
mikio.hirakawa@bofa.com

Matt Shin >>
Research Analyst
Merrill Lynch (Seoul)
matt.shin2@bofa.com

Exhibit 1: Seven components of BofA memory indicator

Jan-Feb MoM improvement continues

	Oct-23	Nov-23	Dec-23	Jan-24
MoM				
DRAM spot price	Up	Up	Up	Up
NAND spot price	Up	Up	Up	Up
Korea semis exports	Down	Up	Up	Up
DRAM ASP	Up	Down	Up	na
NAND ASP	Up	Up	Up	na
DRAM billings	Down	Up	Up	na
NAND billings	Down	Up	Up	na

Source: DRAMeXchange, WSTS, MoTIE Korea, BofA Global Research

BofA GLOBAL RESEARCH

DRAM: Dynamic random-access memory**NAND:** Not-AND memory**ASP:** Average selling price**HBM:** High bandwidth memory**OEM:** Original equipment manufacturer

See Methodology section to understand how we constructed our indicator (standardized YoY changes of seven components).

More abbreviations are in the Appendix section on page 9.

Full details of BofA Memory Indicator

Exhibit 3: Seven components of BofA Memory Indicator – MoM and YoY trends (back-tested)

Jan spot price rebounded further (+5% MoM for both DRAM/NAND) even after Nov-Dec strength; Korea's Jan semis export growth (mostly memory chips) also hit a 6-year high at 56% YoY; we acknowledge potentially decelerating growth rates in Korea semis exports and NAND spot price after Jan-Feb peak, but too early to see a downturn signal

	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24
MoM													
DRAM spot price	Down	Down	Down	Down	Up	Down	Down	Down	Up	Up	Up	Up	Up
NAND spot price	Down	Down	Down	Down	Down	Down	Down	Up	Up	Up	Up	Up	Up
Korea semis exports	Down	Down	Up	Down	Up	Up	Down	Up	Up	Down	Up	Up	Down
DRAM ASP	Down	Up	Down	Up	Up	Down	Up	Up	Up	Up	Down	Down	na
NAND ASP	Up	Down	Down	Up	Down	Down	Up	Down	Down	Up	Up	Up	na
DRAM billings	Down	Up	Up	Down	Up	Up	Down	Up	Up	Down	Up	Up	na
NAND billings	Down	Up	Up	Down	Up	Up	Down	Up	Up	Down	Up	Up	na
Avg of MoM trend	Down	Up	Up	Down	Up	Up	Down	Up	Up	Down	Up	Up	na
YoY													
DRAM spot price	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down
NAND spot price	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Up	Up	Up
Korea semis exports	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Up	Up	Up
DRAM ASP	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Up	na
NAND ASP	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	na
DRAM billings	Down	Down	Down	Down	Down	Down	Down	Down	Up	Up	Up	Up	na
NAND billings	Down	Down	Down	Down	Down	Down	Down	Down	Down	Up	Up	Up	na
Avg of YoY trend	Down	Down	Down	Down	Down	Down	Down	Down	Down	Down	Up	Up	na
Memory indicator	81	80	81	80	81	85	84	88	94	99	105	114	na

Source: DRAmEXchange, WSTS, MoTIE Korea, BofA Global Research estimates.

Notes: *Dec-23 results recovered in all aspects in terms of MoM growth except DRAM ASP (non-HBM price still showed YoY decline)

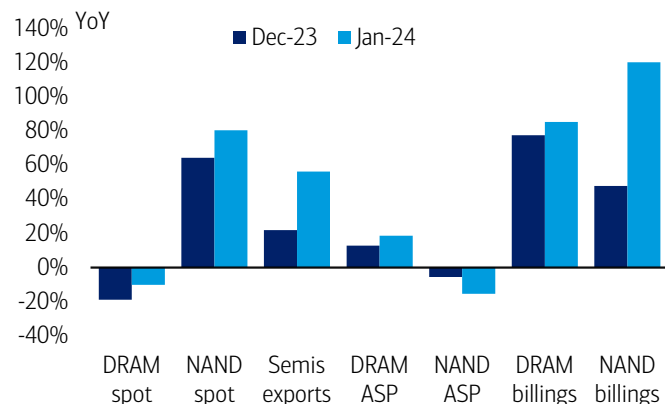
**For Jan-24, only spot prices and exports are reported so far

*** DRAM spot price is based on average MoM change in 8Gb DDR4 and 16Gb DDR5, while NAND spot price is based on average MoM change in 512Gb wafer spot price

BofA GLOBAL RESEARCH

Exhibit 4: Seven components of BofA Memory Indicator – YoY

Jan industry data are expected to be better vs Dec – YoY increase in NAND billings (price x volume), exports and NAND spot outstanding



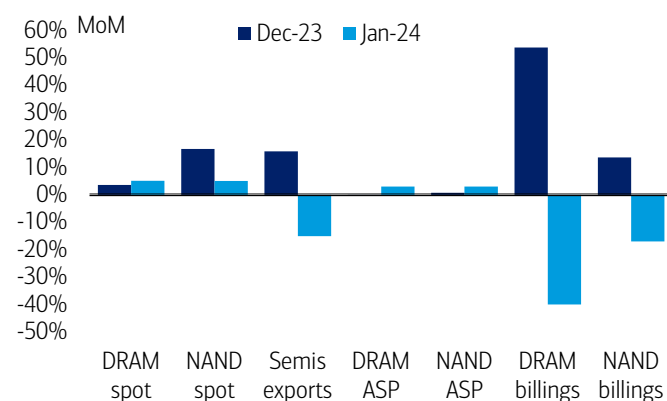
*All December data and January spot/exports are actual, but January billings are our estimates

Source: DRAmEXchange, WSTS, MoTIE Korea, BofA Global Research estimates

BofA GLOBAL RESEARCH

Exhibit 5: Seven components of BofA Memory Indicator – MoM

Most of the components recovered well MoM in Dec 2023; Jan billings expected to be lower due to high base (Dec) but price (spot/ASP) recovery is expected to continue into Jan/Feb



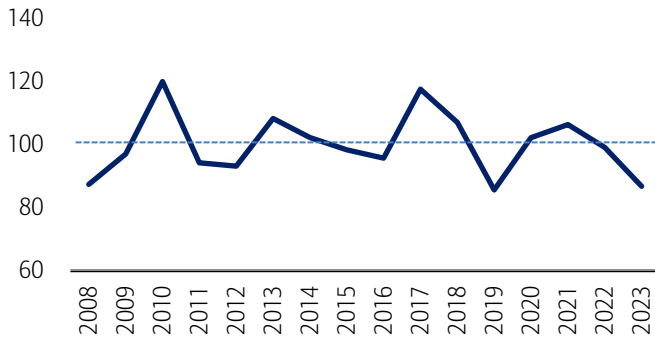
*All December data and January spot/exports are actual, but January billings are our estimates

Source: DRAmEXchange, WSTS, MoTIE Korea, BofA Global Research estimates

BofA GLOBAL RESEARCH

Exhibit 6: BofA memory indicator annual average

2023 indicator (simple average of 12 months) is close to 20-year low (2008, 2019) due mainly to deep 1H23 downturn

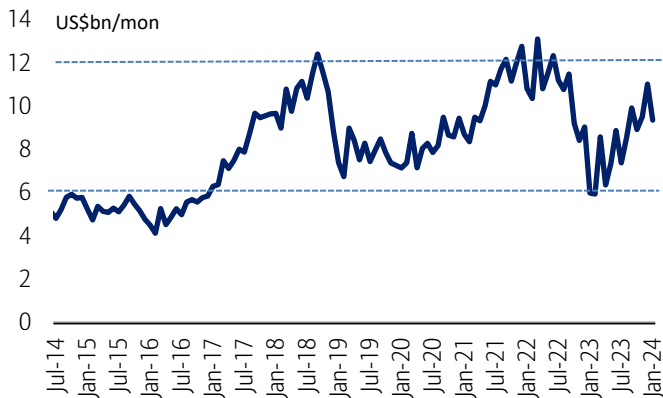


Source: BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 8: Korea semis exports – US\$bn monthly

Down 15% MoM (Korean chipmakers' bit supply cut vs 4Q23) but still resilient at US\$9.4bn in Jan-2024

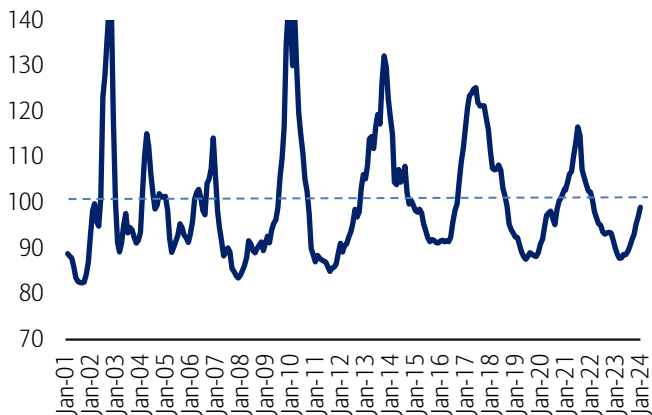


Source: MoTIE, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 10: DRAM spot price - indexed YoY change (historical avg 100)

Still below mid-cycle due to non-HBM (limited price recovery of DDR4)

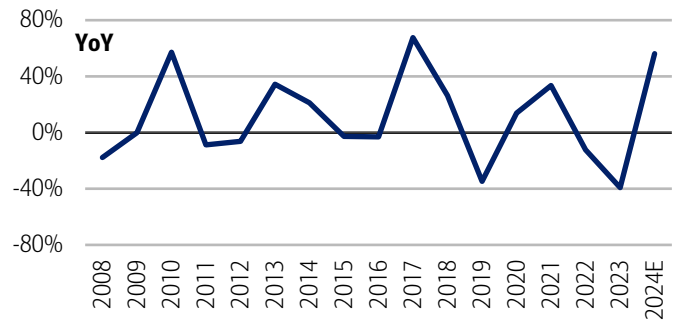


Source: DRAmEXchange, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 7: Global DRAM+NAND annual sales YoY

We forecast +56% in 2024 combined DRAM+NAND sales vs -39% in 2023 and -35% in 2019



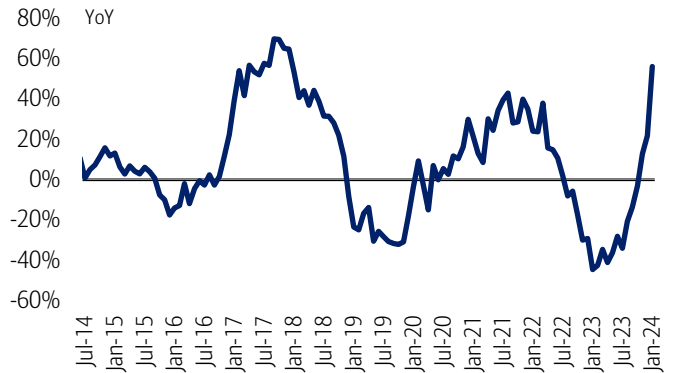
2024E growth is based on our DRAM and NAND estimates

Source: WSTS, BofA Global Research estimates

BofA GLOBAL RESEARCH

Exhibit 9: Korea semis exports – YoY change in monthly US\$bn

Significant YoY rebound seen in Jan-2024 (+56%), even stronger than 2020-21 recovery; HBM and NAND price/volume driven

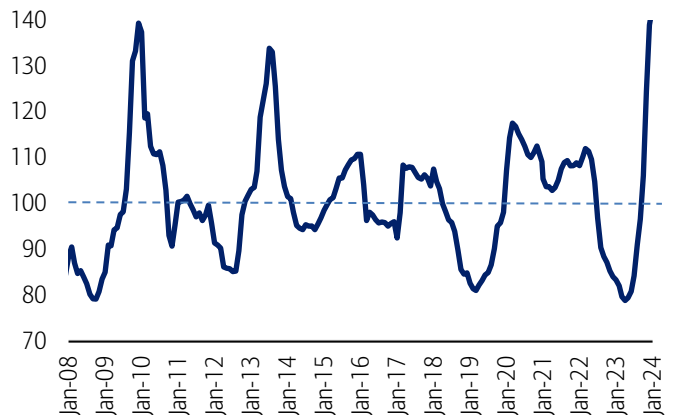


Source: MoTIE, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 11: NAND spot price – indexed YoY chg (historical avg 100)

Already hit peak level but downside low given production cut

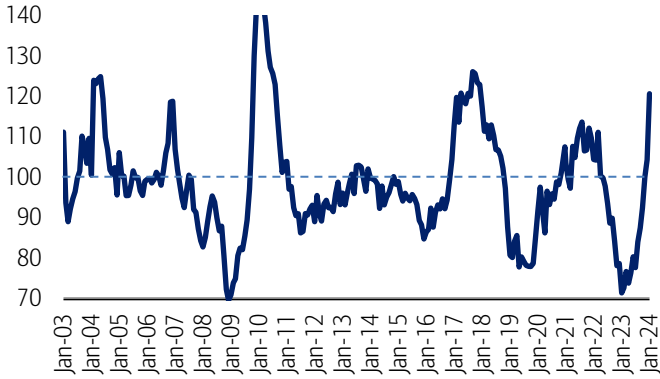


Source: DRAmEXchange, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 12: Korea semis exports - indexed YoY chg (historical avg 100)

Jan-24 export growth (indexed) close to 2017 peak level

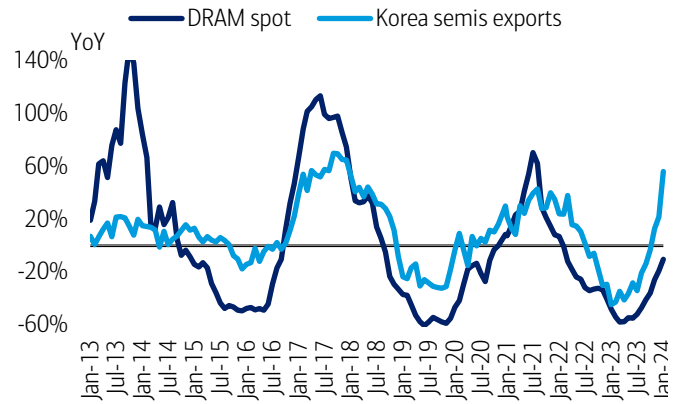


Source: MoTIE, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 13: DRAM spot price and Korea semis exports – YoY change

Korea semis exports growth better than spot due to HBM and DDR5

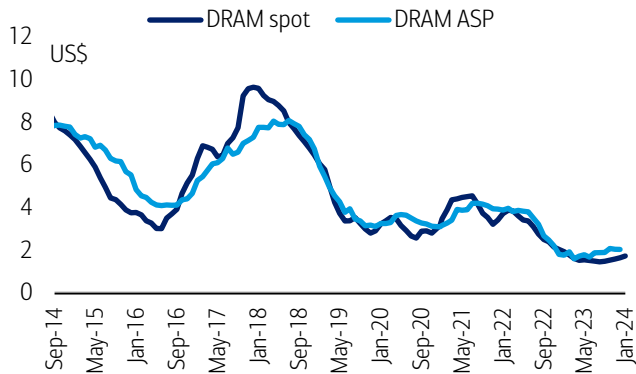


Source: DRAMeXchange, MoTIE, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 14: DRAM spot and ASP trend – month average; 8Gb equiv.

DRAM ASP (mostly contract price) recovery better than spot due to HBM, but both (ASP and spot) still shows only US\$2+/- per GB

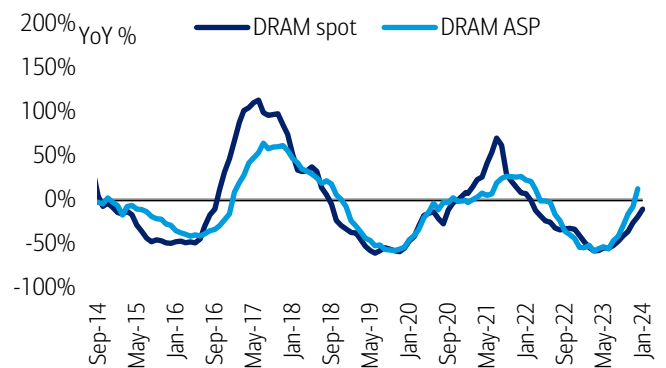


Source: DRAMeXchange, WSTS, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 15: DRAM spot and ASP change – YoY trend

ASP recovered +13% YoY in Dec-23, but still YoY decline seen in Jan spot (-10%)

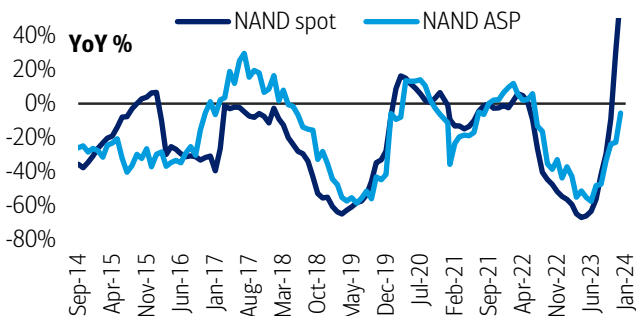


Source: DRAMeXchange, WSTS, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 16: NAND spot and ASP trend – YoY

Dec-23 NAND ASP (mostly contract price) still 6% lower than a year ago despite strongly recovered spot (more than 50% YoY)

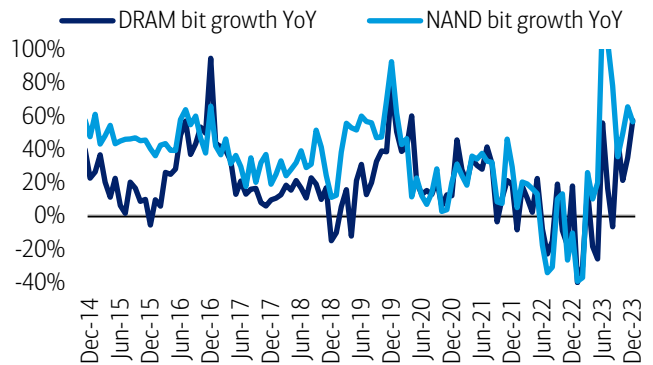


Source: DRAMeXchange, WSTS, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 17: DRAM and NAND bit growth – YoY

Dec-23 bit growth more than 50%+ YoY in both DRAM/NAND

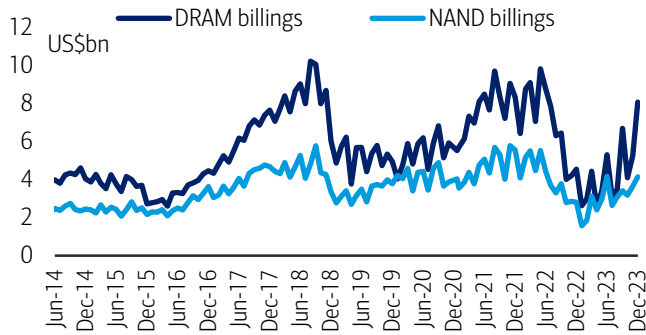


Jun/Jul actual DRAM ASP decline less than what WSTS reported based on major suppliers' 2Q results and guidance Source: WSTS, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 18: DRAM and NAND billings

Dec 2023 DRAM/NAND billings (US\$8/4bn) hit 18-month high

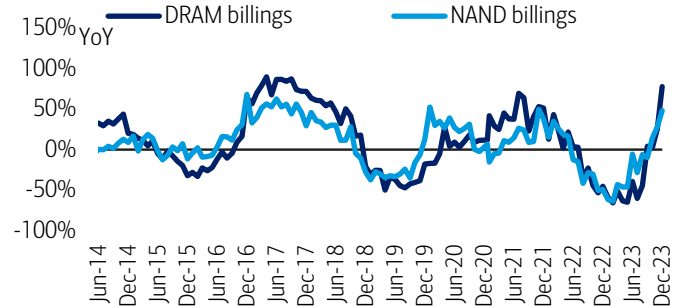


Source: WSTS, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 19: DRAM and NAND billings change – YoY

Strong YoY recovery in Dec 2023 billings seen (DRAM +78%, NAND +48%)

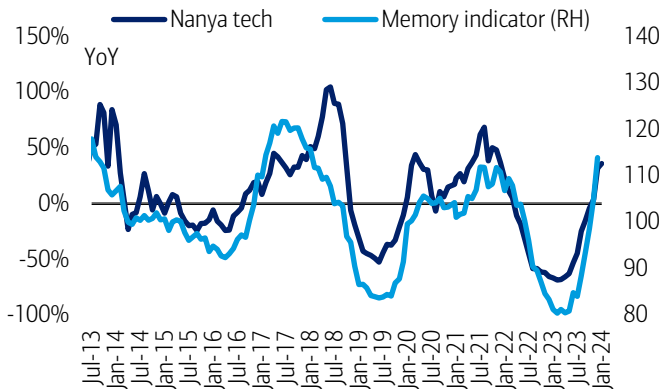


Source: WSTS, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 20: Nanya Tech monthly YoY sales vs Memory indicator

Robust YoY recovery continued in Jan-2024 (+36%) vs Dec (+32%)

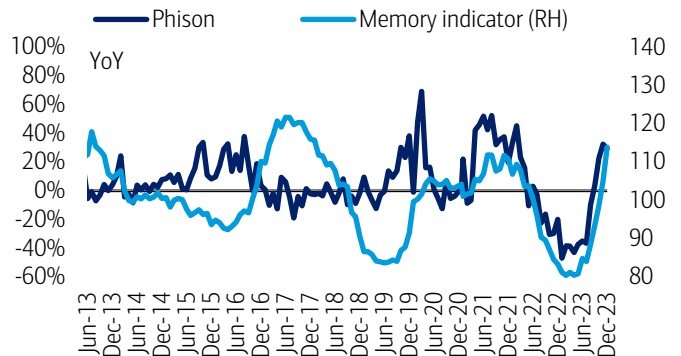


Source: Company report, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 21: Phison monthly and YoY sales vs Memory Indicator

Strong rebound of 23-32% in Oct-Dec 2023; Jan data not yet available

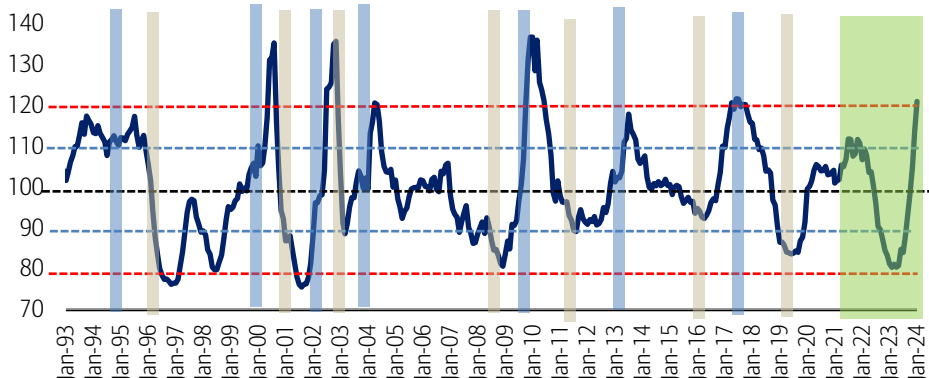


Source: Company report, BofA Global Research

BofA GLOBAL RESEARCH

Exhibit 22: BofA Memory Indicator's overall back-tested trend in the past 30 years

Seven peaks and seven troughs in the past 30 years up to 2020; back to above mid-cycle in Nov/Dec 2023 following 20-year low 1H23



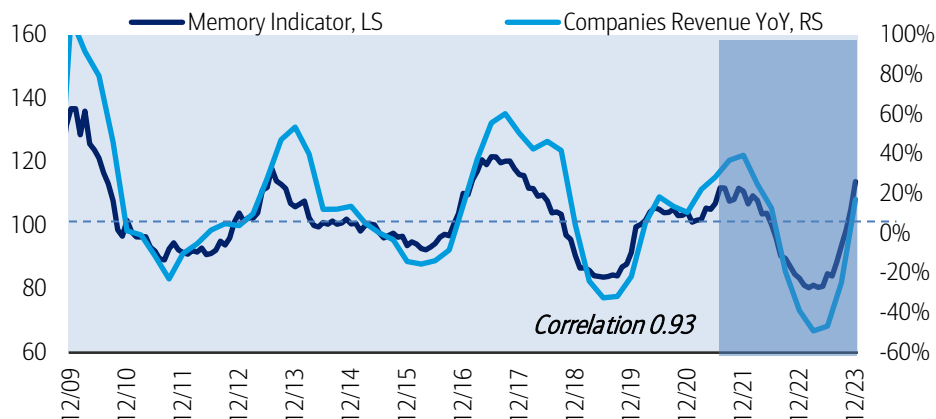
Source: DRAMeXchange, WSTS, MoTIE Korea, BofA Global Research.

*Note: Blue represents Peak, Grey represents Trough, Green represents actual data since April 2021; prior period is back-tested results. This performance is backtested up to March-21 and does not represent the actual performance of any account or fund. Back-tested performance depicts the theoretical (not actual) performance of a particular strategy over the time period indicated. No representation is being made that any actual portfolio is likely to have achieved returns similar to those shown herein.

BofA GLOBAL RESEARCH

Exhibit 23: BofA Memory Indicator is highly correlated with memory companies' revenue growth

Memory chipmakers' 4Q23 revenue growth turned positive after 5 quarters long contraction (3Q22-3Q23); in-line with our memory indicator bottom/recovery through 2H22-2H23



The companies' revenue YoY is the average of Samsung, Hynix, Micron, and Nanya's year-on-year revenue change

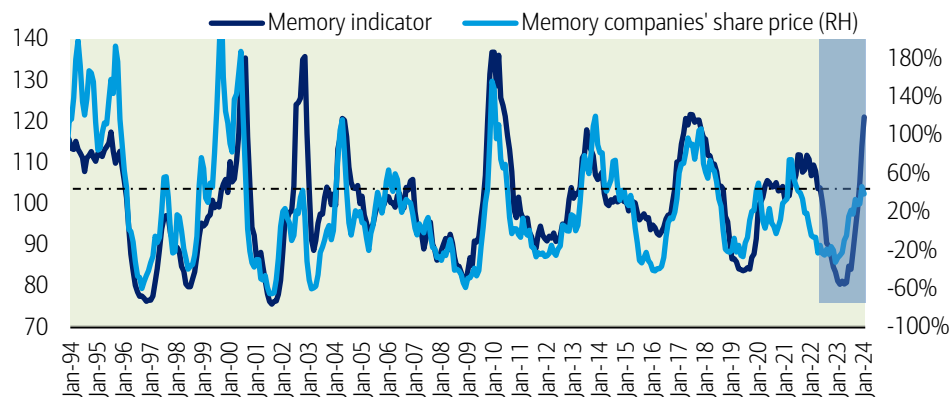
Source: Company report, DRAMeXchange, WSTS, MoTIE Korea, BofA Global Research

The light blue shaded area represents backtested results from January 1991 to March 2021. The dark blue shaded area represents actual data since April 2021. This performance is backtested up to March 2021 and does not represent the actual performance of any account or fund. Backtested performance depicts the theoretical (not actual) performance of a particular strategy over the time period indicated. No representation is being made that any actual portfolio is likely to have achieved returns similar to those shown herein. Historic correlation does not necessarily indicate that correlation will continue in the future.

BofA GLOBAL RESEARCH

Exhibit 24: BofA Memory Indicator is highly correlated with stock performance

Memory stock rally slightly muted as of early Feb but memory indicator recovery on track



Note: Memory companies share price is average of Samsung, Hynix, Micron, and Nanya share price YoY changes

Source: Bloomberg, BofA Global Research

The light green shaded area represents backtested results from January 1991 to March 2021. The blue shaded area represents actual data since April 2021. This performance is backtested up to March 2021 and does not represent the actual performance of any account or fund. Backtested performance depicts the theoretical (not actual) performance of a particular strategy over the time period indicated. No representation is being made that any actual portfolio is likely to have achieved returns similar to those shown herein. Historic correlation does not necessarily indicate that correlation will continue in the future.

BofA GLOBAL RESEARCH

Methodology

We selected our seven components based on what we believe are the key datapoints in understanding the memory cycle. WSTS and DRAMeXchange data represent industry-

level numbers, while Korea semiconductor exports represent macro-level data. Our indicator is equal-weighted among the components as memory companies' revenues are not skewed to a singular factor, but rather influenced by supply and demand for both DRAM and NAND. Further, our current methodology shows the most consistent as well as the highest correlation to companies' revenues (0.93 since 2009 on a back-tested basis). Our Indicator was launched on 19 April 2021.

Spot prices are available with the least time lag (given daily trade), while WSTS data are available with around 33-days lag. Our updated indicator is published early every month and provides a preliminary insight into the previous month as well as a final reading of two months prior. For example, our early-Oct 2022 report showed September preliminary and August final values and will provide insights of the 3Q22 results, which will be confirmed by the companies in their late-October results calls. We believe that this would be useful to tech investors, given that memory companies do not announce monthly results (unlike other Taiwanese companies), and also as memory stocks are sensitive to short-term earnings momentum.

Exhibit 25: Seven elements of our memory indicator; all % YoY and equally weighted

DRAM data focused on 1990s and early 2000s, but full coverage with NAND and Korea exports from 2002

Input	Source	Available since	Frequency	Availability
DRAM spot	DRAMeXchange	Feb-00	Daily	End of every day
NAND spot	DRAMeXchange	Nov-06	Daily	End of every day
DRAM WSTS ASP	World Semiconductor Trade Statistics	Jan-91	Monthly	33-day following end-month
DRAM WSTS billings	World Semiconductor Trade Statistics	Jan-90	Monthly	33-day following end-month
NAND WSTS ASP	World Semiconductor Trade Statistics	Jan-04	Monthly	33-day following end-month
NAND WSTS billings	World Semiconductor Trade Statistics	Jan-04	Monthly	33-day following end-month
Korea exports	Ministry of Trade, Industry, and Energy	Jan-02	Monthly	First of the following month

Source: BofA Global Research

BofA GLOBAL RESEARCH

DRAM/NAND spot prices: Spot prices mostly represent the pricing trend of commodity or low-quality chips traded in the spot market. Current mainstream specs are 8Gb DDR4 DRAM and 256Gb 3D NAND.

DRAM/NAND WSTS billings: WSTS billings represent total global DRAM/NAND sales amount (USD basis; units x prices) during a month.

DRAM/NAND WSTS ASP: We derive it from sales (USD-denominated, even for China, Japan and Europe OEM customers) vs. volume (normally converted into 8Gb DRAM and 256Gb NAND equivalents). The WSTS ASP numbers involve more contract prices (normally settled a month or a quarter ago, thus lagging vs. daily spot prices) for the PC/server/mobile memory chips traded between chipmakers and end-users (OEMs, component makers, DRAM/SSD module makers, etc.).

Korea semiconductor exports: Mostly comprises memory chips fabricated by Samsung and SK Hynix. Combined global market share of Samsung and SK Hynix should be 70-80% / 50-60% for DRAM / NAND, respectively, over the past four years (2017-20).

Limitations to our back-testing: We note that not all seven inputs are available from 1990 (when DRAM WSTS ASP YoY value was available). We thus added them as and when the data became available. The other limitation is the exclusion of Kioxia and Western Digital from our target variable analysis due to complexities regarding the two companies' co-owned JV fabs and only NAND-related results (none for DRAM).

Back-testing disclaimer

This performance is back-tested and does not represent the actual performance of any account or fund. Back-tested performance depicts the theoretical (not actual) performance of a particular strategy over the time period indicated. No representation is

being made that any actual portfolio is likely to have achieved returns similar to those shown herein. In fact, there are frequently sharp differences between back-tested returns and the actual results realized in the actual management of a portfolio. Back-tested performance results are created by applying an investment strategy or methodology to historical data and attempts to give an indication as to how a strategy might have performed during a certain period in the past if the product had been in existence during such time. Back-tested results have inherent limitations, including the fact that they are calculated with the full benefit of hindsight, which allows the security selection methodology to be adjusted to maximize the returns. Further, the results shown do not reflect actual trading or the impact that material economic and market factors might have had on a portfolio manager's decision-making under actual circumstances. Back-tested returns do not reflect advisory fees, trading costs, or other fees or expenses.

Appendix

DRAM: Dynamic random-access memory

DRAM stores data temporarily using billions of tiny capacitors and transistors to support logic processor on a real-time basis. The processor sends/receives data to/from DRAM. Thus, DRAM's capacity (1Gb, 4Gb, 8Gb), speed (2Ghz, 6Ghz) and low-power consumption (1.1V, 1.05V) are critical for processors (Intel CPU, Qualcomm AP, NVIDIA GPU, etc.).

NAND: Not-AND flash memory

NAND stores data permanently in transistors (vs. DRAM temporarily using both capacitor and transistor). NOR (Not OR) used to be a main flash memory in 1990s and early 2000s, but it has been gradually replaced by NAND at a much lower price in the past 10 years. Most NAND is now fabricated at 3D multi-layer (e.g., Samsung's 128-layer) instead of 2D planar.

Memory price

Memory average selling price (ASP) is simply derived from sales (USD-denominated, even for China, Japan and Europe exports) vs. volume (normally converted into 8Gb DRAM and 256Gb NAND). For e.g., US\$3bn revenue vs. 1bn units (either 8Gb or 256Gb equivalent) implies US\$3 ASP.

Spot-market price (currently around US\$2.0 for 8Gb DRAM vs. 512Gb 3D NAND is at \$3.4) is available on a daily basis vs. contract price (normally settled a month or a quarter ago). Spot-market price usually represents just commodity (PC, mobile) or low-quality chips. Lots of chips offer more value-addition (vs. spot) given customization (e.g., Samsung's server DRAM for AWS) or advanced spec (graphic, low-power, high-speed for DDR5, etc.).

WSTS: World Semiconductor Trade Statistics, affiliated with the SIA (Semiconductor Industry Association) and publishes monthly industry data for global semiconductors including DRAM/NAND.

Disclosures

Important Disclosures

FUNDAMENTAL EQUITY OPINION KEY: Opinions include a Volatility Risk Rating, an Investment Rating and an Income Rating. **VOLATILITY RISK RATINGS**, indicators of potential price fluctuation, are: A - Low, B - Medium and C - High. **INVESTMENT RATINGS** reflect the analyst's assessment of both a stock's absolute total return potential as well as its attractiveness for investment relative to other stocks within its Coverage Cluster (defined below). Our investment ratings are: 1 - Buy stocks are expected to have a total return of at least 10% and are the most attractive stocks in the coverage cluster; 2 - Neutral stocks are expected to remain flat or increase in value and are less attractive than Buy rated stocks and 3 - Underperform stocks are the least attractive stocks in a coverage cluster. An investment rating of 6 (No Rating) indicates that a stock is no longer trading on the basis of fundamentals. Analysts assign investment ratings considering, among other things, the 0-12 month total return expectation for a stock and the firm's guidelines for ratings dispersions (shown in the table below). The current price objective for a stock should be referenced to better understand the total return expectation at any given time. The price objective reflects the analyst's view of the potential price appreciation (depreciation).

Investment rating	Total return expectation (within 12-month period of date of initial rating)	Ratings dispersion guidelines for coverage cluster ^{R1}
Buy	≥ 10%	≤ 70%
Neutral	≥ 0%	≤ 30%
Underperform	N/A	≥ 20%

^{R1} Ratings dispersions may vary from time to time where BofA Global Research believes it better reflects the investment prospects of stocks in a Coverage Cluster.

INCOME RATINGS, indicators of potential cash dividends, are: 7 - same/higher (dividend considered to be secure), 8 - same/lower (dividend not considered to be secure) and 9 - pays no cash dividend. *Coverage Cluster* is comprised of stocks covered by a single analyst or two or more analysts sharing a common industry, sector, region or other classification(s). A stock's coverage cluster is included in the most recent BofA Global Research report referencing the stock.

BofA Global Research personnel (including the analyst(s) responsible for this report) receive compensation based upon, among other factors, the overall profitability of Bank of America Corporation, including profits derived from investment banking. The analyst(s) responsible for this report may also receive compensation based upon, among other factors, the overall profitability of the Bank's sales and trading businesses relating to the class of securities or financial instruments for which such analyst is responsible.

Other Important Disclosures

From time to time research analysts conduct site visits of covered issuers. BofA Global Research policies prohibit research analysts from accepting payment or reimbursement for travel expenses from the issuer for such visits.

Prices are indicative and for information purposes only. Except as otherwise stated in the report, for any recommendation in relation to an equity security, the price referenced is the publicly traded price of the security as of close of business on the day prior to the date of the report or, if the report is published during intraday trading, the price referenced is indicative of the traded price as of the date and time of the report and in relation to a debt security (including equity preferred and CDS), prices are indicative as of the date and time of the report and are from various sources including BofA Securities trading desks.

The date and time of completion of the production of any recommendation in this report shall be the date and time of dissemination of this report as recorded in the report timestamp.

Recipients who are not institutional investors or market professionals should seek the advice of their independent financial advisor before considering information in this report in connection with any investment decision, or for a necessary explanation of its contents.

Officers of BofAS or one or more of its affiliates (other than research analysts) may have a financial interest in securities of the issuer(s) or in related investments.

Refer to [BofA Global Research policies relating to conflicts of interest](#).

"BofA Securities" includes BofA Securities, Inc. ("BofAS") and its affiliates. Investors should contact their BofA Securities representative or Merrill Global Wealth Management financial advisor if they have questions concerning this report or concerning the appropriateness of any investment idea described herein for such investor. "BofA Securities" is a global brand for BofA Global Research.

Information relating to Non-US affiliates of BofA Securities and Distribution of Affiliate Research Reports:

BofAS and/or Merrill Lynch, Pierce, Fenner & Smith Incorporated ("MLPF&S") may in the future distribute, information of the following non-US affiliates in the US (short name: legal name, regulator): Merrill Lynch (South Africa): Merrill Lynch South Africa (Pty) Ltd., regulated by The Financial Service Board; MLI (UK): Merrill Lynch International, regulated by the Financial Conduct Authority (FCA) and the Prudential Regulation Authority (PRA); BofASE (France): BofA Securities Europe SA is authorized by the Autorité de Contrôle Prudentiel et de Résolution (ACPR) and regulated by the ACPR and the Autorité des Marchés Financiers (AMF). BofA Securities Europe SA ("BofASE") with registered address at 51, rue La Boétie, 75008 Paris is registered under no 842 602 690 RCS Paris. In accordance with the provisions of French Code Monétaire et Financier (Monetary and Financial Code), BofASE is an établissement de crédit et d'investissement (credit and investment institution) that is authorised and supervised by the European Central Bank and the Autorité de Contrôle Prudentiel et de Résolution (ACPR) and regulated by the ACPR and the Autorité des Marchés Financiers. BofASE's share capital can be found at www.bofam.com/BofASEdisclaimer; BofA Europe (Milan): Bank of America Europe Designated Activity Company, Milan Branch, regulated by the Bank of Italy, the European Central Bank (ECB) and the Central Bank of Ireland (CBI); BofA Europe (Frankfurt): Bank of America Europe Designated Activity Company, Frankfurt Branch regulated by BaFin, the ECB and the CBI; BofA Europe (Madrid): Bank of America Europe Designated Activity Company, Sucursal en España, regulated by the Bank of Spain, the ECB and the CBI; Merrill Lynch (Australia): Merrill Lynch Equities (Australia) Limited, regulated by the Australian Securities and Investments Commission; Merrill Lynch (Hong Kong): Merrill Lynch (Asia Pacific) Limited, regulated by the Hong Kong Securities and Futures Commission (HKSF); Merrill Lynch (Singapore): Merrill Lynch (Singapore) Pte Ltd, regulated by the Monetary Authority of Singapore (MAS); Merrill Lynch (Canada): Merrill Lynch Canada Inc, regulated by the Canadian Investment Regulatory Organization; Merrill Lynch (Mexico): Merrill Lynch Mexico, SA de CV, Casa de Bolsa, regulated by the Comisión Nacional Bancaria y de Valores; Merrill Lynch (Argentina): Merrill Lynch Argentina SA, regulated by Comisión Nacional de Valores; BofAS Japan: BofA Securities Japan Co., Ltd., regulated by the Financial Services Agency; Merrill Lynch (Seoul): Merrill Lynch International, LLC Seoul Branch, regulated by the Financial Supervisory Service; Merrill Lynch (Taiwan): Merrill Lynch Securities (Taiwan) Ltd., regulated by the Securities and Futures Bureau; BofAS India: BofA Securities India Limited, regulated by the Securities and Exchange Board of India (SEBI); Merrill Lynch (Israel): Merrill Lynch Israel Limited, regulated by Israel Securities Authority; Merrill Lynch (DIFC): Merrill Lynch International (DIFC Branch), regulated by the Dubai Financial Services Authority (DFSA); Merrill Lynch (Brazil): Merrill Lynch S.A. Corretora de Títulos e Valores Mobiliários, regulated by Comissão de Valores Mobiliários; Merrill Lynch KSA Company: Merrill Lynch Kingdom of Saudi Arabia Company, regulated by the Capital Market Authority.

This information has been approved for publication and is distributed in the United Kingdom (UK) to professional clients and eligible counterparties (as each is defined in the rules of the FCA and the PRA) by MLI (UK), which is authorized by the PRA and regulated by the FCA and the PRA - details about the extent of our regulation by the FCA and PRA are available from us on request; has been approved for publication and is distributed in the European Economic Area (EEA) by BofASE (France), which is authorized by the ACPR and regulated by the ACPR and the AMF; has been considered and distributed in Japan by BofAS Japan, a registered securities dealer under the Financial Instruments and Exchange Act in Japan, or its permitted affiliates; is issued and distributed in Hong Kong by Merrill Lynch (Hong Kong) which is regulated by HKSF; is issued and distributed in Taiwan by Merrill Lynch (Taiwan); is issued and distributed in India by BofAS India; and is issued and distributed in Singapore to institutional investors and/or accredited investors (each as defined under the Financial Advisers Regulations) by Merrill Lynch (Singapore) (Company Registration No 198602883D). Merrill Lynch (Singapore) is regulated by MAS. Merrill Lynch Equities (Australia) Limited (ABN 65 006 276 795), AFS License 235132 (MLEA) distributes this information in Australia only to 'Wholesale' clients as defined by s.761G of the Corporations Act 2001. With the exception of Bank of America N.A., Australia Branch, neither MLEA nor any of



its affiliates involved in preparing this information is an Authorised Deposit-Taking Institution under the Banking Act 1959 nor regulated by the Australian Prudential Regulation Authority. No approval is required for publication or distribution of this information in Brazil and its local distribution is by Merrill Lynch (Brazil) in accordance with applicable regulations. Merrill Lynch (DIFC) is authorized and regulated by the DFSA. Information prepared and issued by Merrill Lynch (DIFC) is done so in accordance with the requirements of the DFSA conduct of business rules. BofA Europe (Frankfurt) distributes this information in Germany and is regulated by BaFin, the ECB and the CBL. BofA Securities entities, including BofA Europe and BofASE (France), may outsource/delegate the marketing and/or provision of certain research services or aspects of research services to other branches or members of the BofA Securities group. You may be contacted by a different BofA Securities entity acting for and on behalf of your service provider where permitted by applicable law. This does not change your service provider. Please refer to the [Electronic Communications Disclaimers](#) for further information.

This information has been prepared and issued by BofAS and/or one or more of its non-US affiliates. The author(s) of this information may not be licensed to carry on regulated activities in your jurisdiction and, if not licensed, do not hold themselves out as being able to do so. BofAS and/or MLPF&S is the distributor of this information in the US and accepts full responsibility for information distributed to BofAS and/or MLPF&S clients in the US by its non-US affiliates. Any US person receiving this information and wishing to effect any transaction in any security discussed herein should do so through BofAS and/or MLPF&S and not such foreign affiliates. Hong Kong recipients of this information should contact Merrill Lynch (Asia Pacific) Limited in respect of any matters relating to dealing in securities or provision of specific advice on securities or any other matters arising from, or in connection with, this information. Singapore recipients of this information should contact Merrill Lynch (Singapore) Pte Ltd in respect of any matters arising from, or in connection with, this information. For clients that are not accredited investors, expert investors or institutional investors Merrill Lynch (Singapore) Pte Ltd accepts full responsibility for the contents of this information distributed to such clients in Singapore.

General Investment Related Disclosures:

Taiwan Readers: Neither the information nor any opinion expressed herein constitutes an offer or a solicitation of an offer to transact in any securities or other financial instrument. No part of this report may be used or reproduced or quoted in any manner whatsoever in Taiwan by the press or any other person without the express written consent of BofA Securities. This document provides general information only, and has been prepared for, and is intended for general distribution to, BofA Securities clients. Neither the information nor any opinion expressed constitutes an offer or an invitation to make an offer, to buy or sell any securities or other financial instrument or any derivative related to such securities or instruments (e.g., options, futures, warrants, and contracts for differences). This document is not intended to provide personal investment advice and it does not take into account the specific investment objectives, financial situation and the particular needs of, and is not directed to, any specific person(s). This document and its content do not constitute, and should not be considered to constitute, investment advice for purposes of ERISA, the US tax code, the Investment Advisers Act or otherwise. Investors should seek financial advice regarding the appropriateness of investing in financial instruments and implementing investment strategies discussed or recommended in this document and should understand that statements regarding future prospects may not be realized. Any decision to purchase or subscribe for securities in any offering must be based solely on existing public information on such security or the information in the prospectus or other offering document issued in connection with such offering, and not on this document.

Securities and other financial instruments referred to herein, or recommended, offered or sold by BofA Securities, are not insured by the Federal Deposit Insurance Corporation and are not deposits or other obligations of any insured depository institution (including, Bank of America, N.A.). Investments in general and, derivatives, in particular, involve numerous risks, including, among others, market risk, counterparty default risk and liquidity risk. No security, financial instrument or derivative is suitable for all investors. Digital assets are extremely speculative, volatile and are largely unregulated. In some cases, securities and other financial instruments may be difficult to value or sell and reliable information about the value or risks related to the security or financial instrument may be difficult to obtain. Investors should note that income from such securities and other financial instruments, if any, may fluctuate and that price or value of such securities and instruments may rise or fall and, in some cases, investors may lose their entire principal investment. Past performance is not necessarily a guide to future performance. Levels and basis for taxation may change.

This report may contain a short-term trading idea or recommendation, which highlights a specific near-term catalyst or event impacting the issuer or the market that is anticipated to have a short-term price impact on the equity securities of the issuer. Short-term trading ideas and recommendations are different from and do not affect a stock's fundamental equity rating, which reflects both a longer term total return expectation and attractiveness for investment relative to other stocks within its Coverage Cluster. Short-term trading ideas and recommendations may be more or less positive than a stock's fundamental equity rating.

BofA Securities is aware that the implementation of the ideas expressed in this report may depend upon an investor's ability to "short" securities or other financial instruments and that such action may be limited by regulations prohibiting or restricting "shortselling" in many jurisdictions. Investors are urged to seek advice regarding the applicability of such regulations prior to executing any short idea contained in this report.

Foreign currency rates of exchange may adversely affect the value, price or income of any security or financial instrument mentioned herein. Investors in such securities and instruments, including ADRs, effectively assume currency risk.

BofAS or one of its affiliates is a regular issuer of traded financial instruments linked to securities that may have been recommended in this report. BofAS or one of its affiliates may, at any time, hold a trading position (long or short) in the securities and financial instruments discussed in this report.

BofA Securities, through business units other than BofA Global Research, may have issued and may in the future issue trading ideas or recommendations that are inconsistent with, and reach different conclusions from, the information presented herein. Such ideas or recommendations may reflect different time frames, assumptions, views and analytical methods of the persons who prepared them, and BofA Securities is under no obligation to ensure that such other trading ideas or recommendations are brought to the attention of any recipient of this information.

In the event that the recipient received this information pursuant to a contract between the recipient and BofAS for the provision of research services for a separate fee, and in connection therewith BofAS may be deemed to be acting as an investment adviser, such status relates, if at all, solely to the person with whom BofAS has contracted directly and does not extend beyond the delivery of this report (unless otherwise agreed specifically in writing by BofAS). If such recipient uses the services of BofAS in connection with the sale or purchase of a security referred to herein, BofAS may act as principal for its own account or as agent for another person. BofAS is and continues to act solely as a broker-dealer in connection with the execution of any transactions, including transactions in any securities referred to herein.

Copyright and General Information:

Copyright 2024 Bank of America Corporation. All rights reserved. iQdatabase® is a registered service mark of Bank of America Corporation. This information is prepared for the use of BofA Securities clients and may not be redistributed, retransmitted or disclosed, in whole or in part, or in any form or manner, without the express written consent of BofA Securities. BofA Global Research information is distributed simultaneously to internal and client websites and other portals by BofA Securities and is not publicly-available material. Any unauthorized use or disclosure is prohibited. Receipt and review of this information constitutes your agreement not to redistribute, retransmit, or disclose to others the contents, opinions, conclusion, or information contained herein (including any investment recommendations, estimates or price targets) without first obtaining express permission from an authorized officer of BofA Securities.

Materials prepared by BofA Global Research personnel are based on public information. Facts and views presented in this material have not been reviewed by, and may not reflect information known to, professionals in other business areas of BofA Securities, including investment banking personnel. BofA Securities has established information barriers between BofA Global Research and certain business groups. As a result, BofA Securities does not disclose certain client relationships with, or compensation received from, such issuers. To the extent this material discusses any legal proceeding or issues, it has not been prepared as nor is it intended to express any legal conclusion, opinion or advice. Investors should consult their own legal advisers as to issues of law relating to the subject matter of this material. BofA Global Research personnel's knowledge of legal proceedings in which any BofA Securities entity and/or its directors, officers and employees may be plaintiffs, defendants, co-defendants or co-plaintiffs with or involving issuers mentioned in this material is based on public information. Facts and views presented in this material that relate to any such proceedings have not been reviewed by, discussed with, and may not reflect information known to, professionals in other business areas of BofA Securities in connection with the legal proceedings or matters relevant to such proceedings.

This information has been prepared independently of any issuer of securities mentioned herein and not in connection with any proposed offering of securities or as agent of any issuer of any securities. None of BofAS any of its affiliates or their research analysts has any authority whatsoever to make any representation or warranty on behalf of the issuer(s). BofA Global Research policy prohibits research personnel from disclosing a recommendation, investment rating, or investment thesis for review by an issuer prior to the publication of a research report containing such rating, recommendation or investment thesis.

Any information relating to the tax status of financial instruments discussed herein is not intended to provide tax advice or to be used by anyone to provide tax advice. Investors are urged to seek tax advice based on their particular circumstances from an independent tax professional.

The information herein (other than disclosure information relating to BofA Securities and its affiliates) was obtained from various sources and we do not guarantee its accuracy. This information may contain links to third-party websites. BofA Securities is not responsible for the content of any third-party website or any linked content contained in a third-party website. Content contained on such third-party websites is not part of this information and is not incorporated by reference. The inclusion of a link does not imply any endorsement by or any affiliation with BofA Securities. Access to any third-party website is at your own risk, and you should always review the terms and privacy policies at third-party websites before submitting any personal information to them. BofA Securities is not responsible for such terms and privacy policies and expressly disclaims any liability for them.



All opinions, projections and estimates constitute the judgment of the author as of the date of publication and are subject to change without notice. Prices also are subject to change without notice. BofA Securities is under no obligation to update this information and BofA Securities ability to publish information on the subject issuer(s) in the future is subject to applicable quiet periods. You should therefore assume that BofA Securities will not update any fact, circumstance or opinion contained herein. Certain outstanding reports or investment opinions relating to securities, financial instruments and/or issuers may no longer be current. Always refer to the most recent research report relating to an issuer prior to making an investment decision.

In some cases, an issuer may be classified as Restricted or may be Under Review or Extended Review. In each case, investors should consider any investment opinion relating to such issuer (or its security and/or financial instruments) to be suspended or withdrawn and should not rely on the analyses and investment opinion(s) pertaining to such issuer (or its securities and/or financial instruments) nor should the analyses or opinion(s) be considered a solicitation of any kind. Sales persons and financial advisors affiliated with BofAS or any of its affiliates may not solicit purchases of securities or financial instruments that are Restricted or Under Review and may only solicit securities under Extended Review in accordance with firm policies. Neither BofA Securities nor any officer or employee of BofA Securities accepts any liability whatsoever for any direct, indirect or consequential damages or losses arising from any use of this information.