Strategic Asset Allocation Models

Peering into the future with the help of market prices

XIII Meeting on International Reserves Management, CEMLA

BANCO DE MÉXICO

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- Introduction

- Strategic Asset Allocation
  Building the strategic portfolio with the help of market prices

- Active Management
  The fallacy of the long-term investor
  Absolute return strategies

- In the pursuit of a global portfolio
  Understanding the relative attractiveness of Mexican financial assets

Introduction

- Banco de México maintains an international reserve portfolio of **180 billion US dollars**.
- The primary objective of our reserve management is the **preservation of capital**.
- Our asset allocation is based on the following principles:
  - **The numeraire of the reserve portfolio is the U.S. dollar**. The selection of the numeraire is the most important decision in regards to currency allocation.
  - **The allocation to non-USD assets is based purely on the financial benefits of each asset class** (diversification and risk-return properties). In other words, Banco de México does not follow:
    - Asset-Liability Management approach
    - Balance of payments approach
  - The determination of the optimal portfolio follows a holistic view to harvest the maximum possible benefits of diversification. Hence, **Banco de México does not tranche its reserve portfolio**.
  - The investment horizon of the portfolio is **one year**.

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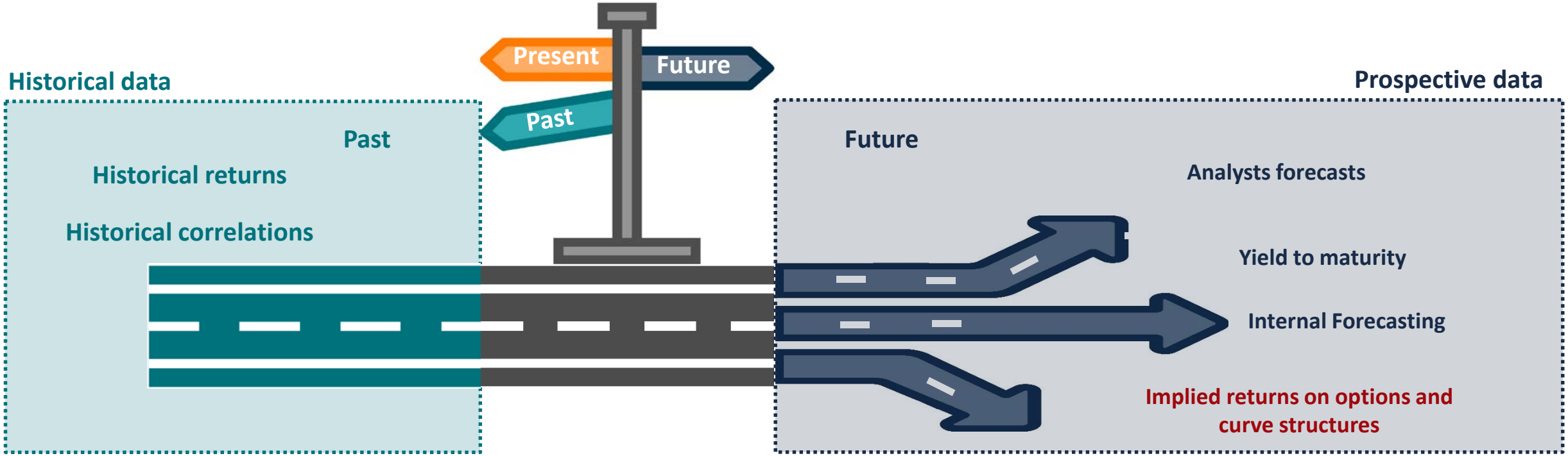
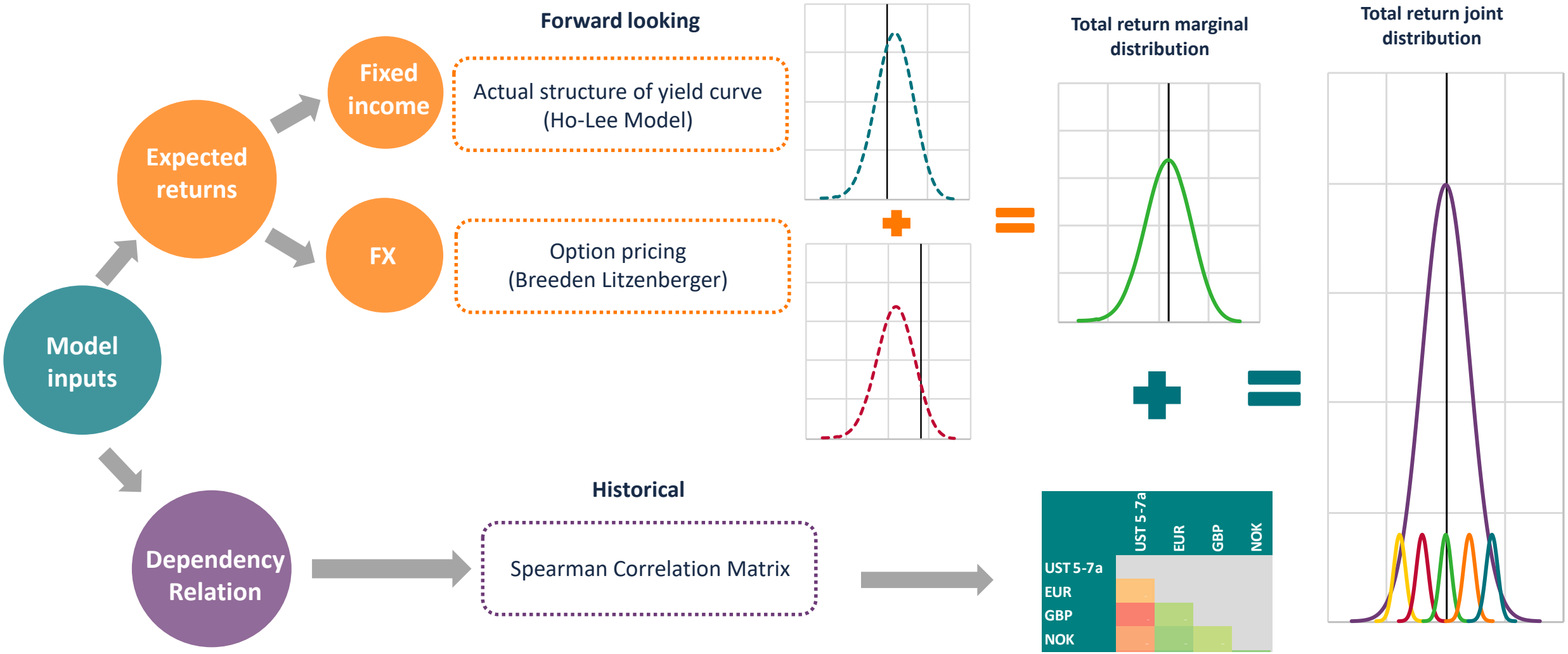
Strategic Asset Allocation Process
Peering into the Future with the Help of Market Prices

- In the last few years, Banco de México has been working on enhancing its SAA framework, so that it can become more robust, forward-looking, and more aligned to the objective of capital preservation.
- The core of such methodology is to rely on market-based information to extract the inputs to our SAA models.



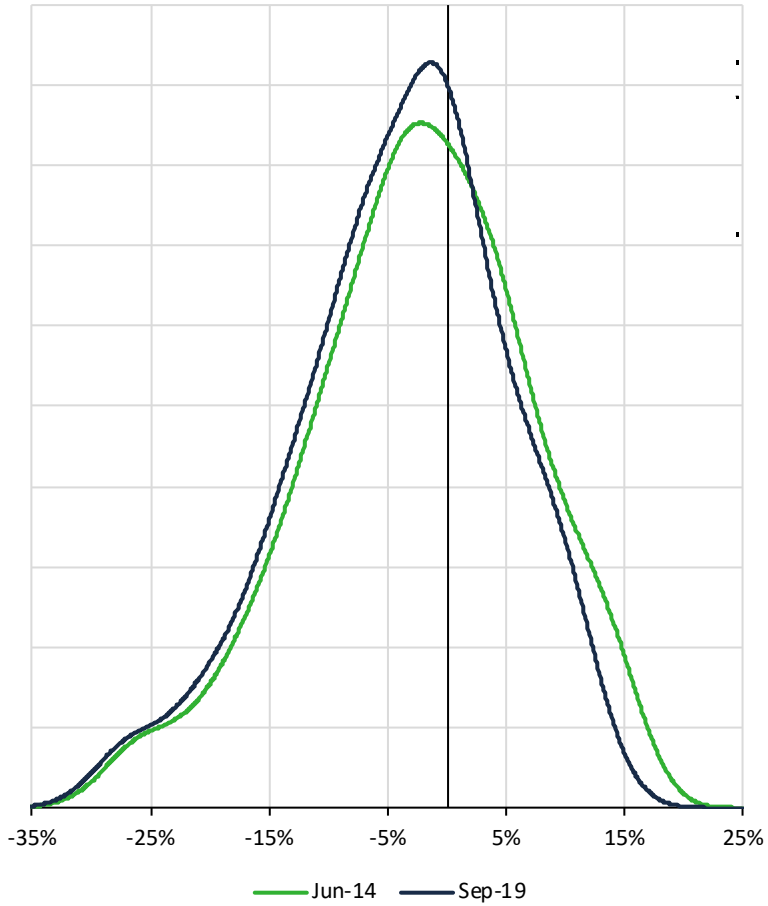
Strategic Asset Allocation Process - Inputs

- The composition of the international reserve portfolio is determined using an optimization methodology that minimizes **CVaR** for a given level of expected return, using market prices as the main source of information.



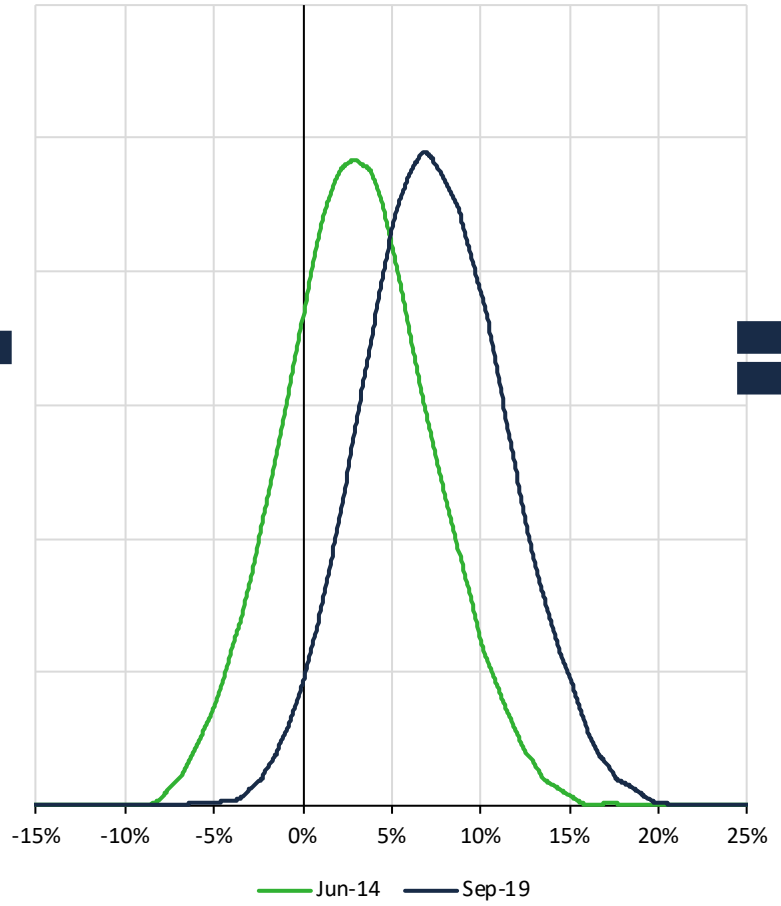
Example: Distribution of returns of Mexican assets

Implied* Distribution of Mexican Peso Annual Returns
Density



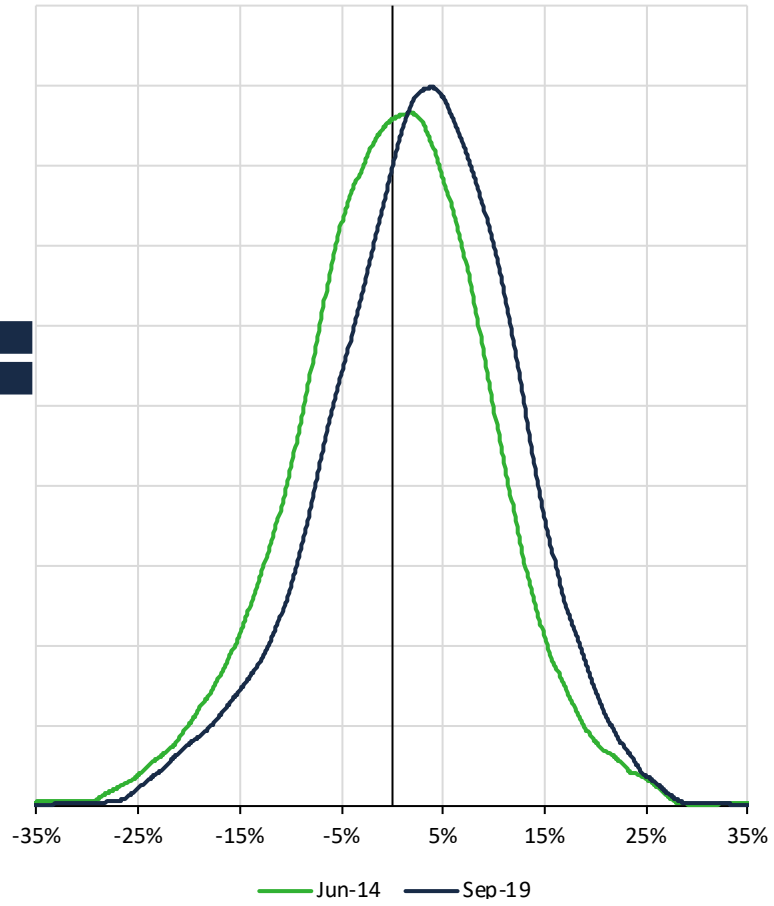
	Mean	Volatility	CVaR
Jun-14	-2.6%	9.7%	24.5%
Sep-19	-4.0%	9.2%	25.3%

Implied* Distribution of Mexican Government Bonds Annual Returns
Density



	Mean	Volatility	CVaR
Jun-14	3.1%	4.3%	5.5%
Sep-19	7.4%	4.2%	1.0%

Implied* Distribution of Mexican Government Bonds Annual Returns with FX Exposure
Density

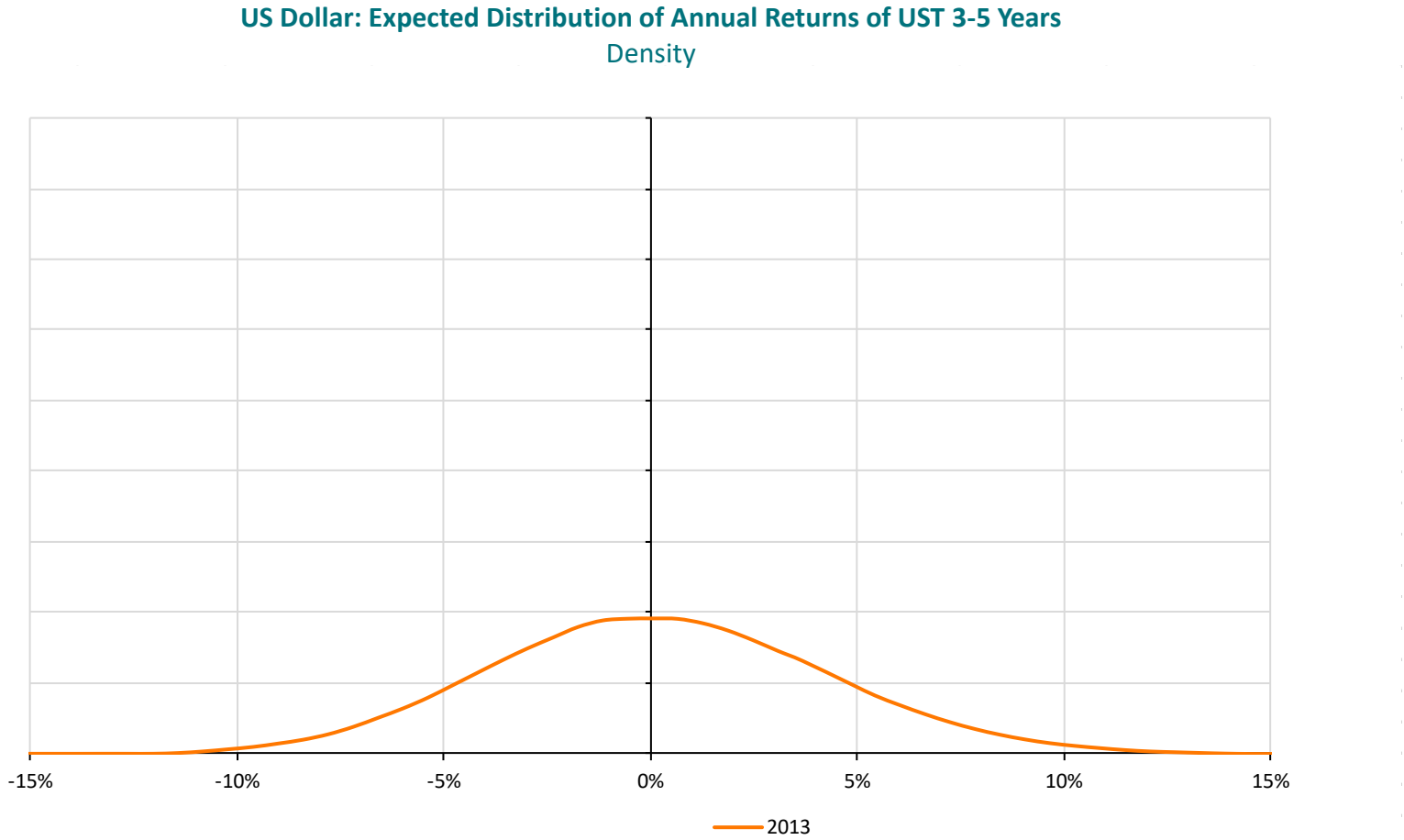


	Mean	Volatility	CVaR
Jun-14	0.0%	9.8%	21.7%
Sep-19	2.8%	9.6%	18.9%

Source: Bank of Mexico with data from Bloomberg. * The implied distribution functions for FX, Fixed Income and Total Return securities are obtained using the Breeden-Litzenberger methodology, the Ho-Lee model, and a Copula model that combines the first two, respectively.

How do the Expected Returns Distributions of Eligible Assets Look Like?

- Expected return distributions for US dollar fixed income assets have improved significantly when compared to previous years, due to the higher level of interest rates and the reduction in market volatility.



Source: Bank of Mexico with data from Bank of America / Merrill Lynch and Bloomberg. Non-overlapping returns.

How do the Expected Returns Distributions of Eligible Assets Look Like?

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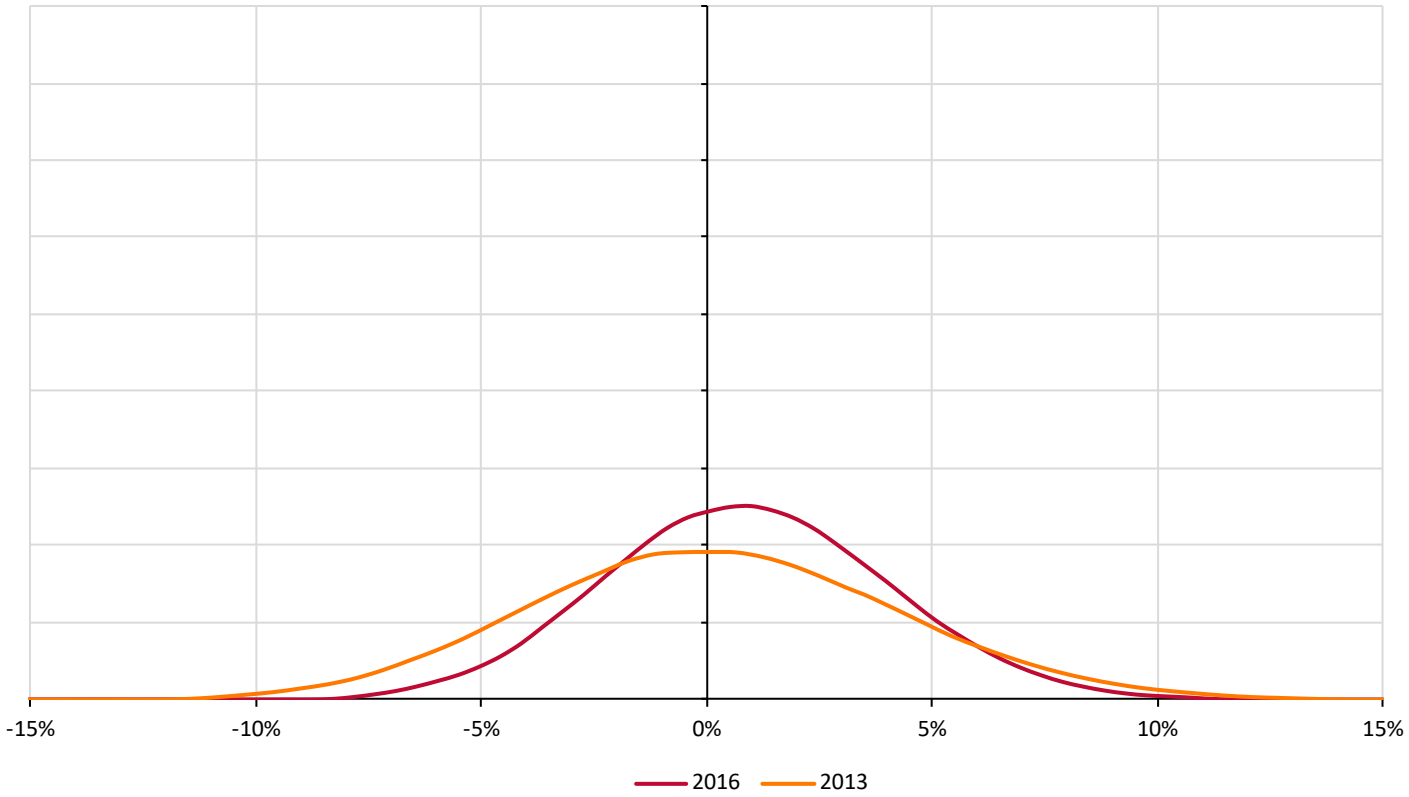
US Dollar: Expected Distribution of Annual Returns of UST 3-5 Years

Density



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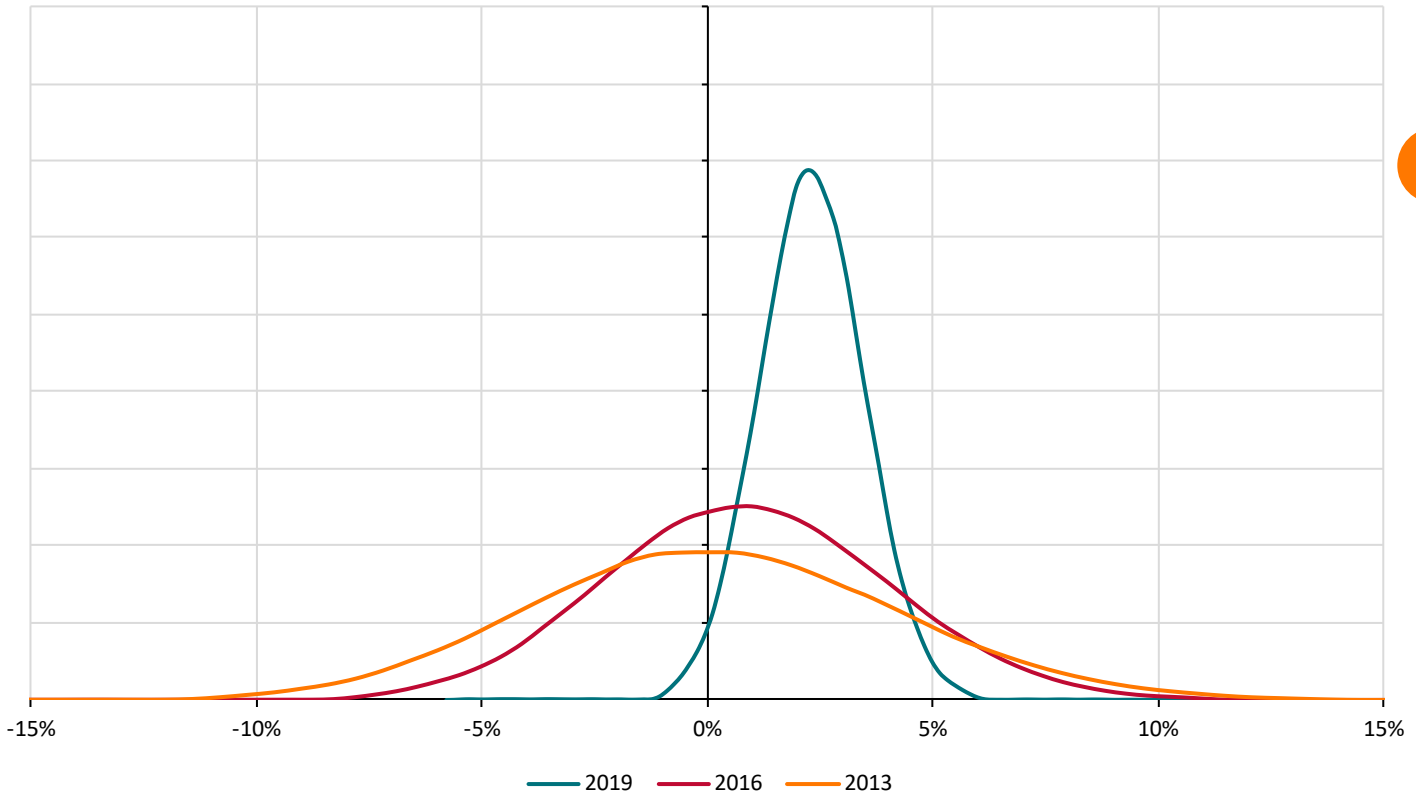


1 **Expected returns in USD fixed income assets looked more attractive in early 2019 as monetary policy normalization in the US pushed interest rates higher.**

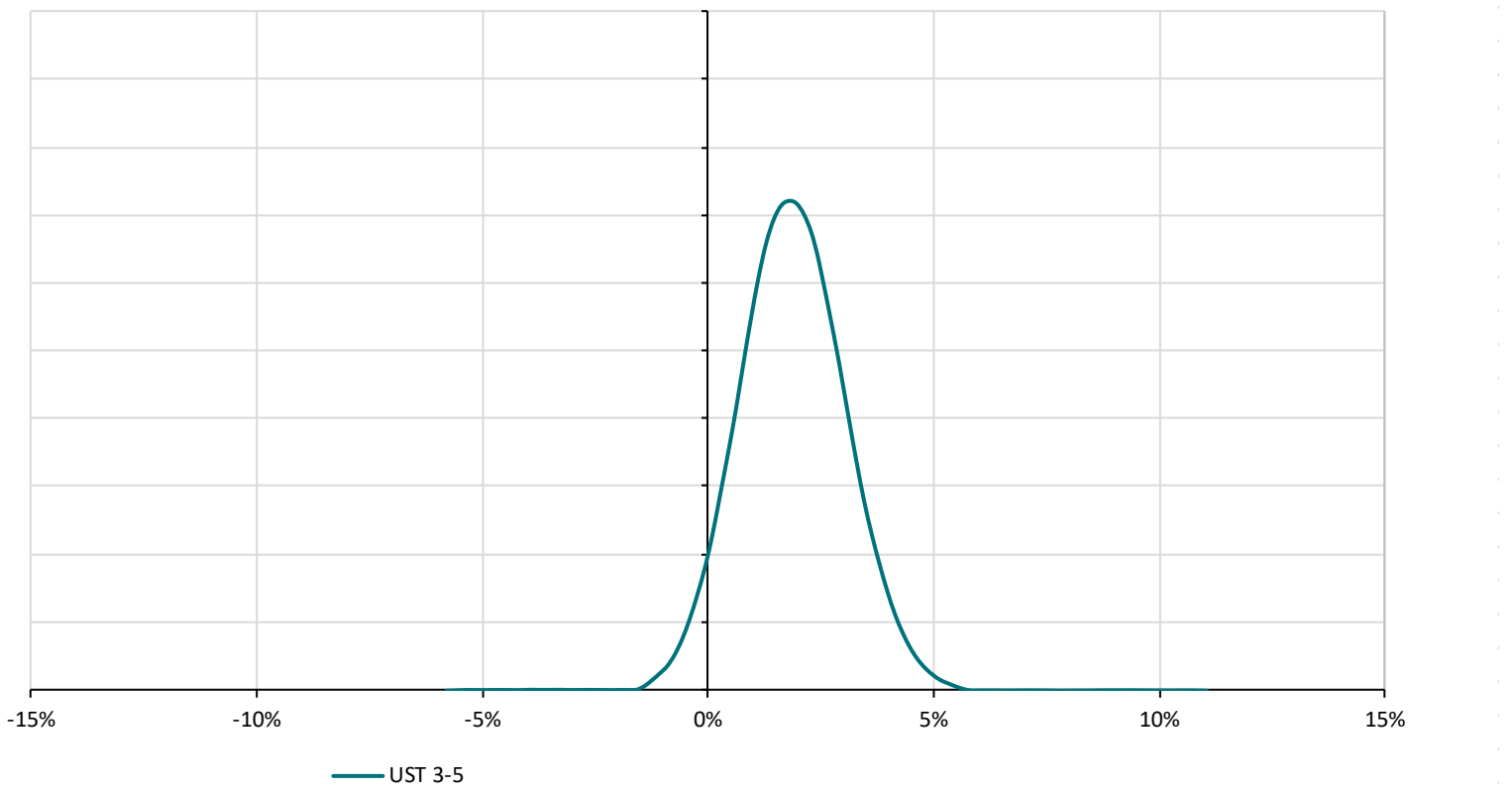
Source: Bank of Mexico with data from Bank of America / Merrill Lynch and Bloomberg. Non-overlapping returns.

How do the Expected Returns Distributions of Eligible Assets Look Like?

- Moreover, the distribution of US dollar fixed income returns is statistically more efficient than that of fixed income assets denominated in other currencies by showing higher expected returns (due to relatively higher yields in the US), and a lower variance (due to the high volatility associated with FX exposures).

Distribution of Annual Returns of 3-5 Year Government Bonds in Selected Currencies

Density



Source: Bank of Mexico with data from Bank of America / Merrill Lynch and Bloomberg.
Note: the annual return for currencies includes both government bonds income and FX returns measured in USD terms. In the particular case of CNH, the 3 month local rate return is used.

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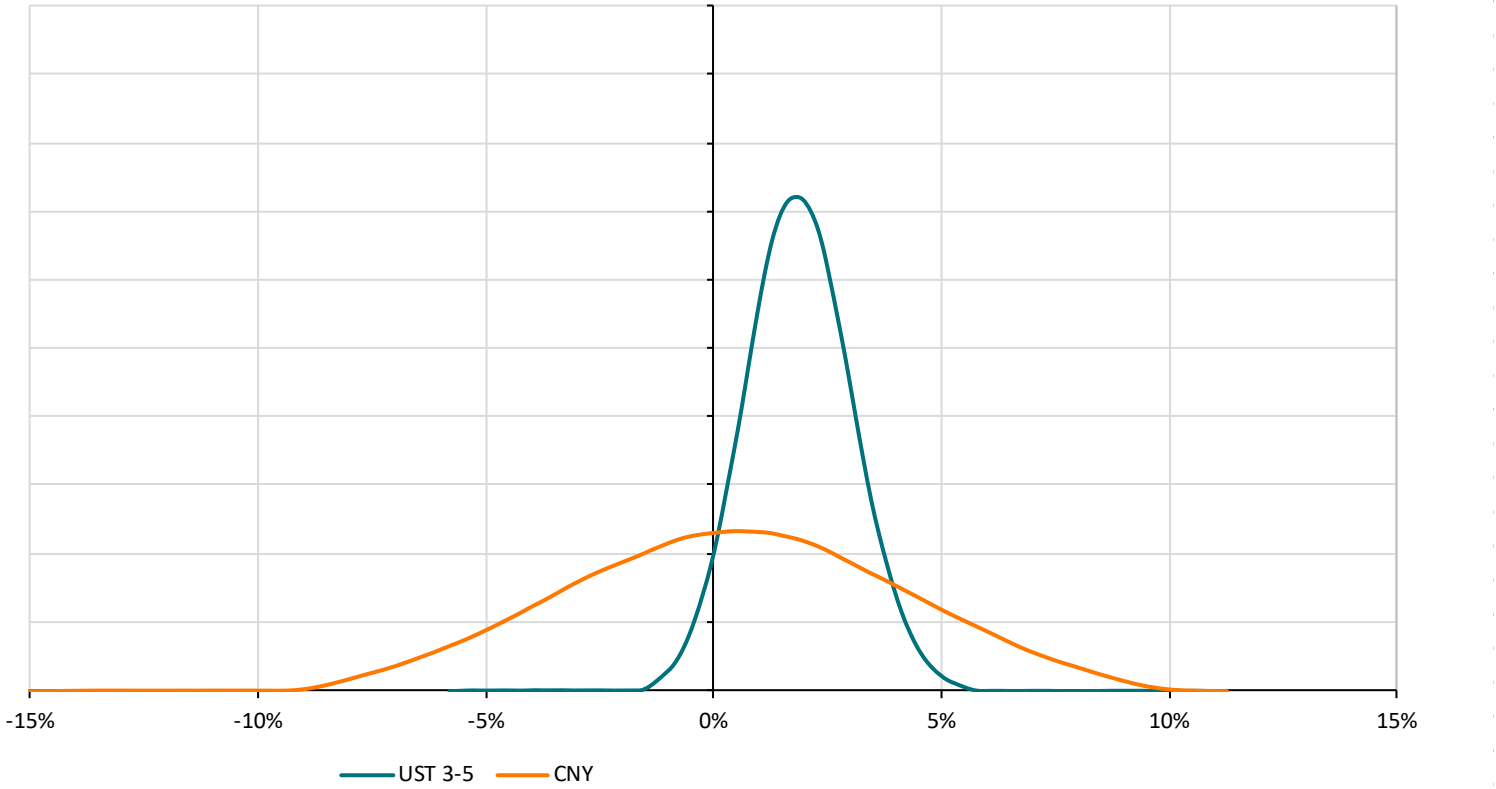

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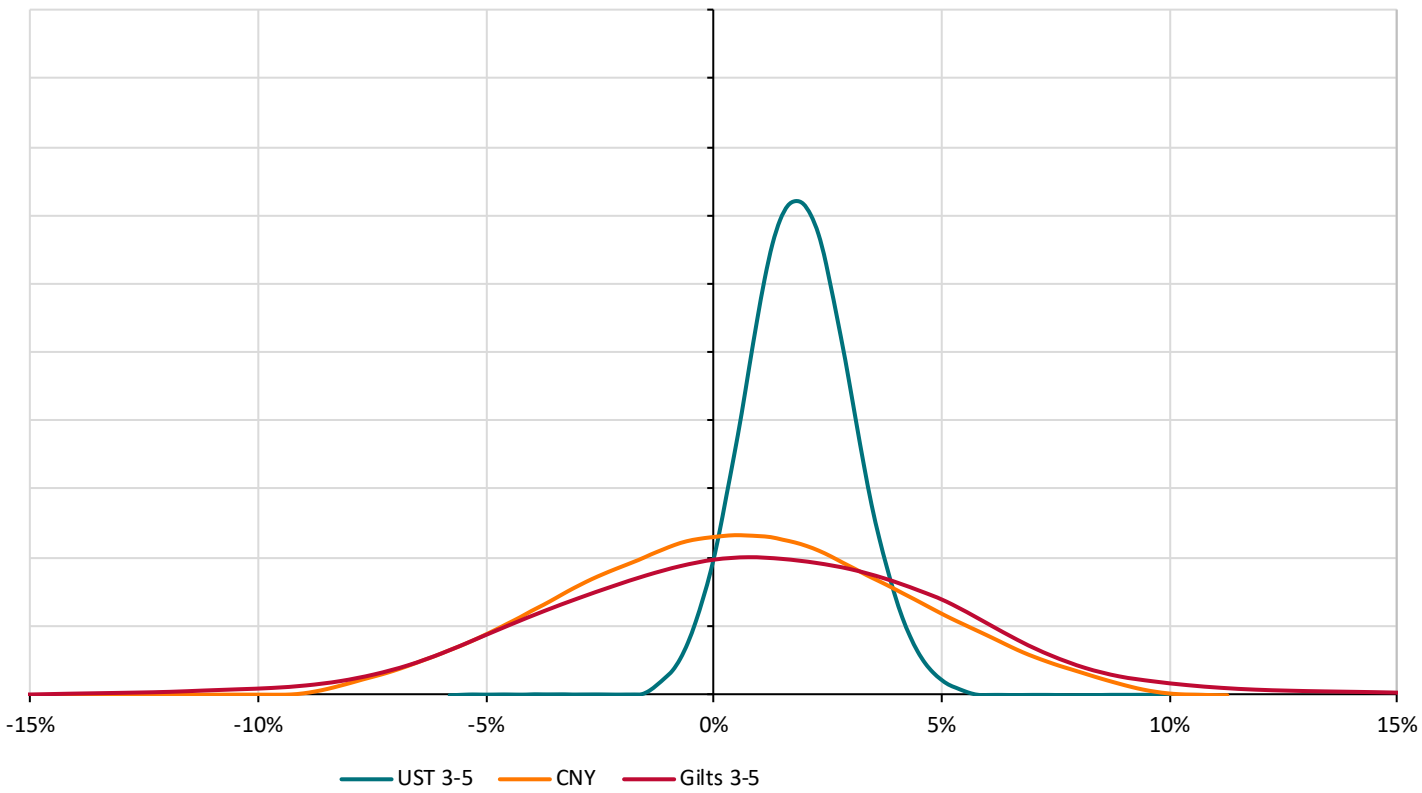

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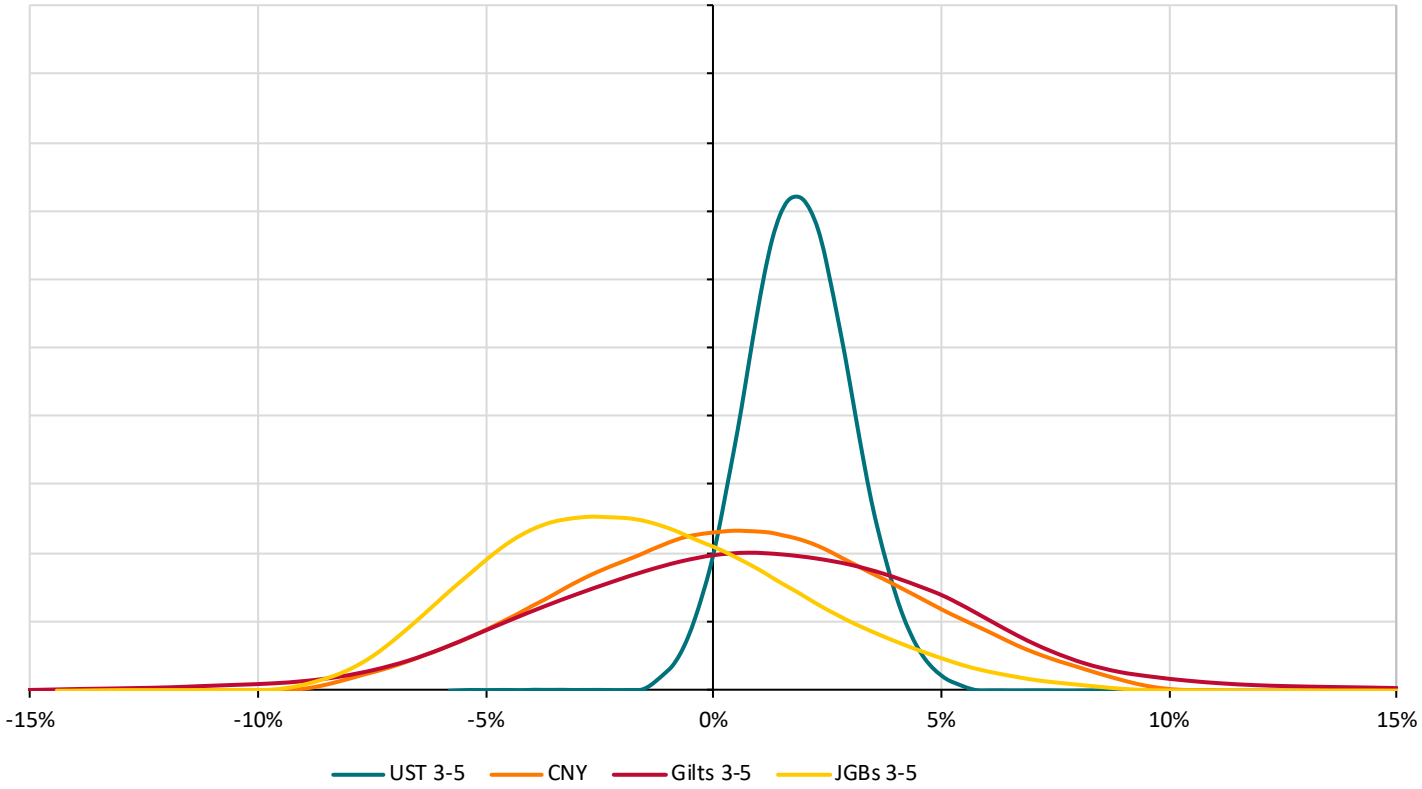

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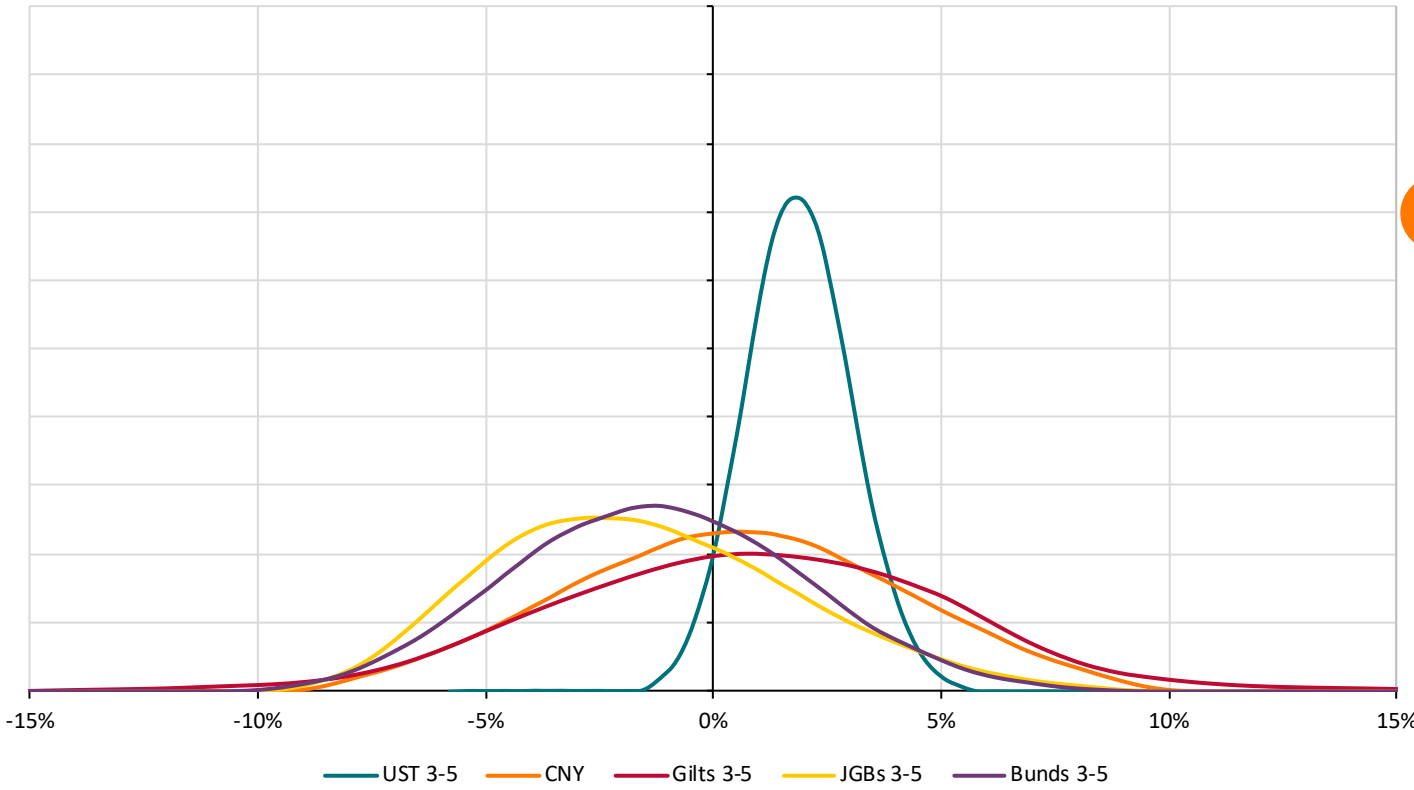


2 **USD fixed income assets dominate FI securities denominated in other currencies.**

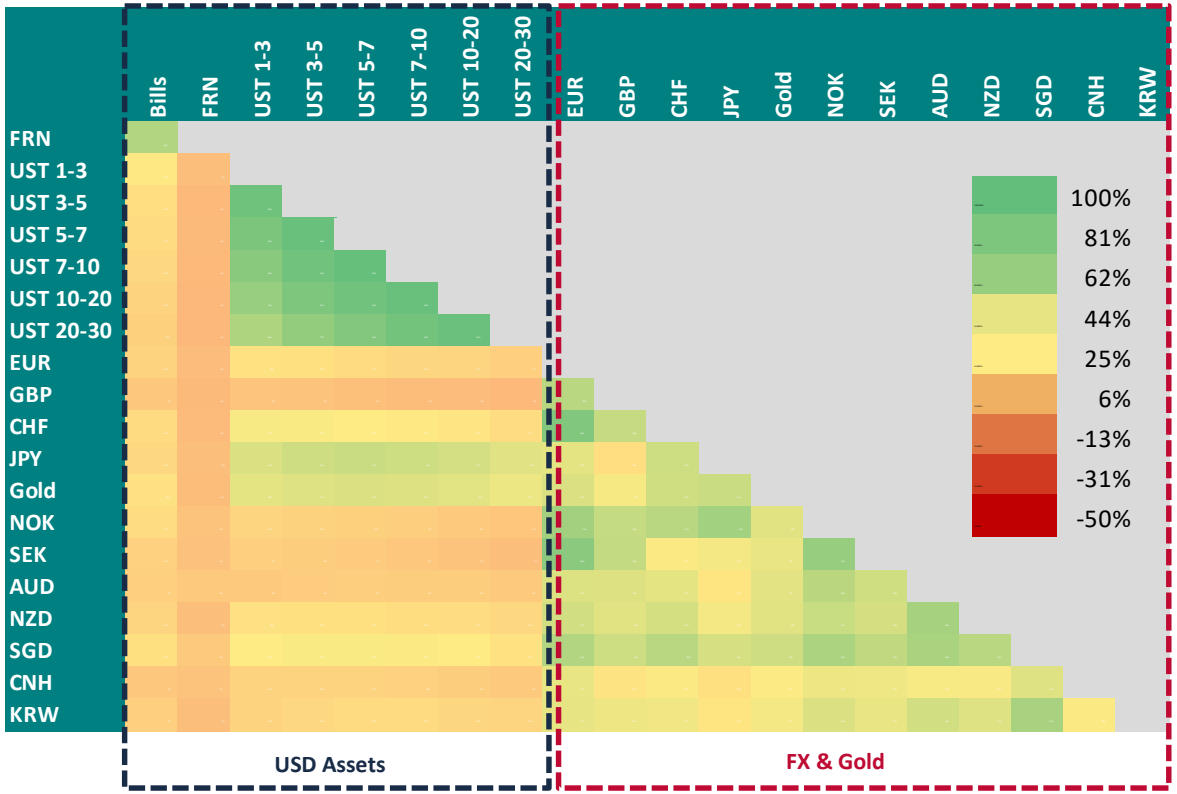
Source: Bank of Mexico with data from Bank of America / Merrill Lynch and Bloomberg.
Note: the annual return for currencies includes both government bonds income and FX returns measured in USD terms. In the particular case of CNH, the 3 month local rate return is used.

How do the Historical Relationships Between Assets are Incorporated?

- Correlation matrices confirm that currencies offer diversification benefits, though these are more prominent for non-traditional reserve currencies.

Correlation Matrix Between UST at Different Maturities and Selected Currencies

Density

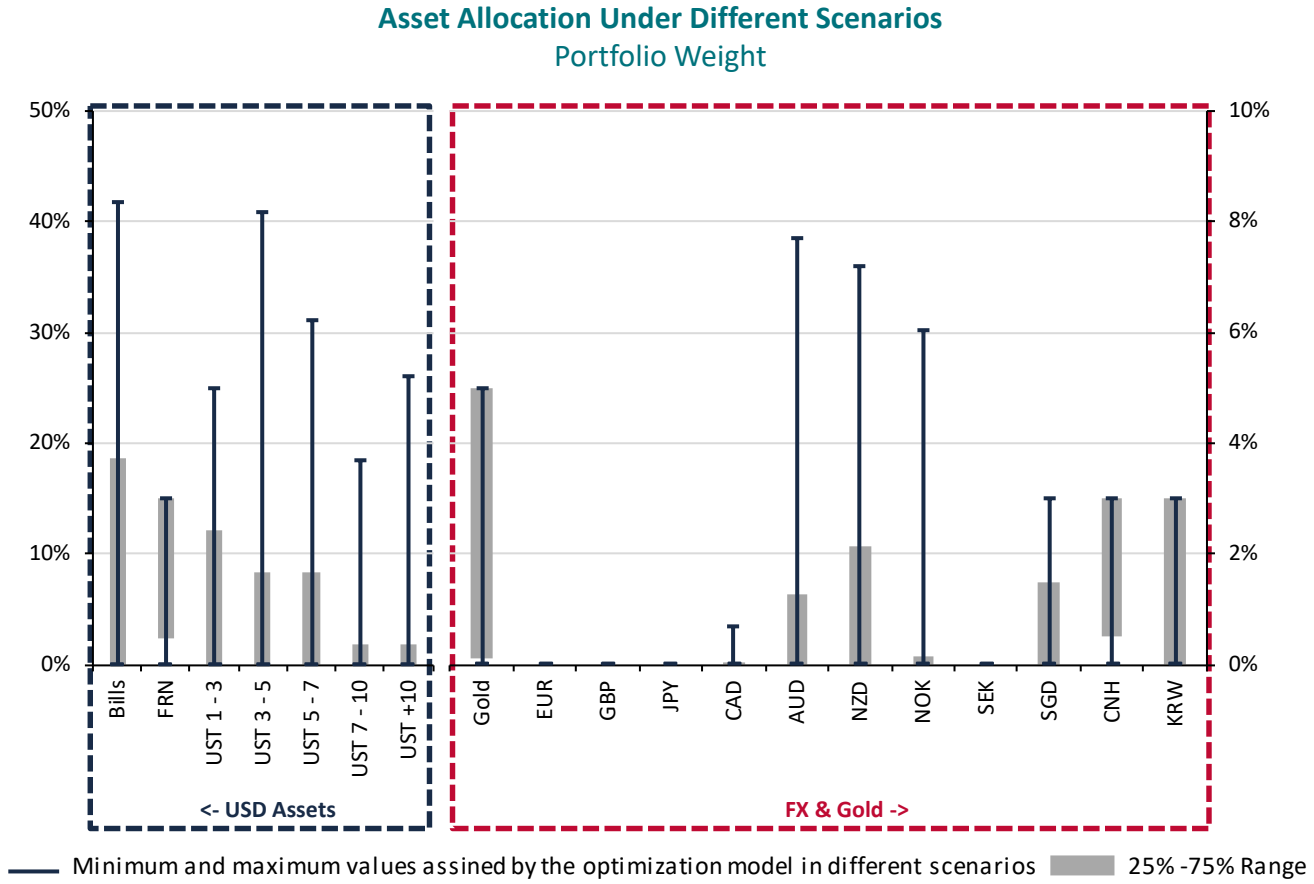


3 **Non-traditional reserve currencies dominate traditional reserve currencies.**

Source: Bank of Mexico with data from Bank of America / Merrill Lynch and Bloomberg.
Note: Spearman Correlation calculated using non-overlapping annual returns with data from 2013 to 2017

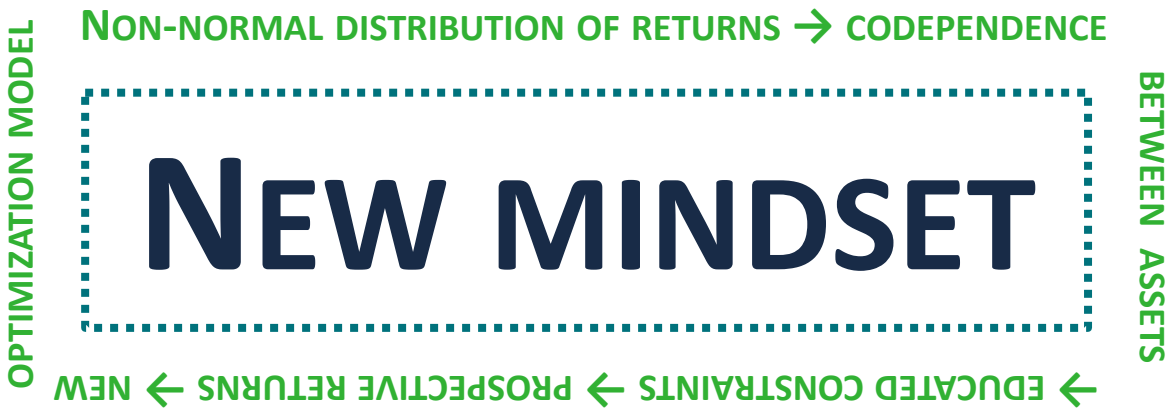
How Are the Restrictions to the Model Determined?

- To have educated restrictions set on our models, we run the optimization process under different historical scenarios (e.g. global financial crisis, European debt crisis), and see what would have been the optimal allocation under these circumstances. We then determine the minimum and maximum allocation for each asset class to be used in the new asset allocation analysis.



Source: Bank of Mexico with data from Bank of America / Merrill Lynch and Bloomberg.
Note: the portfolio is optimized using historic weekly non-overlapping returns for different time periods: the dotcom crisis (2000-2002), restrictive monetary policy period in the US (2004-2007), US financial crisis (2007-2009), European sovereign debt crisis (2010-2012), as well as other periods (2015-2018, 2013-2018, 2000-2018, 2002-2004).

4 **Restrictions allow for some discretionary considerations in the SAA process (i.e. liquidity, market structure, traditional reserve assets)**

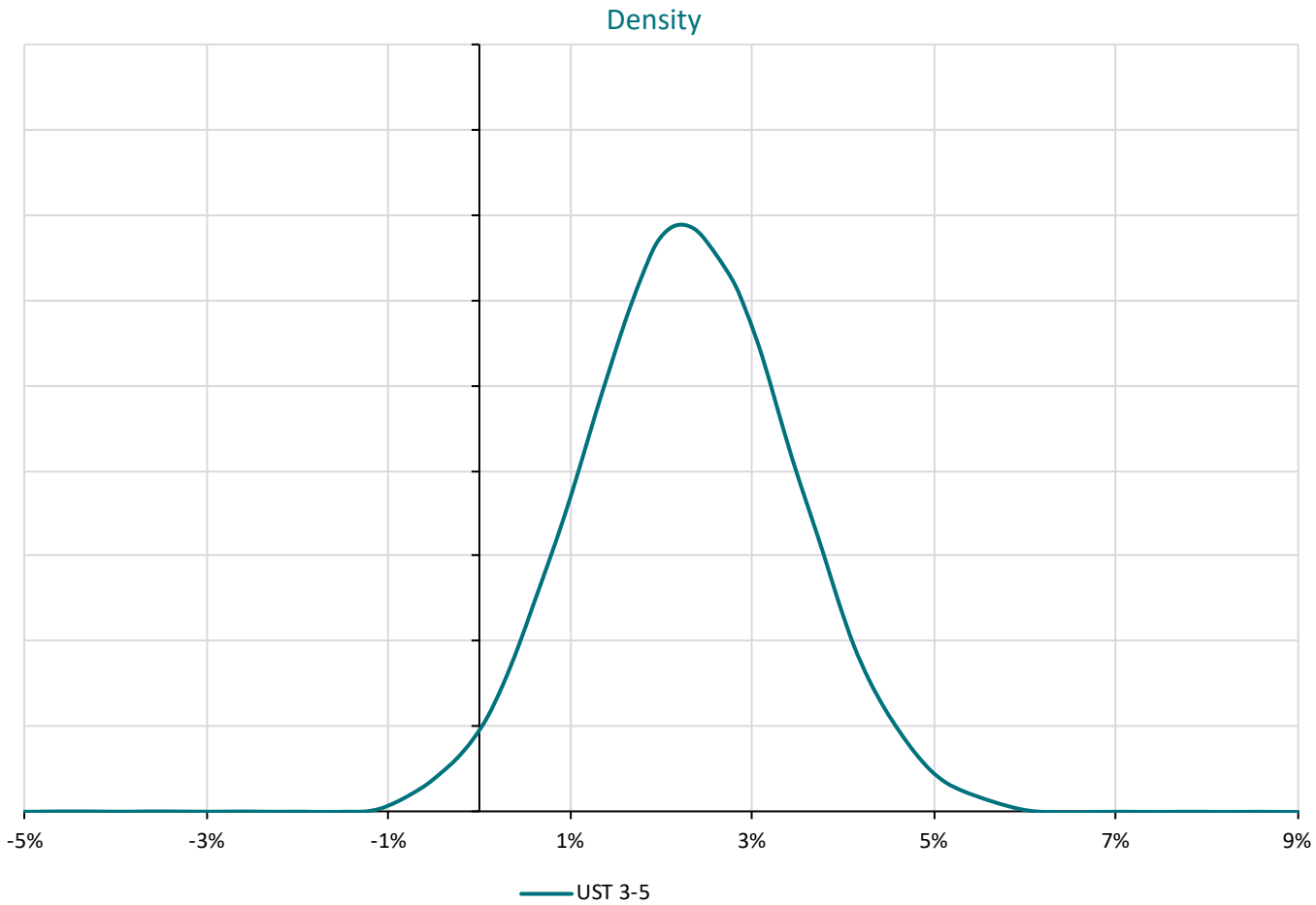


WHAT IS THE RESULT?

What is the Result?

- The portfolio´s expected distribution of returns has an attractive risk-return profile when compared to that of a UST 3-5 years exposure. In fact, the distribution is farther right in terms of expected return, and it is also narrower (measured in terms of volatility or other left tail measures).

Distribution of Non-Overlapping Annual Returns of UST 3-5 Years and the Optimized Portfolio



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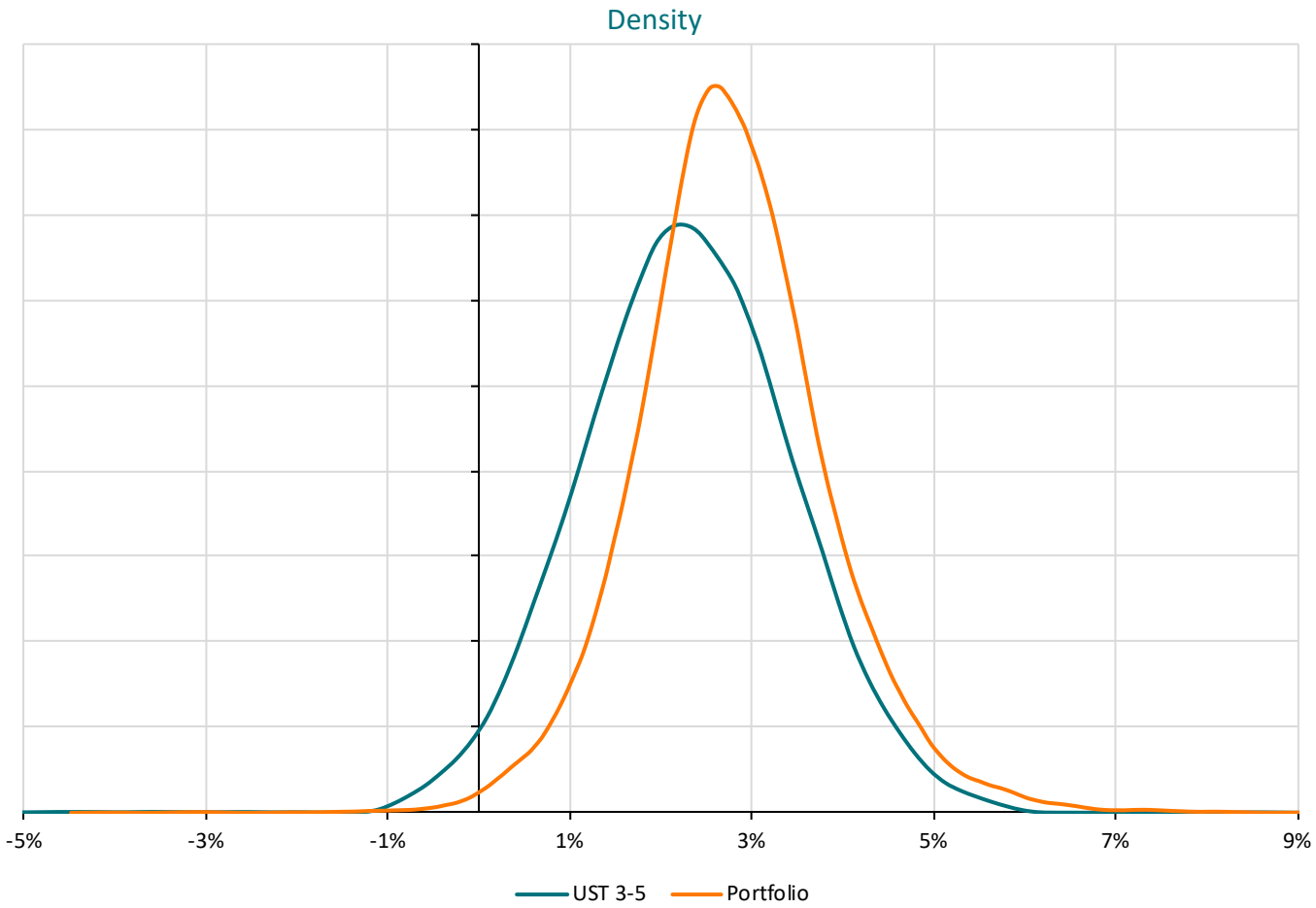
Distribution of Non-Overlapping Annual Returns of UST 3-5 Years and the Optimized Portfolio



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- Moreover, given the aforementioned arguments, the bulk of our risk exposure lies within the US fixed income markets.

Distribution of Non-Overlapping Annual Returns of UST 3-5 Years and the Optimized Portfolio

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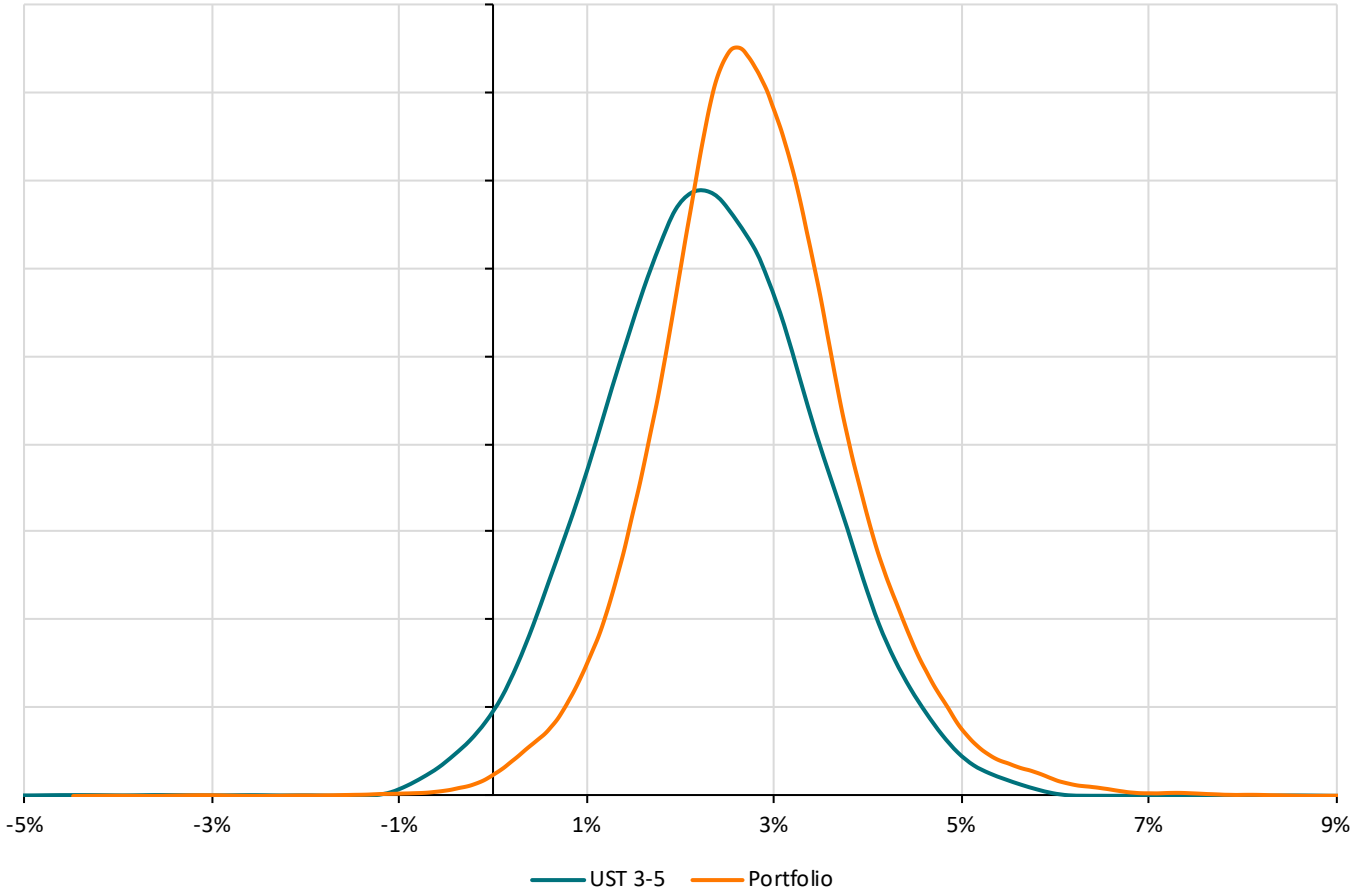
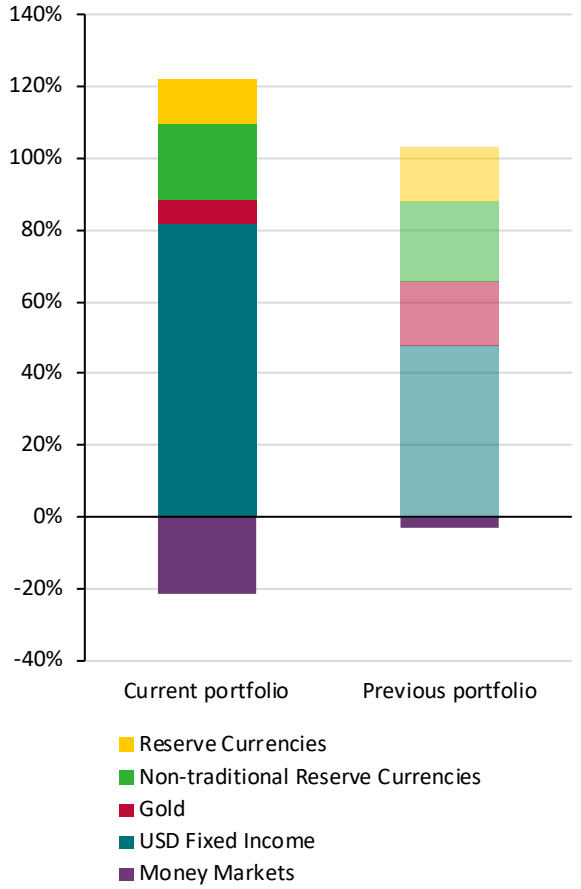


Contribution to CVaR

Percentage

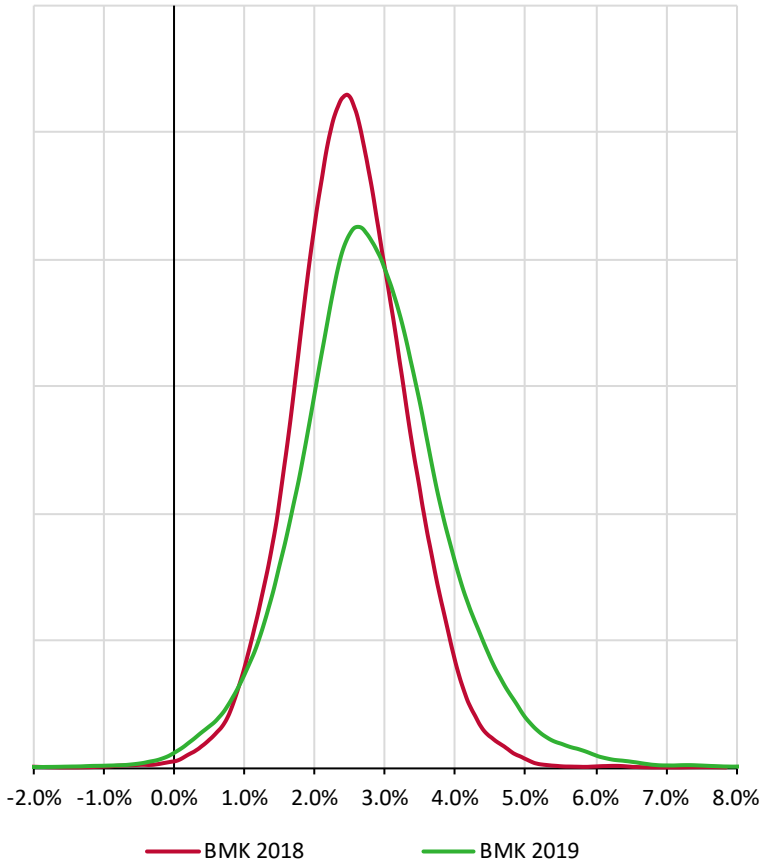


Source: Bank of Mexico with data from Bank of America / Merrill Lynch and Bloomberg.

What is the Result?

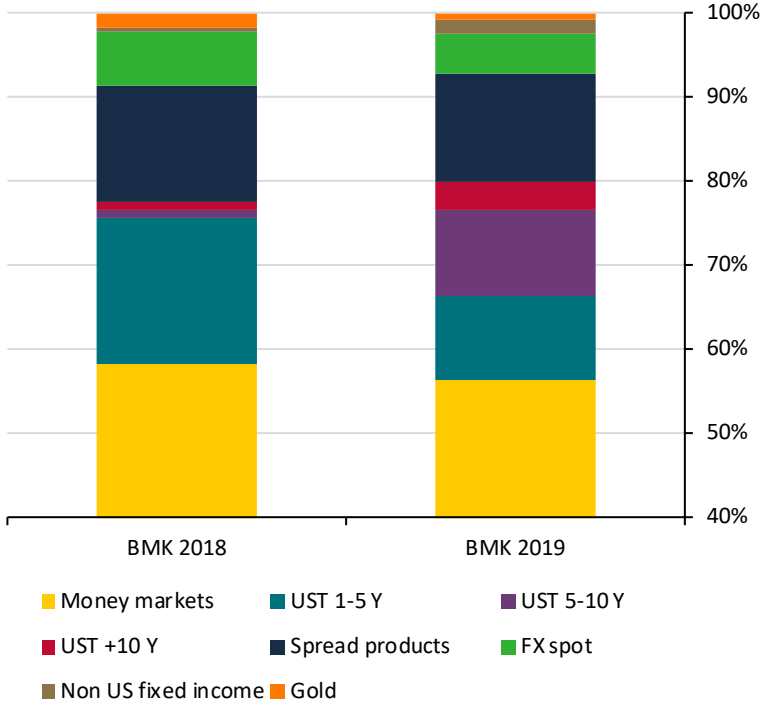
- In 2019, we chose a portfolio that had a very similar left tail distribution to that of 2018´s benchmark but that was tilted to the right. This was achieved by increasing the duration of the portfolio, by reducing gold exposure, and by reallocating risk between our basket of eligible currencies (similar USD exposure overall). We believe that the portfolio is better suited to weather the U.S. economy's late cycle environment.

Expected Return Distributions
Density



Source: Central Bank of Mexico

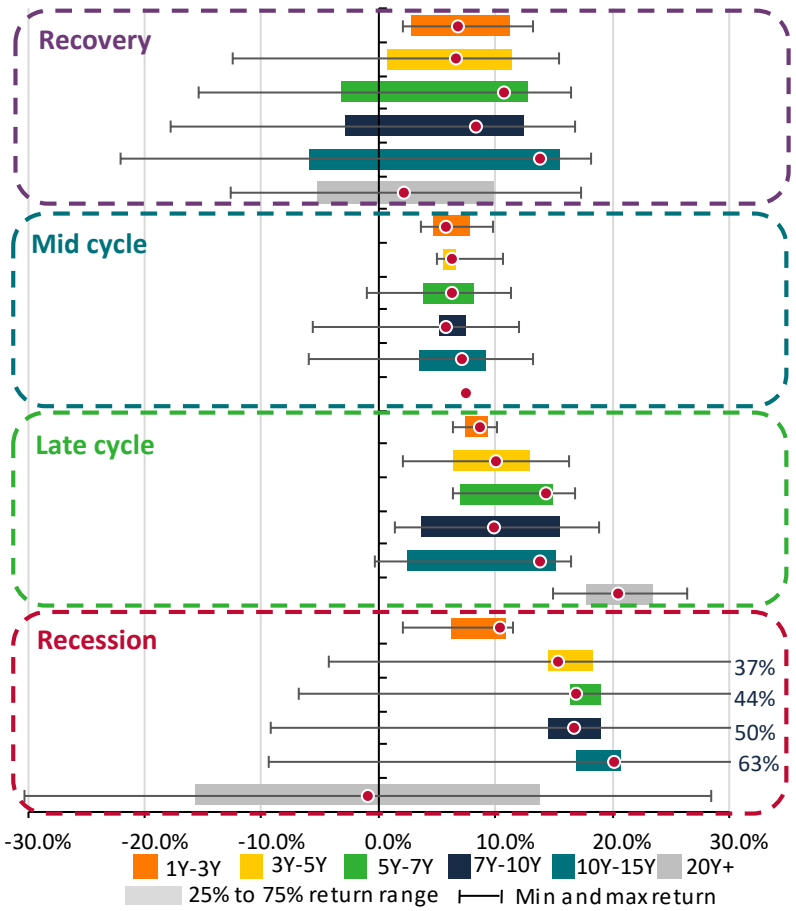
Strategic Asset Allocation Portfolios' Composition
Percentage



Portfolio metrics		
	BMK 2018	BMK 2019
Expected return	2.49%	2.80%
CVaR	0.82%	0.60%
Duration	1.25 years	2 years

Source: Central Bank of Mexico

UST Return Range During Different Economic Stages
Percentage



Source: Central Bank of Mexico with data from Bloomberg indices. Data since Nov. 1973.

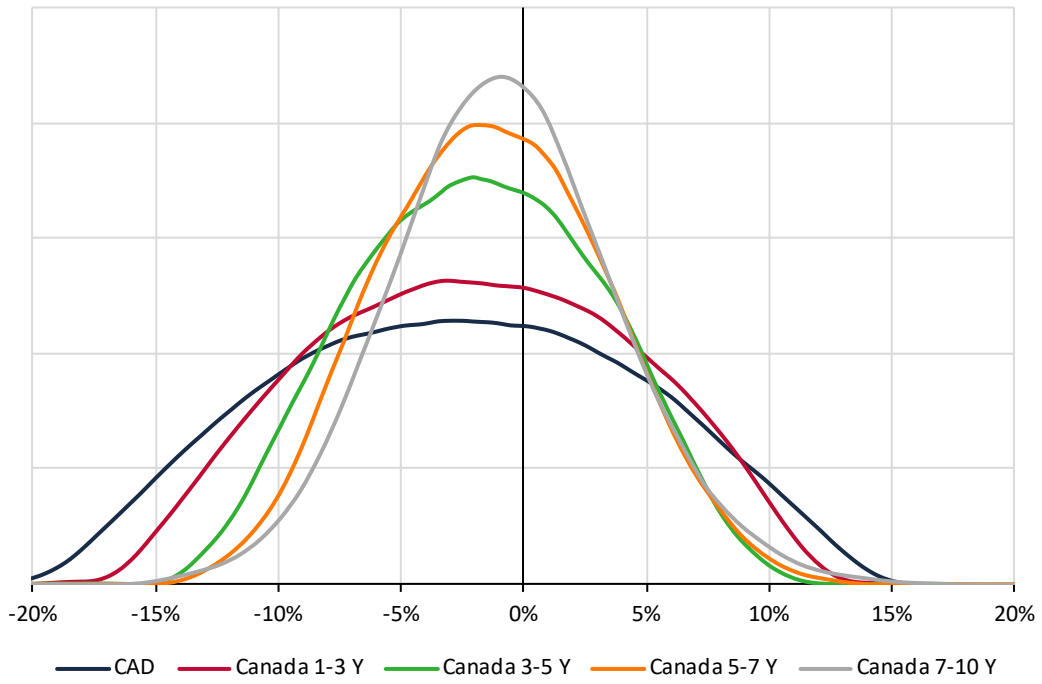
New Findings: A new Understanding of FX and FI risk Combined

- Our traditional approach to investing in a new currency included the use of short-term securities. Nevertheless, this year we learned that there is a powerful diversification benefit of using as an investment vehicle the long end of sovereign yield curves. Intuitively, this is attained due to the fact that - excluding a credit event - yields and FX returns are negatively correlated.

- Therefore, this year we incorporated new fixed income yield curves and reassigned our non-USD investments from the short to the long end of the curve.

Implied Annual Returns Distribution: Canadian Dollar and Sovereign Curve

Density



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Implied Annual Returns Distribution: Australian Dollar and Sovereign Curve

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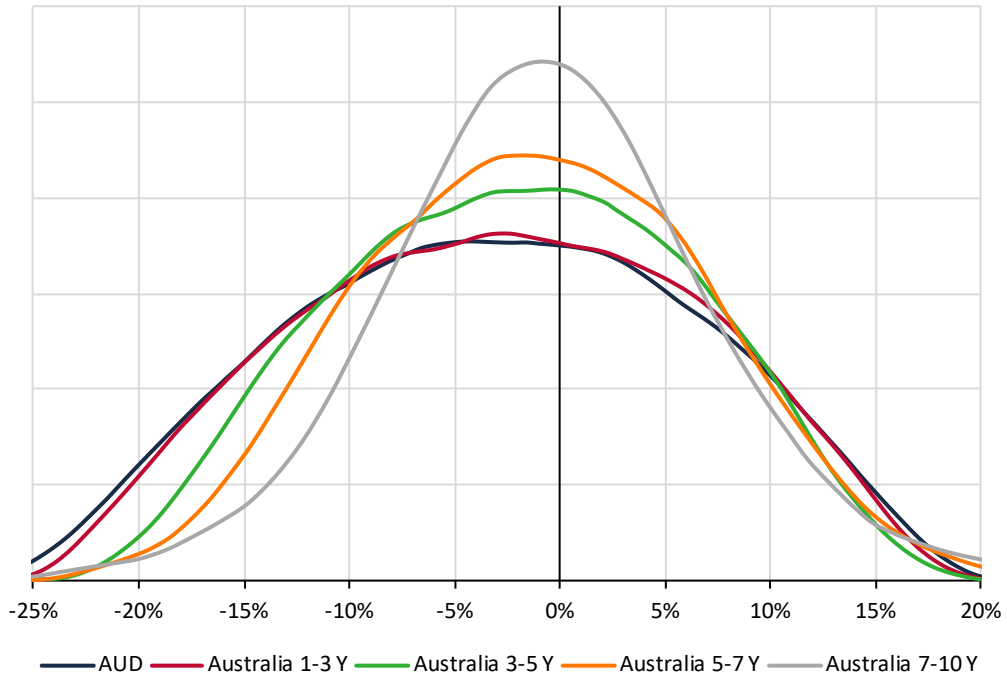

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New Findings: Investment Horizon

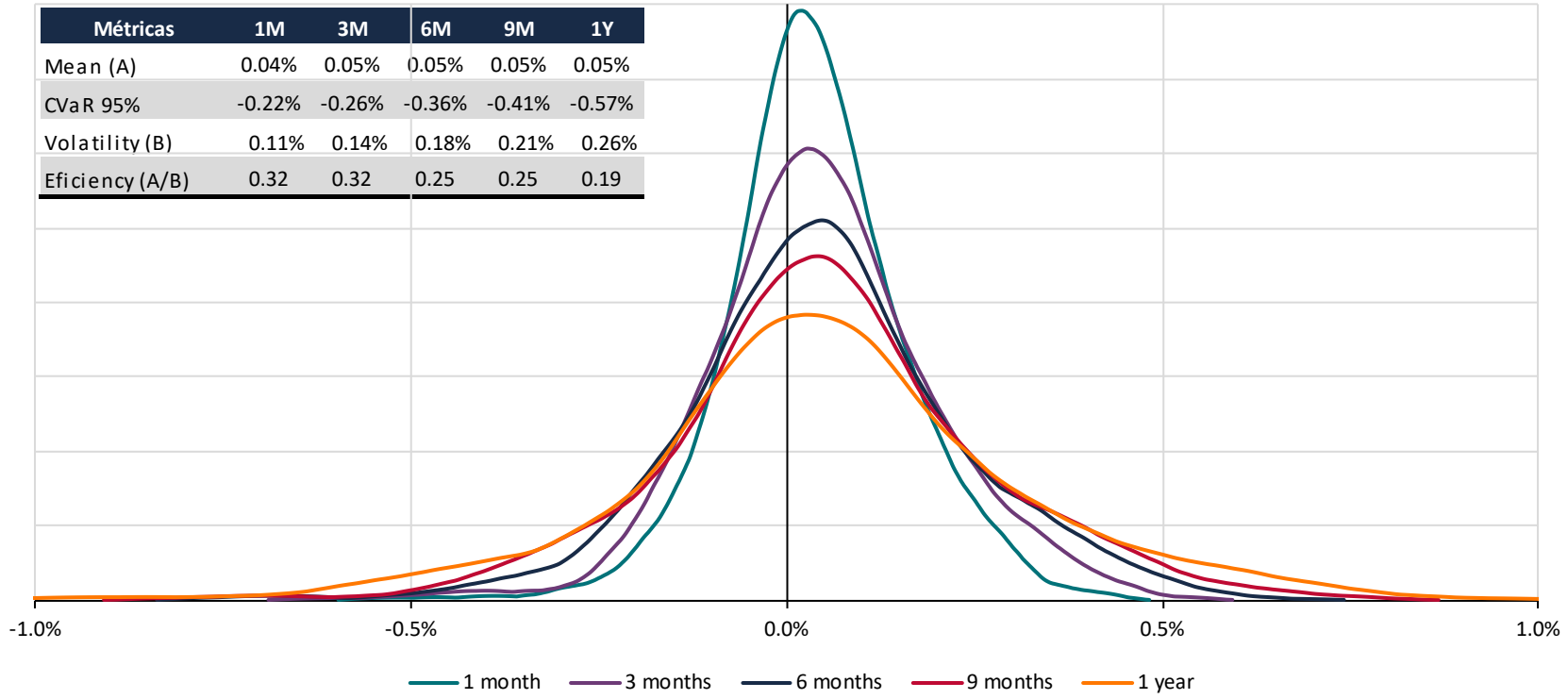
- Some of the traditional SAA premises (including having a long-term approach to SAA) might not be optimal and may only be the consequence of legacy. In this regard, we replicated our approach at different frequencies in order to gauge the impact of the investment horizon decision.

- Our finding suggests that increasing the frequency of the optimization procedure generates a strategy with a better risk-return profile. However, given practical issues such as transaction costs, we believe 3 months is the right spot and we are now using this tool to guide our tactical decisions.

Distribution of Realized Weekly Returns of Optimization Strategies at Different Frequencies

Density

Métricas	1M	3M	6M	9M	1Y
Mean (A)	0.04%	0.05%	0.05%	0.05%	0.05%
CVaR 95%	-0.22%	-0.26%	-0.36%	-0.41%	-0.57%
Volatility (B)	0.11%	0.14%	0.18%	0.21%	0.26%
Eficiency (A/B)	0.32	0.32	0.25	0.25	0.19



Source: Central Bank of Mexico with data from Bloomberg indices. To analyze the investment horizon we used non-overlapping weekly returns from 2006 and assuming independence we accumulated for 3, 6, 9 and 12 months. For each iteration, given a fixed date starting in 2006, we used 5 years of historical returns to adjust the marginal probability density of each asset and to determine the maximum likelihood parameters of a t-student copula. Given the t copula parameters, we simulated 10,000 realizations of the percentiles of each asset, which were then transformed into returns with the help of each marginal density. Once we get the compounded returns for each horizon, we defined individual and group boundaries for the allocation and implement the optimization by maximizing the excess returns for a fixed level of risk defined as the 95% CVaR. Finally, we evaluated the portfolio returns using the weights obtained from the optimization for the different horizons. This process was implemented for each week between 2006 and 2018.

Investment Strategies Diversification - Absolute Return Portfolios

- With time, we also realized that the use of benchmark portfolios to frame investment decisions could expose us to risks that we may not always want to bear. For instance, a sudden increase of interest rates (normalization of term-premium).
- As such, having alternative investment portfolios – not subject to a benchmark – could allow portfolio managers to focus in those strategies in which they have their highest conviction. In fact, they could even benefit from the normalization of interest rates through carrying negative duration in their portfolios.
- With said objective in mind, we launched a pilot program of **absolute return portfolios** through our External Asset Management Program.

Strategy Diversification		
	Benchmarked Strategies	**Non-Benchmarked Strategies**
Return	• Portfolio's return highly correlated to the benchmark's return	• Higher flexibility. The investment decisions depend solely on the degree of conviction and downside-risk management considerations • Ability to adopt long and short positions • Capital preservation in an environment of higher interest rates (particularly in United States) • Higher returns through active management
Risk	• Exposure to risk factors inherent to the benchmark	• Dynamically allocate risk to maximize risk-adjusted return opportunities

Correlation Matrix of the Assets in the International Reserves Portfolio
Percentage

		Benchmark	MBS	Gold	Cash	Manager 1	Manager 2	Manager 3
	Benchmark	100%						
	MBS	68%	100%					
	Gold	60%	28%	100%				
	Cash	3%	-2%	-2%	100%			
Absolute Return Mandate	Manager 1	-58%	-70%	-29%	-4%	100%		
	Manager 2	-32%	-47%	-13%	-1%	33%	100%	
	Manager 3	56%	81%	28%	0%	-59%	-58%	100%

Source: Central Bank of Mexico with data from Bank of America/Merrill Lynch indices. Weekly non-overlapping returns. Data since March 2017.

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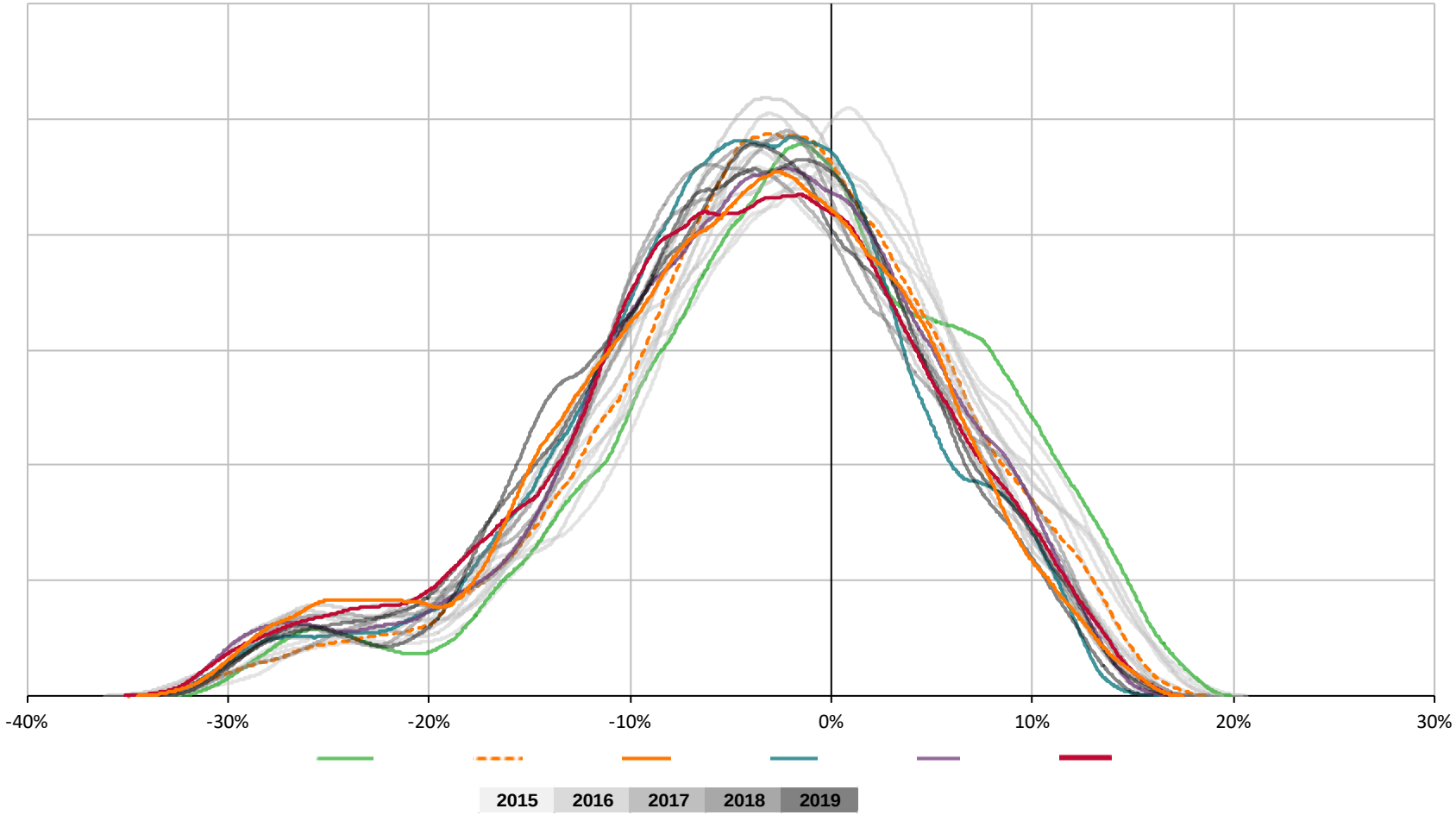
Mexican Peso return distribution

- We have also used these forward-looking methodologies to enhance our market intelligence activities. In particular, to analyze our own country´s assets, to understand the perspective of international investors in Mexican securities; and to analyze the structure of the market and identify potential opportunities and vulnerabilities.

Implied* Distribution of Mexican Peso Annual Returns

Density



Date	Mean	Volatility	CVaR 95%
Jun 15	-2.0%	9.0%	23.4%
Dec 16	-1.8%	9.3%	24.4%
Jun 16	-3.9%	9.1%	26.0%
Oct 16	-3.2%	8.9%	24.5%
Dec 16	-4.9%	9.3%	26.6%
Jun 17	-4.6%	9.4%	26.4%
Dec 17	-4.8%	8.6%	25.7%
Jun 18	-4.8%	9.1%	26.2%
Dec 18	-4.3%	9.2%	26.7%
Jun 19	-4.9%	8.7%	25.5%
Ago 19	-4.8%	9.4%	26.7%

US presidential election

Source: Bank of Mexico with data from Bloomberg. * The implied distribution functions for FX, Fixed Income and Total Return securities are obtained using the Breeden-Litzenberger methodology, the Ho-Lee model, and a Copula model that combines the first two, respectively.

FX returns

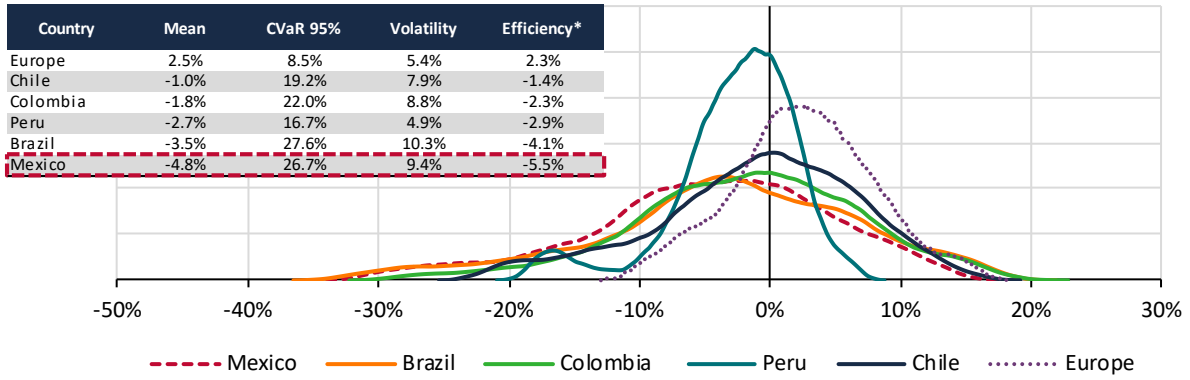
- The methodology also allows for a comparison between different countries and offers a different perspective for the understanding of their market structures.
- For example, the countries with narrower densities for FX returns are usually the ones that intervene in their currency markets more actively.

Implied* Distribution of Annual Returns for Selected Currencies as of August 29, 2019

Density

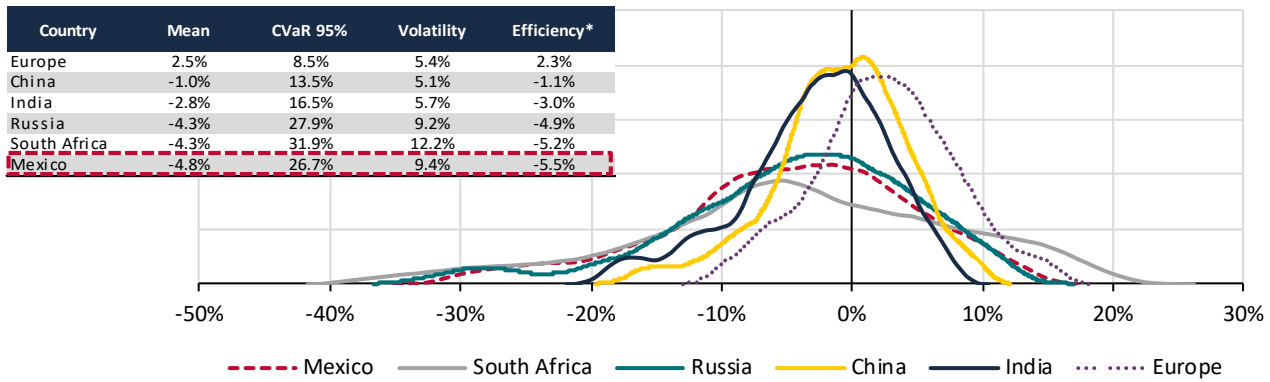
Latin America

Country	Mean	CVaR 95%	Volatility	Efficiency*
Europe	2.5%	8.5%	5.4%	2.3%
Chile	-1.0%	19.2%	7.9%	-1.4%
Colombia	-1.8%	22.0%	8.8%	-2.3%
Peru	-2.7%	16.7%	4.9%	-2.9%
Brazil	-3.5%	27.6%	10.3%	-4.1%
Mexico	-4.8%	26.7%	9.4%	-5.5%



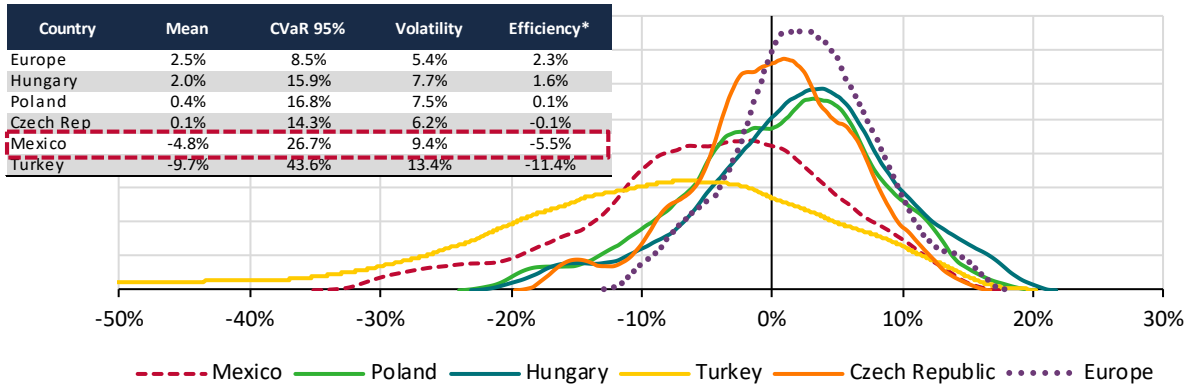
BRICS Excluding Brazil

Country	Mean	CVaR 95%	Volatility	Efficiency*
Europe	2.5%	8.5%	5.4%	2.3%
China	-1.0%	13.5%	5.1%	-1.1%
India	-2.8%	16.5%	5.7%	-3.0%
Russia	-4.3%	27.9%	9.2%	-4.9%
South Africa	-4.3%	31.9%	12.2%	-5.2%
Mexico	-4.8%	26.7%	9.4%	-5.5%



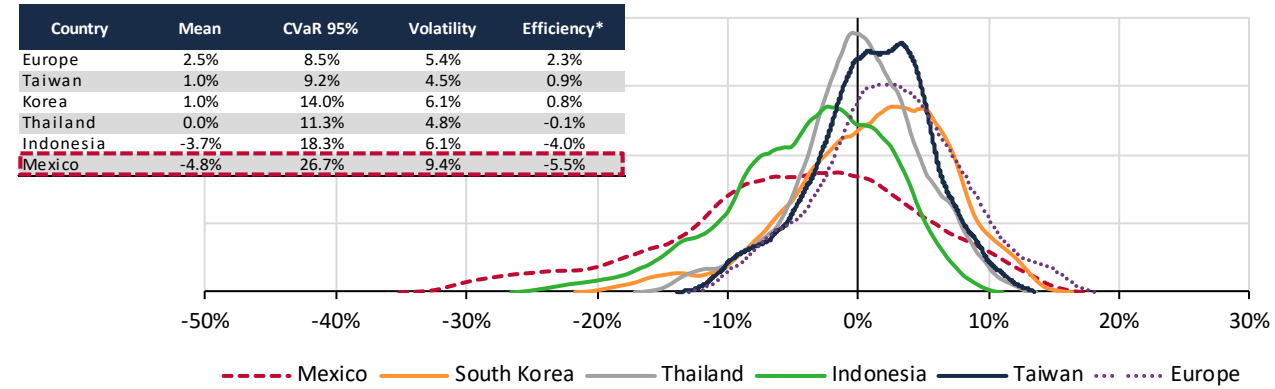
Emerging Europe

Country	Mean	CVaR 95%	Volatility	Efficiency*
Europe	2.5%	8.5%	5.4%	2.3%
Hungary	2.0%	15.9%	7.7%	1.6%
Poland	0.4%	16.8%	7.5%	0.1%
Czech Rep	0.1%	14.3%	6.2%	-0.1%
Mexico	-4.8%	26.7%	9.4%	-5.5%
Turkey	-9.7%	43.6%	13.4%	-11.4%



Emerging Asia

Country	Mean	CVaR 95%	Volatility	Efficiency*
Europe	2.5%	8.5%	5.4%	2.3%
Taiwan	1.0%	9.2%	4.5%	0.9%
Korea	1.0%	14.0%	6.1%	0.8%
Thailand	0.0%	11.3%	4.8%	-0.1%
Indonesia	-3.7%	18.3%	6.1%	-4.0%
Mexico	-4.8%	26.7%	9.4%	-5.5%

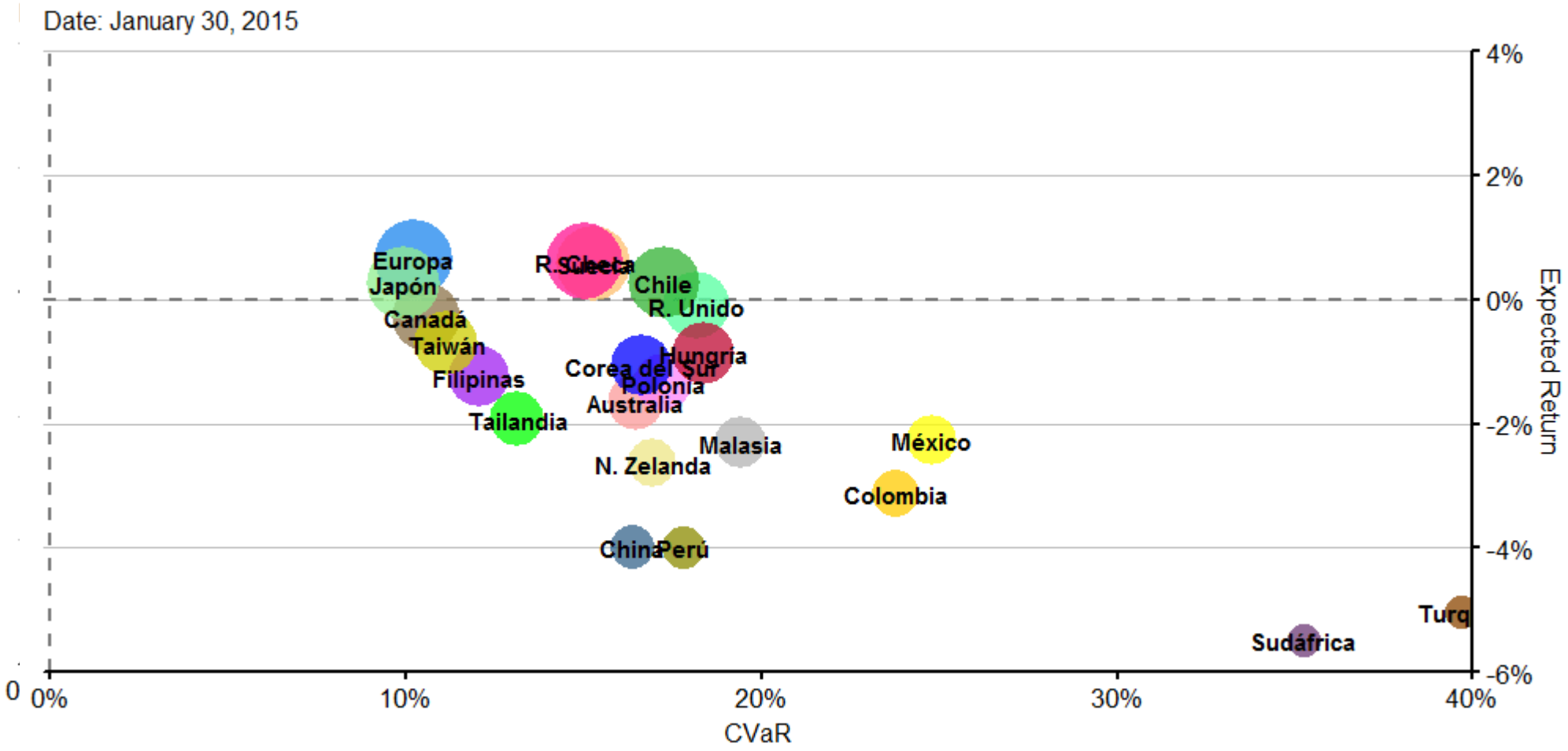


Source: Bank of Mexico with Bloomberg data. Returns implied in one year options. Rendimientos implícitos en las opciones de mercado a un horizonte de un año* The implied distribution functions for FX, Fixed Income and Total Return securities are obtained using the Breeden-Litzenberger methodology, the Ho-Lee model, and a Copula model that combines the first two, respectively. Efficiency is measured as the expected value of the utility derived from the associated wealth at each return. The utility function is the natural log of wealth.

Historic perspective of relative efficiency: FX returns

- This process is also helpful in analyzing historical patterns, detecting regime changes, and identifying shifts in investment flows in global markets.

Relative Efficiency of the Return Density for Selected Exchange Rates
Percentage



Source: Bank of Mexico with data from Bloomberg. * The implied distribution functions for FX, Fixed Income and Total Return securities are obtained using the Breeden-Litzenberger methodology, the Ho-Lee model, and a Copula model that combines the first two, respectively.

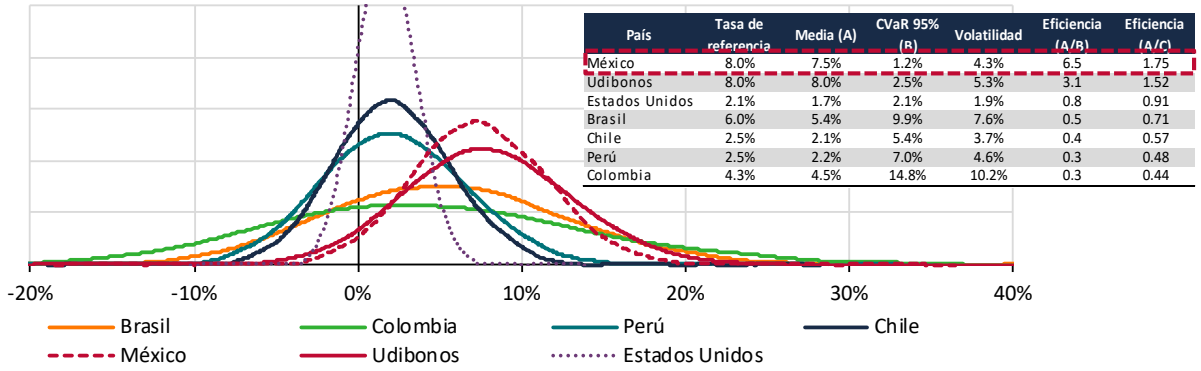
Local currency fixed income returns

- Local currency denominated fixed income returns show a narrower dispersion, and are usually centered on positive levels, around each country's reference rate.

Implied* Distribution of Annual Returns in Local Currency Fixed Income for Selected Countries as of August 29, 2019

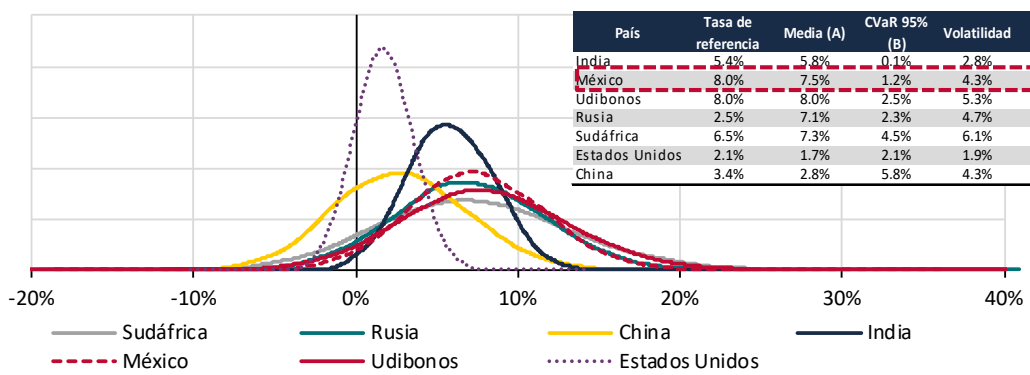
Density

Latinoamérica



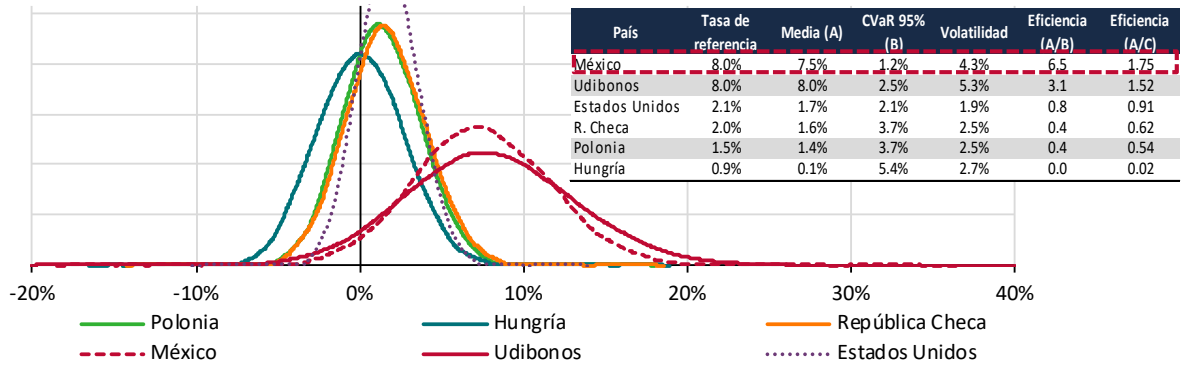
País	Tasa de referencia	Media (A)	CVaR 95% (B)	Volatilidad	Eficiencia (A/B)	Eficiencia (A/C)
México	8.0%	7.5%	1.2%	4.3%	6.5	1.75
Udibonos	8.0%	8.0%	2.5%	5.3%	3.1	1.52
Estados Unidos	2.1%	1.7%	2.1%	1.9%	0.8	0.91
Brasil	6.0%	5.4%	9.9%	7.6%	0.5	0.71
Chile	2.5%	2.1%	5.4%	3.7%	0.4	0.57
Perú	2.5%	2.2%	7.0%	4.6%	0.3	0.48
Colombia	4.3%	4.5%	14.8%	10.2%	0.3	0.44

BRICS excluyendo Brasil



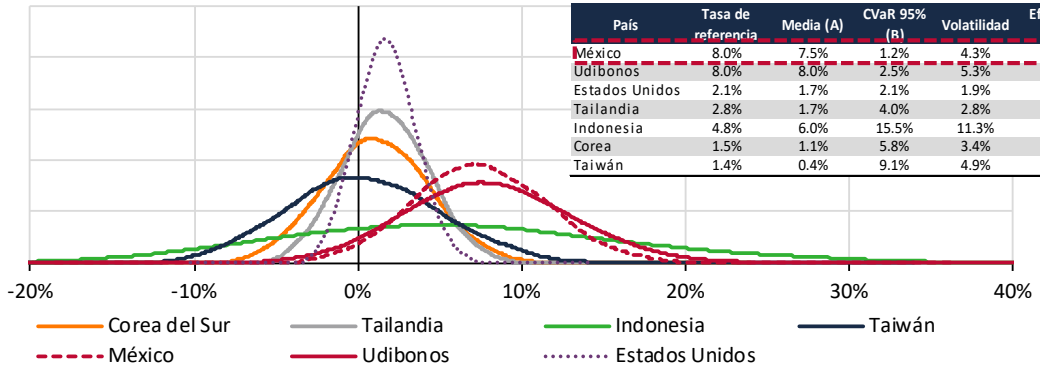
País	Tasa de referencia	Media (A)	CVaR 95% (B)	Volatilidad	Eficiencia (A/B)	Eficiencia (A/C)
India	5.4%	5.8%	0.1%	2.8%	49.0	2.09
México	8.0%	7.5%	1.2%	4.3%	6.5	1.75
Udibonos	8.0%	8.0%	2.5%	5.3%	3.1	1.52
Rusia	2.5%	7.1%	2.3%	4.7%	3.0	1.49
Sudáfrica	6.5%	7.3%	4.5%	6.1%	1.6	1.21
Estados Unidos	2.1%	1.7%	2.1%	1.9%	0.8	0.91
China	3.4%	2.8%	5.8%	4.3%	0.5	0.66

Europa del este



País	Tasa de referencia	Media (A)	CVaR 95% (B)	Volatilidad	Eficiencia (A/B)	Eficiencia (A/C)
México	8.0%	7.5%	1.2%	4.3%	6.5	1.75
Udibonos	8.0%	8.0%	2.5%	5.3%	3.1	1.52
Estados Unidos	2.1%	1.7%	2.1%	1.9%	0.8	0.91
R. Checa	2.0%	1.6%	3.7%	2.5%	0.4	0.62
Polonia	1.5%	1.4%	3.7%	2.5%	0.4	0.54
Hungría	0.9%	0.1%	5.4%	2.7%	0.0	0.02

Asia



País	Tasa de referencia	Media (A)	CVaR 95% (B)	Volatilidad	Eficiencia (A/B)	Eficiencia (A/C)
México	8.0%	7.5%	1.2%	4.3%	6.5	1.75
Udibonos	8.0%	8.0%	2.5%	5.3%	3.1	1.52
Estados Unidos	2.1%	1.7%	2.1%	1.9%	0.8	0.91
Tailandia	2.8%	1.7%	4.0%	2.8%	0.4	0.60
Indonesia	4.8%	6.0%	15.5%	11.3%	0.4	0.53
Corea	1.5%	1.1%	5.8%	3.4%	0.2	0.34
Taiwán	1.4%	0.4%	9.1%	4.9%	0.0	0.08

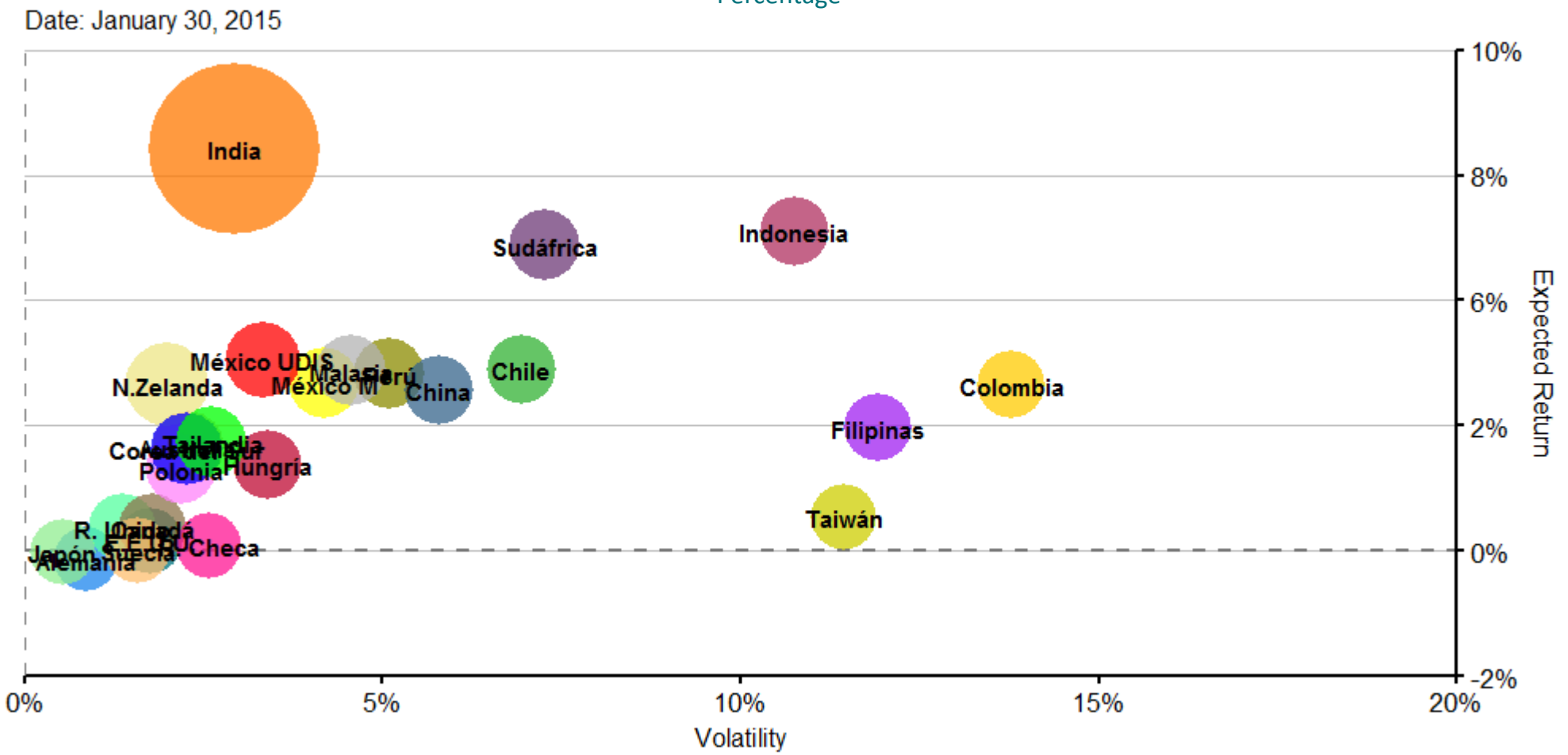
Source: Bank of Mexico with data from Bloomberg. * The implied distribution functions for FX, Fixed Income and Total Return securities are obtained using the Breeden-Litzenberger methodology, the Ho-Lee model, and a Copula model that combines the first two, respectively.

Historic perspective of relative efficiency: local currency fixed income returns

- Local currency denominated fixed income returns are dominated by India and Indonesia at the beginning of the reviewed period (2015-2017), and by Mexico from 2017 onwards.
- It is also worth noting that there seems to be a positive relationship between expected return and volatility, as well as a gradual deterioration in relative efficiency in developed markets.

Relative Efficiency of the Return Density for Selected Local Currency Fixed Income Markets

Percentage



Source: Bank of Mexico with data from Bloomberg. * The implied distribution functions for FX, Fixed Income and Total Return securities are obtained using the Breeden-Litzenberger methodology, the Ho-Lee model, and a Copula model that combines the first two, respectively.

Unhedged local currency fixed income returns

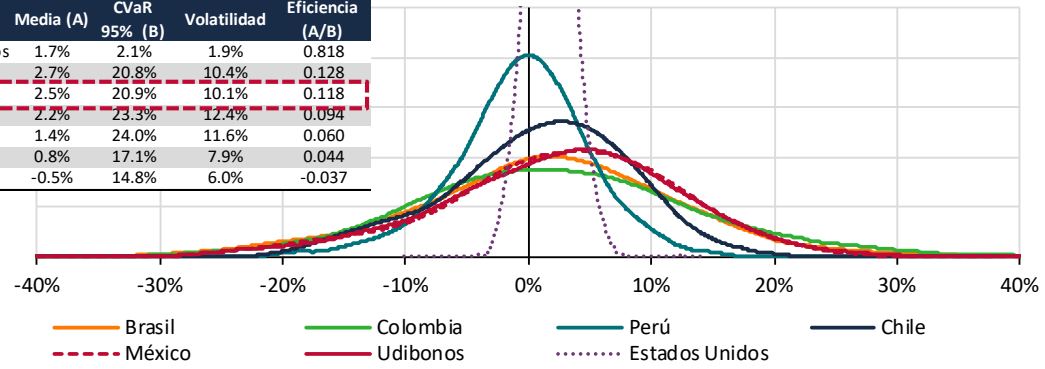
- It is also useful to study the distribution of returns that an investor with a US dollar numeraire, such as a reserve manager, would face when buying local currency denominated bonds without hedging the currency exposure.
- In the case of Mexico, the high returns that can be obtained from the fixed income component and the expectation of lower rates going forward, are partially offset by the risk associated to the currency exposure. The countries with a higher efficiency, showing a higher expected return and lower relative volatility, are India, South Korea, Thailand, and China.

Implied* Distribution of Unhedged Annual Returns in Local Currency Fixed Income for Selected Countries as of August 29, 2019

Density

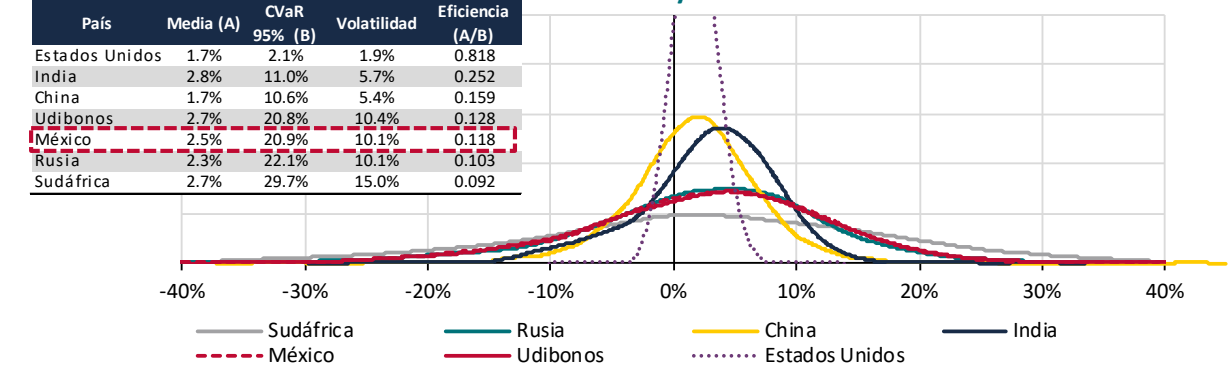
Latinoamérica

País	Media (A)	CVaR 95% (B)	Volatilidad	Eficiencia (A/B)
Estados Unidos	1.7%	2.1%	1.9%	0.818
Udibonos	2.7%	20.8%	10.4%	0.128
México	2.5%	20.9%	10.1%	0.118
Colombia	2.2%	23.3%	12.4%	0.094
Brasil	1.4%	24.0%	11.6%	0.060
Chile	0.8%	17.1%	7.9%	0.044
Perú	-0.5%	14.8%	6.0%	-0.037



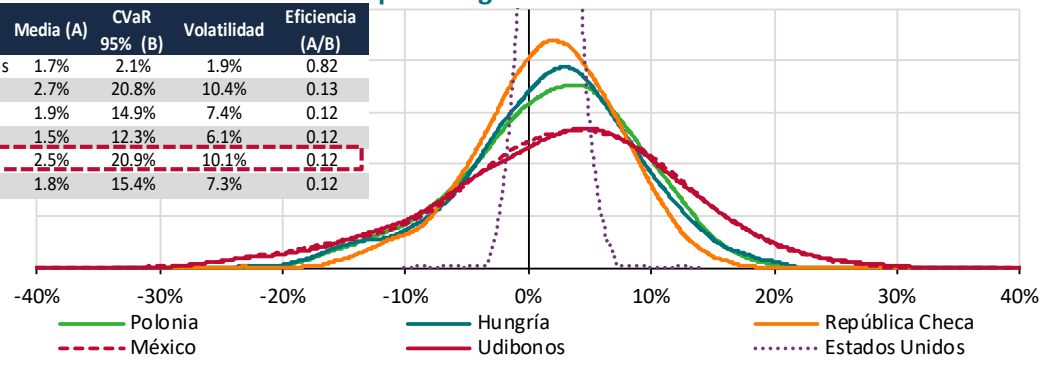
BRICS excluyendo Brasil

País	Media (A)	CVaR 95% (B)	Volatilidad	Eficiencia (A/B)
Estados Unidos	1.7%	2.1%	1.9%	0.818
India	2.8%	11.0%	5.7%	0.252
China	1.7%	10.6%	5.4%	0.159
Udibonos	2.7%	20.8%	10.4%	0.128
México	2.5%	20.9%	10.1%	0.118
Rusia	2.3%	22.1%	10.1%	0.103
Sudáfrica	2.7%	29.7%	15.0%	0.092



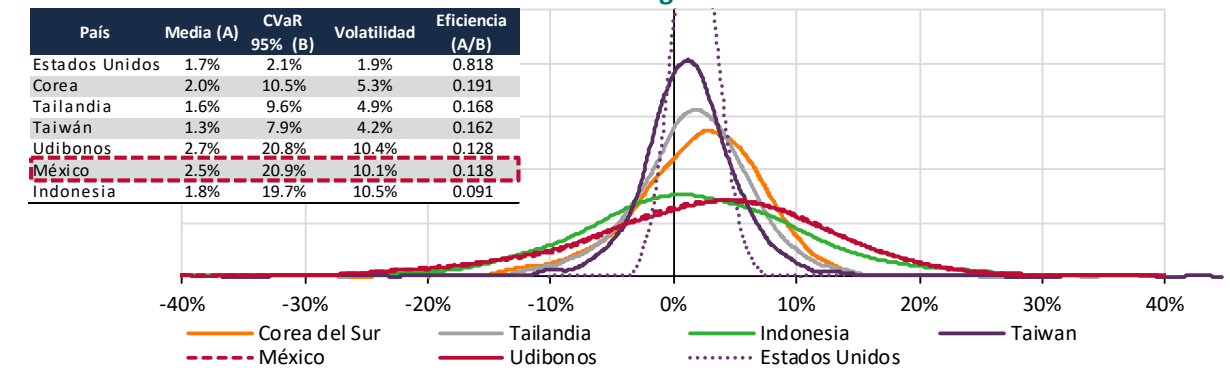
Europa emergente

País	Media (A)	CVaR 95% (B)	Volatilidad	Eficiencia (A/B)
Estados Unidos	1.7%	2.1%	1.9%	0.82
Udibonos	2.7%	20.8%	10.4%	0.13
Polonia	1.9%	14.9%	7.4%	0.12
R. Checa	1.5%	12.3%	6.1%	0.12
México	2.5%	20.9%	10.1%	0.12
Hungría	1.8%	15.4%	7.3%	0.12



Asia emergente

País	Media (A)	CVaR 95% (B)	Volatilidad	Eficiencia (A/B)
Estados Unidos	1.7%	2.1%	1.9%	0.818
Corea	2.0%	10.5%	5.3%	0.191
Tailandia	1.6%	9.6%	4.9%	0.168
Taiwán	1.3%	7.9%	4.2%	0.162
Udibonos	2.7%	20.8%	10.4%	0.128
México	2.5%	20.9%	10.1%	0.118
Indonesia	1.8%	19.7%	10.5%	0.091



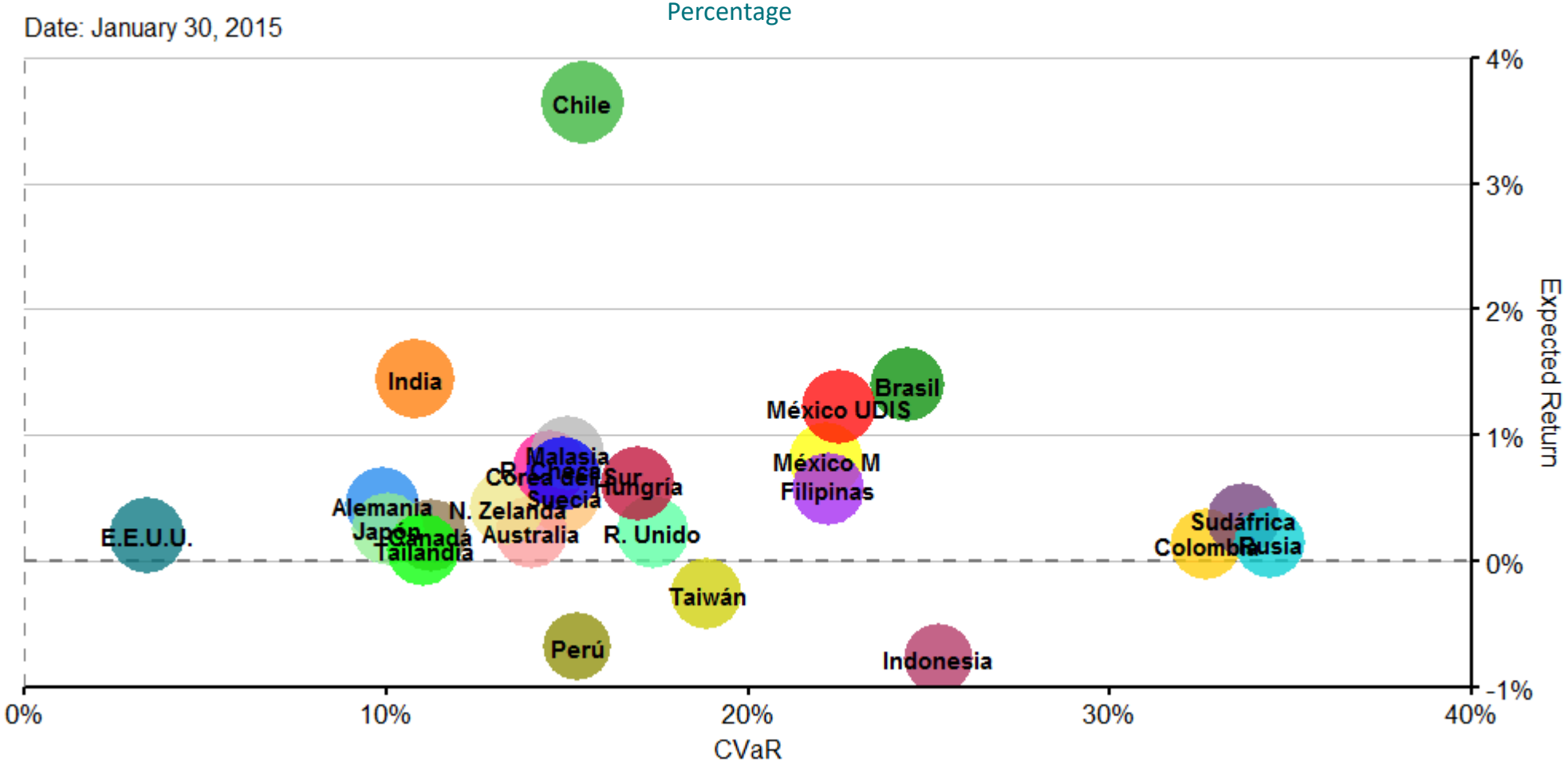
Source: Bank of Mexico with data from Bloomberg. * The implied distribution functions for FX, Fixed Income and Total Return securities are obtained using the Breeden-Litzenberger methodology, the Ho-Lee model, and a Copula model that combines the first two, respectively.

Historic perspective of relative efficiency: unhedged fixed income returns

- Our study period shows that as the Federal Reserve started its policy normalization process, the return distribution for the US becomes noticeably dominant. All the other countries also follow the US in increasing its expected returns.

Relative Efficiency of the Density of Unhedged Returns for Selected Local Currency Fixed Income Markets

Percentage



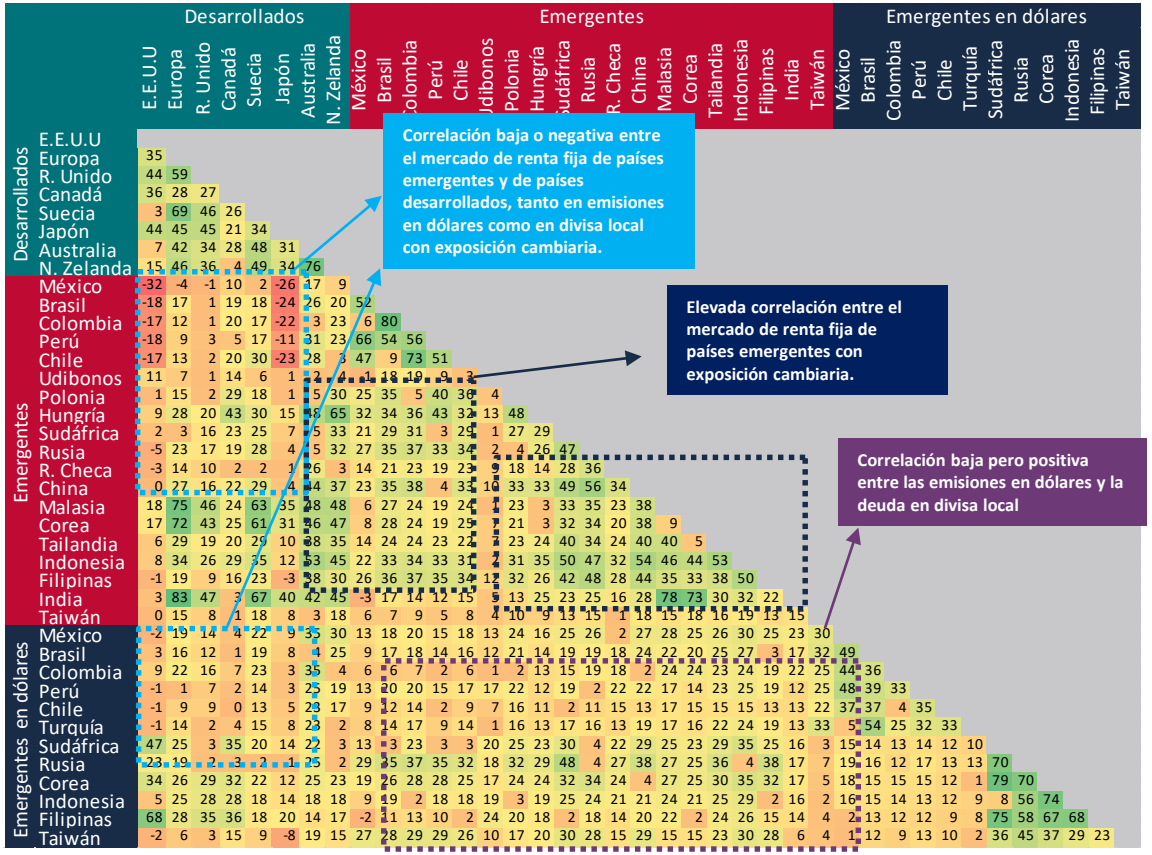
Source: Bank of Mexico with data from Bloomberg. * The implied distribution functions for FX, Fixed Income and Total Return securities are obtained using the Breeden-Litzenberger methodology, the Ho-Lee model, and a Copula model that combines the first two, respectively.

Optimal portfolio: Unhedged global local currency fixed income

- The inclusion of unhedged Emerging Market local currency fixed income assets in a global portfolio offers important diversification benefits. It is worth noting the negative correlation of UST and JGBs with the local currency markets of Mexico, Brazil, Colombia, Perú and Chile.
- This results in a portfolio with an overweight in emerging markets and underweight in developed markets.

Matriz de correlaciones de activos de renta fija de mercados globales seleccionados

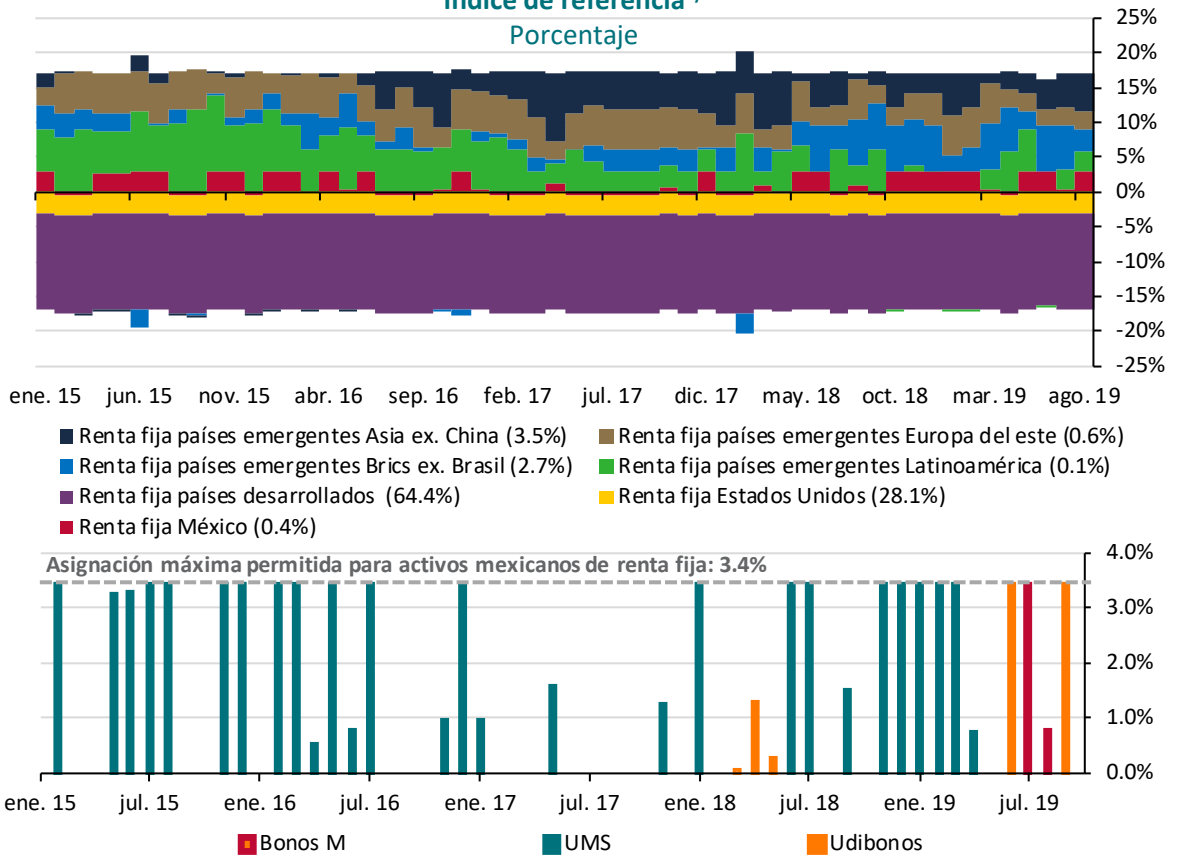
Porcentaje



Fuente: Banco de México con datos de los índices de Bloomberg. *Rendimientos semanales sin traslape (non-overlapping) anualizados. Datos de 2014-2019. La correlación de Spearman está dada por $\rho_S = \frac{Cov(F_X,F_Y)}{\sqrt{Var(F_X)}\sqrt{Var(F_Y)}}$, mientras que la correlación lineal está definida como: $\rho_P = \frac{Cov(X,Y)}{\sqrt{Var(X)}\sqrt{Var(Y)}}$

Renta fija global: evolución de la sobre/sub exposición del portafolio óptimo[1/] respecto a un índice de referencia[2/]

Porcentaje



Fuente: Banco de México con datos de Bloomberg. Nota: se realizó una optimización de portafolios a fin de mes en un período que comprende de enero de 2015 a agosto de 2019. 1/ Se usa el portafolio de máxima razón de eficiencia , definida como el cociente del rendimiento entre el CVaR. 2/ Se utilizó el índice Barclays Global Government Index Unhedged.

Optimal portfolio: Unhedged equity markets

- The inclusion of unhedged Emerging Market equity offers some diversification benefits.
- Russia, South Korea, and Indonesia show a low correlation to developed markets while Mexican equity has a positive correlation of around 30% with developed markets.
- The resulting optimal unhedged global equity portfolios show a clear tendency to overweight equity from the US, Latin America and BRICS excluding Brazil, and an underweight in other developed markets.

Matriz de correlaciones de activos de renta variable de mercados globales seleccionados

Porcentaje

	E.E.U.U	Europa	R. Unido	Canadá	Suecia	Japón	Australia	N. Zelanda	México	Brasil	Chile	Polonia	Turquía	Sudáfrica	Rusia	China	Malasia	Corea	Tailandia	Indonesia	Taiwán
Desarrollados																					
E.E.U.U																					
Europa	52																				
R. Unido	6	80																			
Canadá	66	54	56																		
Suecia	47	9	73	51																	
Japón	-1	18	19	9	3																
Australia	25	35	5	40	36	4															
N. Zelanda	32	34	36	43	32	13	48														
Emergentes																					
México	24	32	33	33	32	11	29	28													
Brasil	21	29	31	3	29	1	27	29	53												
Chile	23	35	38	4	33	10	33	33	52	49											
Polonia	8	28	24	19	25	7	21	3	35	32	38										
Turquía	22	33	34	33	31	2	31	35	59	50	54	44									
Sudáfrica	26	36	37	35	34	12	32	26	45	42	44	33	50								
Rusia	-3	17	14	12	15	5	13	25	23	23	28	73	32	22							
China	13	18	20	15	18	13	24	16	27	25	27	25	30	25	23						
Malasia	9	17	18	14	16	12	21	14	19	19	24	20	27	3	17	49					
Corea	6	6	7	2	6	1	2	13	16	15	2	24	24	19	22	44	36				
Tailandia	13	20	20	15	17	17	22	12	19	19	22	14	25	19	12	48	39	33			
Indonesia	9	12	14	2	9	7	16	11	13	2	13	15	15	13	13	37	37	4	35		
Taiwán	13	3	23	3	3	20	25	23	44	30	29	23	35	25	16	15	14	13	14	12	

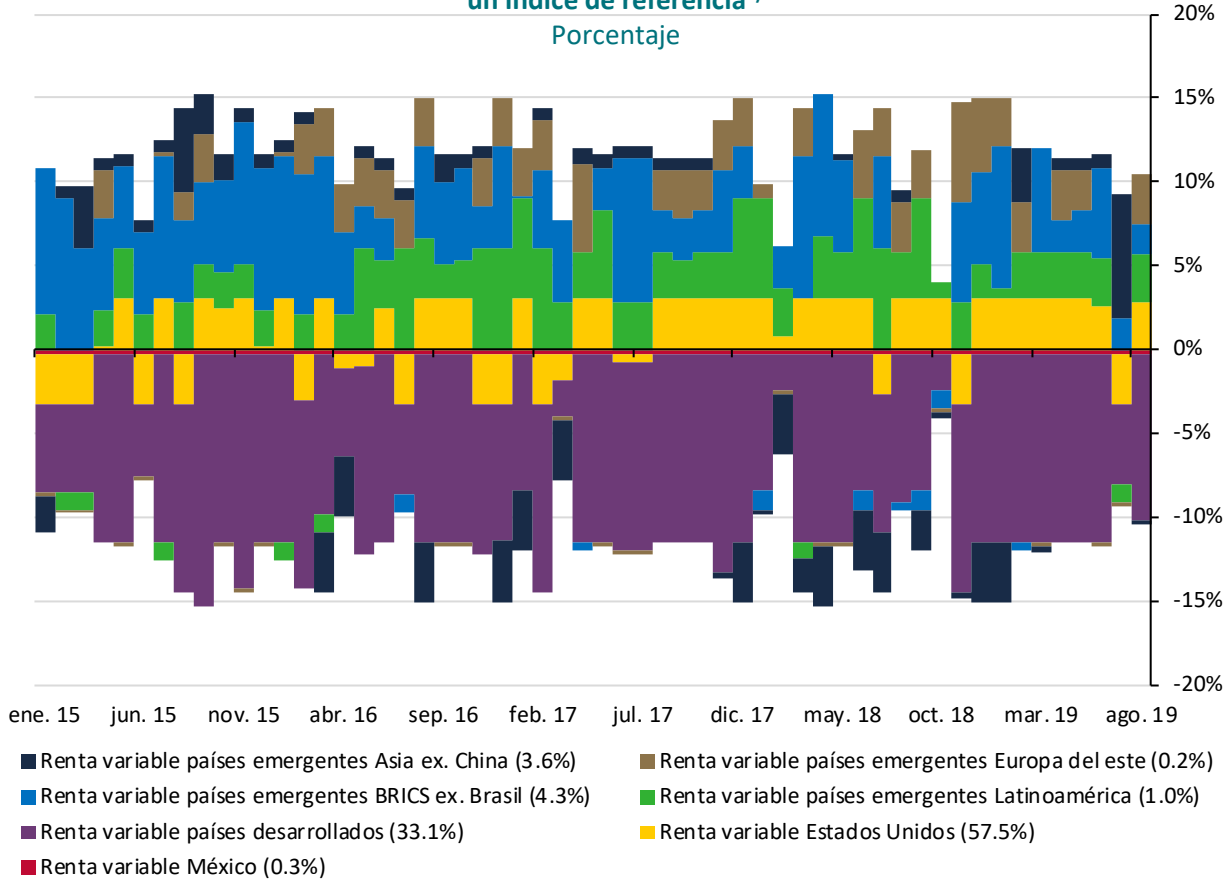
Correlación elevada y positiva con el mercado accionario de países desarrollados

Correlación baja con el mercado accionario de países desarrollados

Fuente: Banco de México con datos de los índices de Bloomberg. *Rendimientos semanales sin traslape (non-overlapping) anualizados. Datos de 2014-2019. La correlación de Spearman está dada por $\rho_S = \frac{Cov(F_X,F_Y)}{\sqrt{Var(F_X)}\sqrt{Var(F_Y)}}$, mientras que la correlación lineal está definida como: $\rho_P = \frac{Cov(X,Y)}{\sqrt{Var(X)}\sqrt{Var(Y)}}$

Renta variable global: evolución de la sobre/sub exposición del portafolio óptimo[1/] respecto a un índice de referencia[2/]

Porcentaje



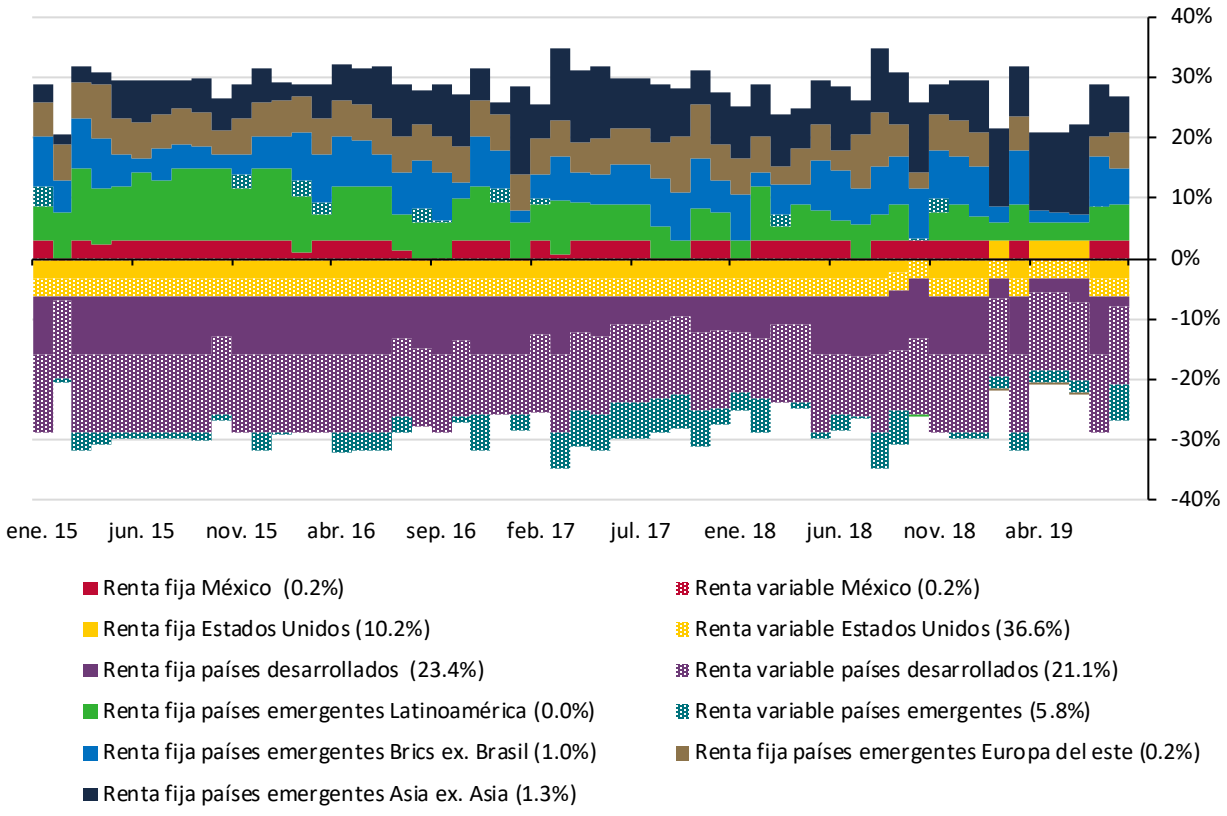
Fuente: Banco de México con datos de Bloomberg. Nota: se realizó una optimización de portafolios a fin de mes en un período que comprende de enero de 2015 a agosto de 2019. 1/ Se usa el portafolio de máxima razón de eficiencia , definida como el cociente del rendimiento entre el CVaR. 2/ Se utilizo el índice MSCI global.

Optimal portfolio: Unhedged global multi-asset portfolio

- The optimal global multi-asset portfolio suggests an increase to fixed income markets, specifically in EM, and a lower exposure to equities.
- In the case of Mexico, the model recommends a long position of Mexican assets in 36 out of the 56 months in our study. Such exposure is concentrated in dollar denominated bonds (UMS).

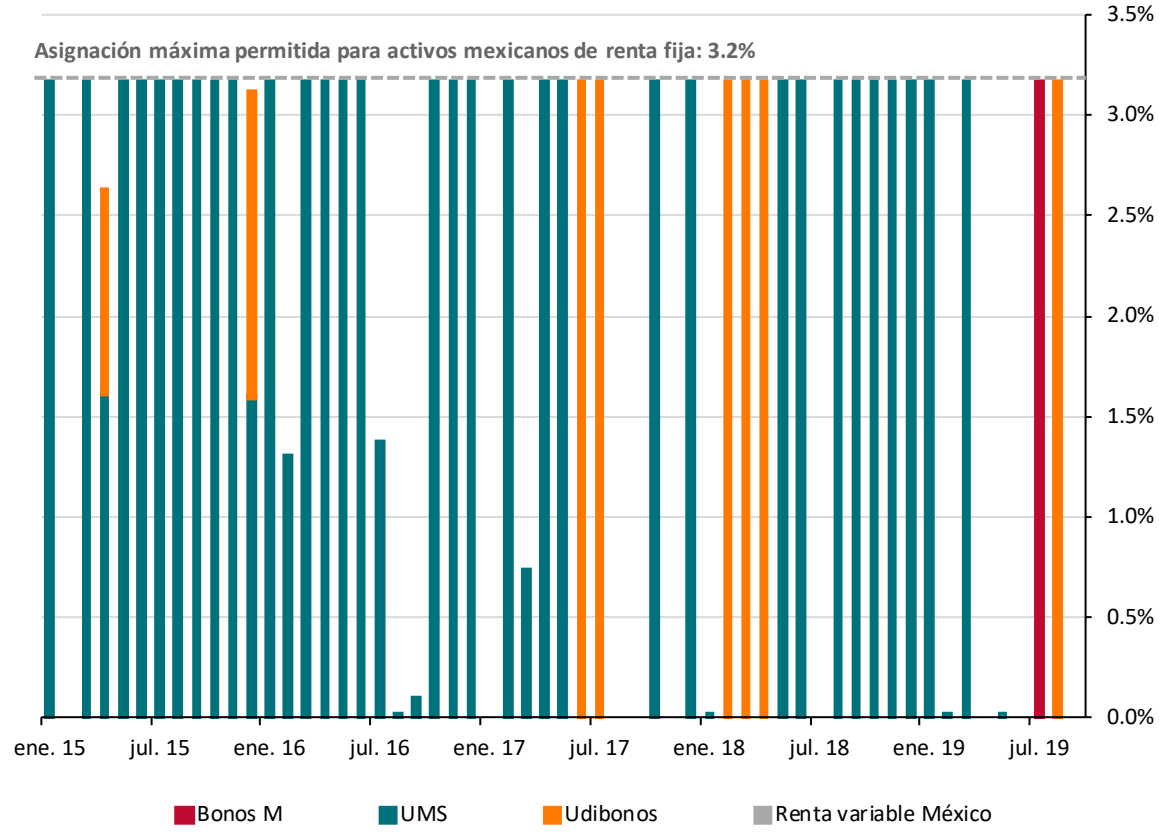
Evolución de la sobre/sub exposición del portafolio multi-activo global óptimo[1/] respecto a un índice de referencia[2/]

Porcentaje



Multi-activo global: evolución de la sobre/sub exposición del portafolio óptimo[1/] respecto a un índice de referencia[2/]

Porcentaje



Fuente: Banco de México con datos de Bloomberg. Nota: se realizó una optimización de portafolios a fin de mes en un período que comprende de enero de 2015 a agosto de 2019. 1/ Se usa el portafolio de máxima razón de eficiencia , definida como el cociente del rendimiento entre el CVaR. 2/ Se utilizo el índice Barclays Global Government Index Unhedged, el índice MSCI global y el índice MSCI mercados emergentes.

Final Remarks

- Financial markets the last few years have posed **unprecedented challenges for reserve managers**, mainly because of the transition to a more normal stance of monetary policy in the US, and the zero to negative yield environment in other developed markets.

- Banco de México has approached this new economic and financial landscape with a reassessment of the reserve management priorities towards **capital preservation**.

- In doing so, we had to reassess the way in which we analyze asset class returns, and therefore, the steps to determine our Strategic Asset Allocation. Our models have **moved away from relying on historical information, into more prospective indicators** that can be extracted from market prices (options and yield curves).

- Our methodology has proven useful not only to guide our SAA, but also to **enhance our active management decision process**. In that regard, we have also transitioned from market-timing strategies, into more systematic trading positions.

- Finally, this methodology can also be used to **assess the relative attractiveness of different assets and understand global flows** from an investor perspective.

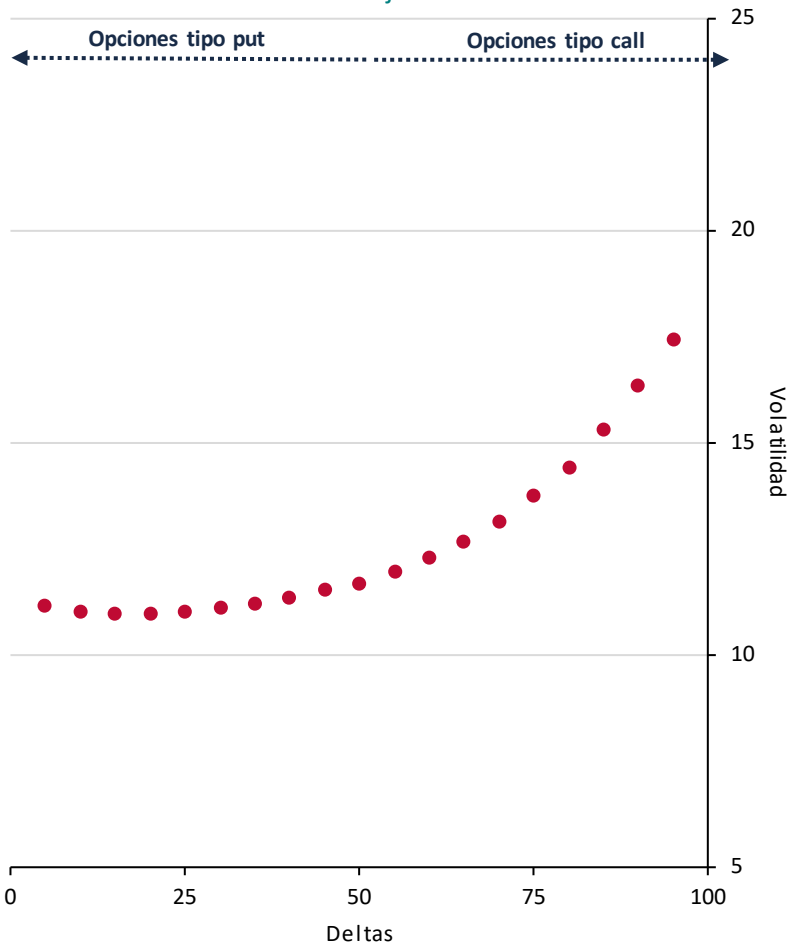
- Going forward, Banco de México will continue to evaluate and embrace methodologies that enhance the risk-return profile of its investment portfolio. It will also keep a **flexible approach to adapt its investment strategies to the changing conditions of financial markets.**

Appendix

METODOLOGÍA: DISTRIBUCIONES PROSPECTIVAS PARA EL RENDIMIENTO CAMBIARIO - BREEDEN LITZENBERGER

1 **Curva de volatilidad implícita en opciones del peso mexicano (USDMXN)**

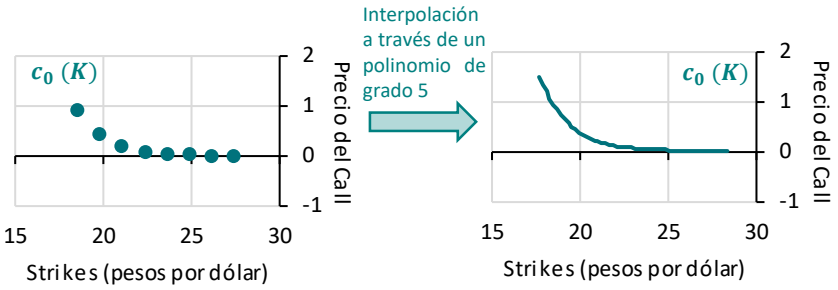
Porcentaje



Fuente: Banco de México con datos de Bloomberg. *Rendimientos implícitos en las opciones de mercado a un horizonte de un año al 19 de agosto de 2019. Las distribuciones implícitas se obtienen con base en el modelo de Ho-Lee y kernels Epanechnikov.

2 **Utilizar la metodología de Breeden-Litzenberger**

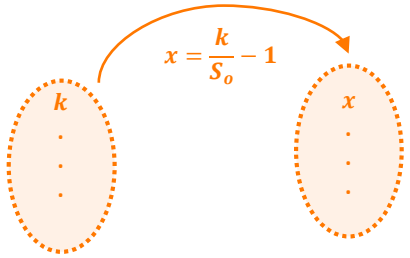
a) Obtener una curva "continua" de precios de un *call* europeo para diferentes strikes



b) Calcular la segunda derivada numérica de dicha curva respecto al strike

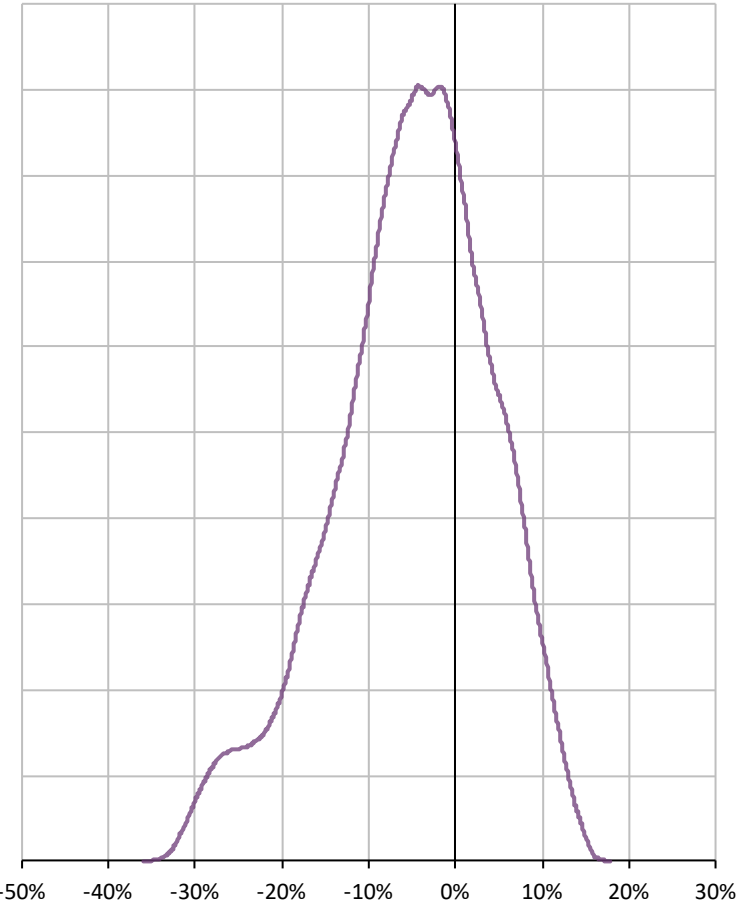
$$\frac{\partial^2 c_0(K)}{\partial K^2} \approx \frac{c_0(K-d) + c_0(K+d) - 2c_0(K)}{d^2}$$

c) Transformar a de una distribución de precios a una de rendimientos



3 **Distribución de rendimientos del peso mexicano**

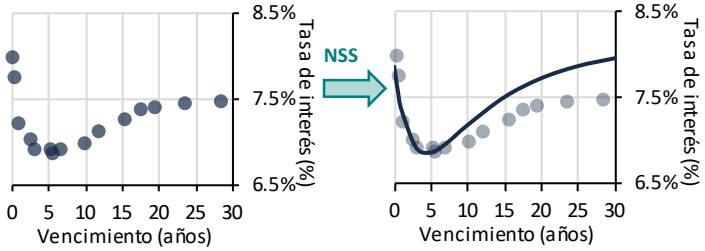
Densidad



Fuente: Banco de México con datos de Bloomberg.

METODOLOGÍA: DISTRIBUCIONES PROSPECTIVAS PARA EL RENDIMIENTO DE ACTIVOS DE RENTA FIJA - MODELO HO-LEE

El primer paso necesario es obtener una curva cupón cero continua, para lo cual se ajusta el modelo de Nelson-Siegel-Svensson (NSS) a los datos de la curva de rendimiento de bonos cuponados observada en el mercado.



Posteriormente, se asume que la curva de rendimiento depende únicamente de la evolución de la tasa de corto plazo, que no existen posibilidades de arbitraje y que dicha evolución sigue un proceso binomial con la siguiente especificación:

$$r_t \begin{cases} q & r_{t+1}^{u} = r_t + \boldsymbol{\theta}_t dt + \sigma \cdot \sqrt{dt} \\ 1-q & r_{t+1}^{d} = r_t + \boldsymbol{\theta}_t dt - \sigma \cdot \sqrt{dt} \end{cases}$$

Donde:

- $\boldsymbol{r_t}$ es la tasa libre de riesgo de corto plazo
- $\boldsymbol{d_t}$ es el plazo en el que puede cambiar la tasa de corto plazo
- $\boldsymbol{\sigma}$ es la volatilidad de la tasa de interés de corto plazo
- $\boldsymbol{q}$ es la probabilidad neutral en riesgo

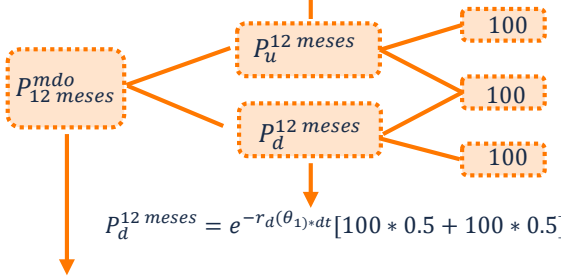
Asumamos que se tiene la siguiente curva cupón cero con $q = 0.5$ y $d_t = 0.5$.

Periodo	Vencimiento	Precio	Tasa spot
t=1	6 meses	$P_{6\ meses}^{mdo}$	$r_{6\ meses}^{mdo}$
t=2	12 meses	$P_{12\ meses}^{mdo}$	$r_{12\ meses}^{mdo}$
t=3	18 meses	$P_{18\ meses}^{mdo}$	$r_{18\ meses}^{mdo}$

Y que la volatilidad de la tasa de corto plazo se estima con un GARCH(1,1) , lo que genera: $\widehat{\boldsymbol{\sigma}}$

En este proceso semestral y utilizando el bono de 12 meses, se tiene que:

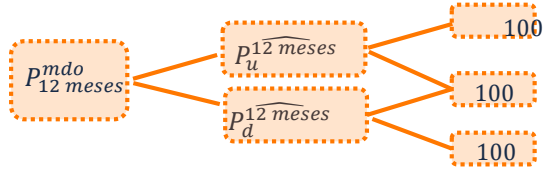
$$P_u^{12\ meses} = e^{-r_u(\theta_1)*dt}[100*0.5 + 100*0.5]$$

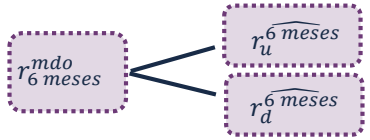


$$P_d^{12\ meses} = e^{-r_d(\theta_1)*dt}[100*0.5 + 100*0.5]$$

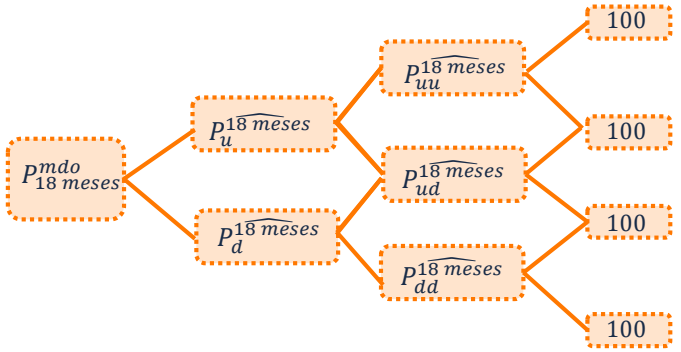
$$P_{12\ meses}^{mdo} = e^{-r_{6\ meses}^{mdo}dt}[P_u^{12\ meses}(\theta_1)*0.5 + P_d^{12\ meses}(\theta_1)*5]$$

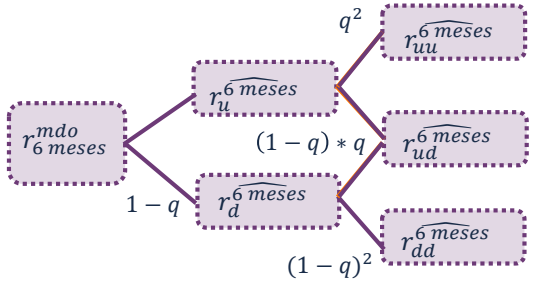
Esta genera una ecuación con una incógnita a partir de la cual se obtiene $\widehat{\boldsymbol{\theta_1}}$. Así, se generan los siguientes dos elementos:





Así, utilizando el bono de 18 meses y los resultados anteriores, se repite el proceso hasta encontrar $\widehat{\boldsymbol{\theta_2}}$ y obtener:





Este proceso se repite hasta obtener $\{\widehat{\boldsymbol{\theta_3}}, \widehat{\boldsymbol{\theta_4}}, \ldots, \widehat{\boldsymbol{\theta_n}}\}$ y generar una trayectoria semestral para todas los plazos disponibles en la curva cero y obtener un árbol neutral de la tasa de corto plazo hasta el último vencimiento.

Las trayectorias de los procesos de cada bono son utilizadas para obtener las distribuciones de rendimientos.

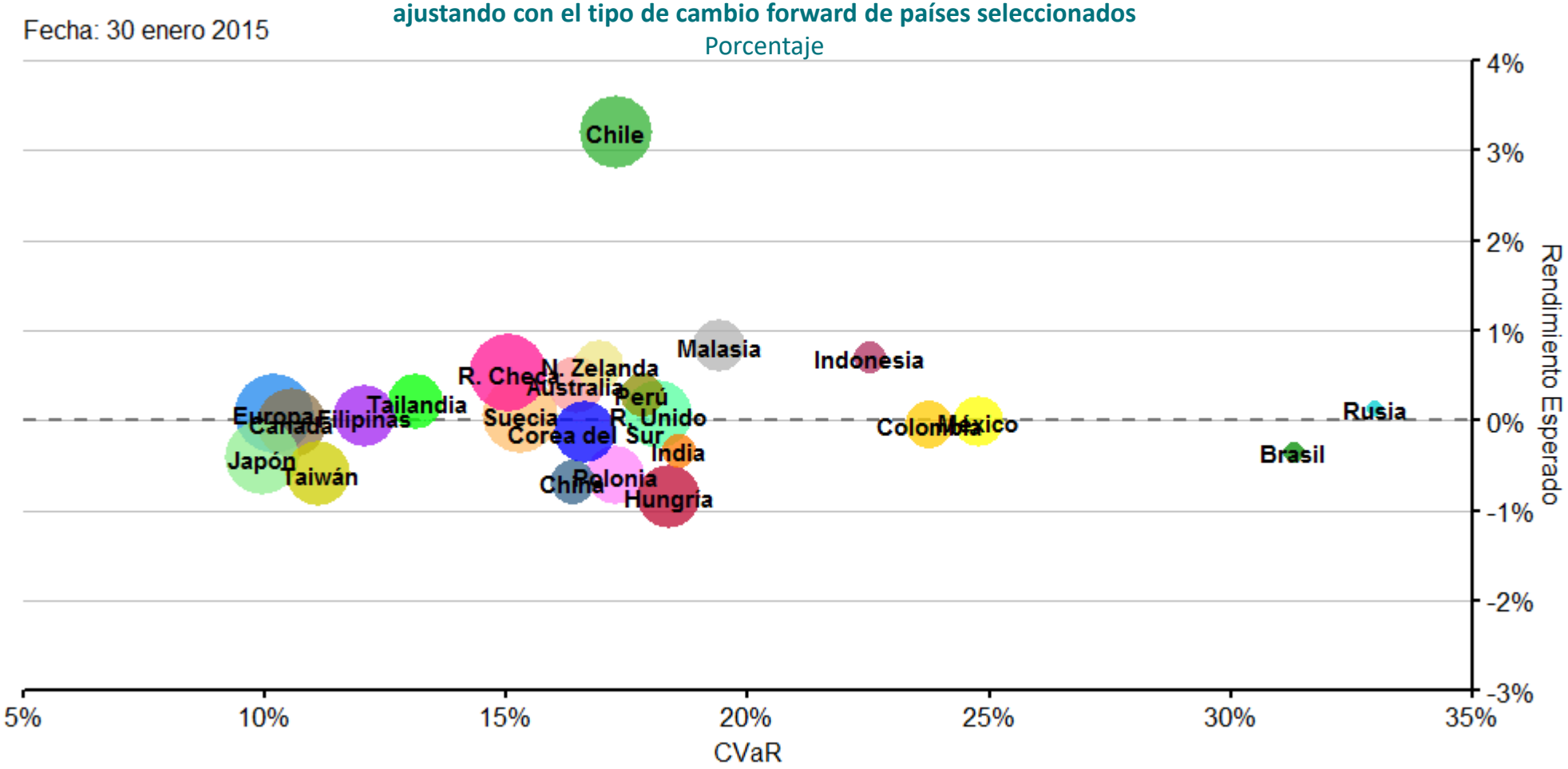
METODOLOGÍA: DISTRIBUCIONES PROSPECTIVAS PARA EL RENDIMIENTO DE ACTIVOS DE RENTA FIJA - MODELO HO-LEE

Fuente: Banco de México con datos al 29 de agosto de 2019.

UNA PERSPECTIVA HISTÓRICA DE LA EFICIENCIA RELATIVA: RENDIMIENTO CAMBIARIO AJUSTADO CON EL TIPO DE CAMBIO FORWARD

- El rendimiento cambiario implícito en opciones, cuando se excluye la apreciación/depreciación asociada al tipo de cambio forward, muestra que la relación riesgo y rendimiento tiene una pendiente cercana a cero.
- Adicionalmente, sobresale que, en el caso de México, el peso muestra un rendimiento esperado cercano a cero y un CVaR elevado en comparación con otros países de mercados emergentes. En efecto, en los últimos meses, el peso muestra una de las razones de eficiencia más bajas de la muestra.

Evolución de la eficiencia relativa de la distribución de los rendimientos anuales en el mercado cambiario ajustando con el tipo de cambio forward de países seleccionados



Fuente: Banco de México con datos de Bloomberg. *Rendimientos implícitos en las opciones de mercado a un horizonte de un año con base en información mensual del 30 de enero de 2015 al 29 de agosto de 2019. Las distribuciones implícitas utilizan la metodología de Breeden-Litzenberger y kernels Epanechnikov.

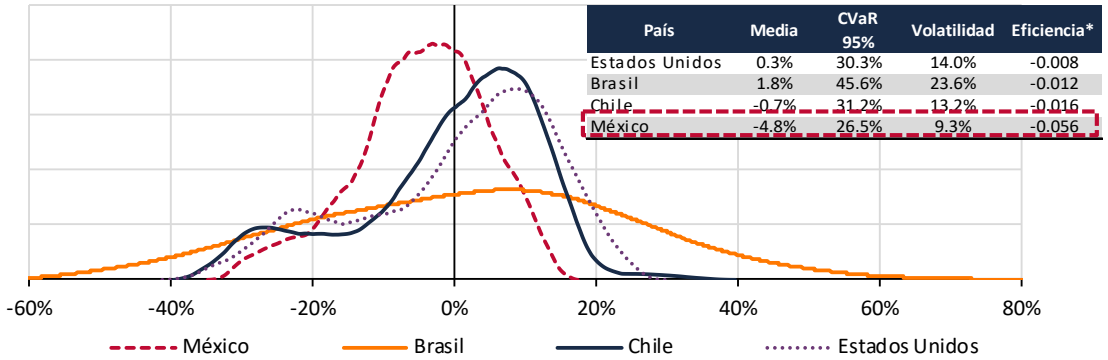
Rendimiento de renta variable local con exposición al tipo de cambio

- La distribuciones de rendimientos totales (incluyendo FX) del mercado accionario son menos homogéneas que los otros mercados, pero resalta: 1) el elevado nivel de volatilidad (muy superior al de los otros mercados); 2) el bajo nivel de eficiencia y; 3) en muchos casos, el sesgo a observar pérdidas importantes.
- En este mercado, la distribución de México es la menos atractiva en términos de eficiencia, al tener el rendimiento esperado más bajo. Lo anterior, es probablemente el resultado del elevado nivel de correlación entre el mercado de renta variable y el peso mexicano.

Distribución implícita en precios de mercado de los rendimientos anuales de renta variable sin cobertura cambiaria de países seleccionados al 29 de agosto de 2019

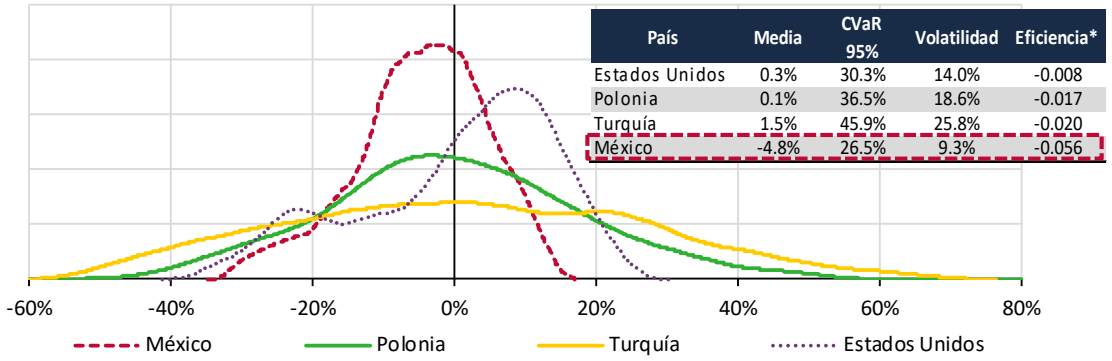
Densidad

Latinoamérica



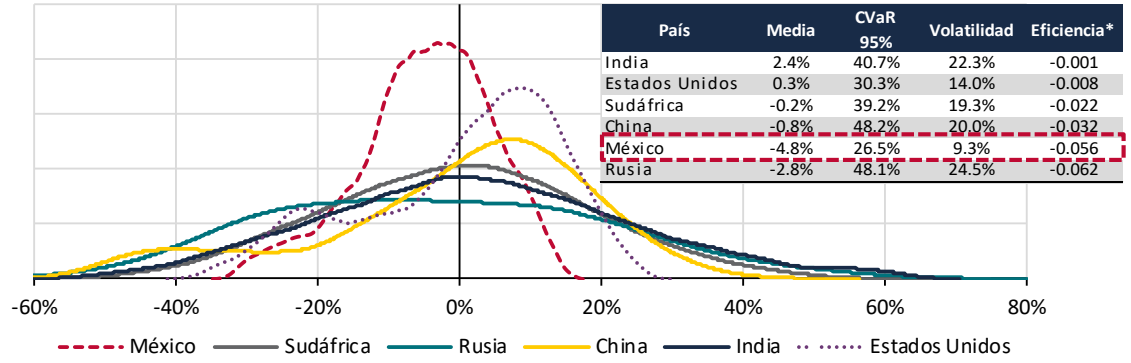
País	Media	CVaR 95%	Volatilidad	Eficiencia*
Estados Unidos	0.3%	30.3%	14.0%	-0.008
Brasil	1.8%	45.6%	23.6%	-0.012
Chile	-0.7%	31.2%	13.2%	-0.016
México	-4.8%	26.5%	9.3%	-0.056

Europa del este



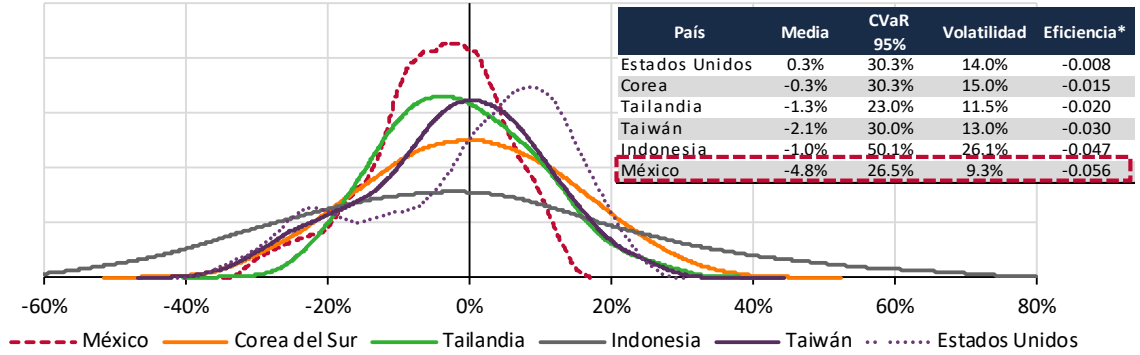
País	Media	CVaR 95%	Volatilidad	Eficiencia*
Estados Unidos	0.3%	30.3%	14.0%	-0.008
Polonia	0.1%	36.5%	18.6%	-0.017
Turquía	1.5%	45.9%	25.8%	-0.020
México	-4.8%	26.5%	9.3%	-0.056

BRICS excluyendo Brasil



País	Media	CVaR 95%	Volatilidad	Eficiencia*
India	2.4%	40.7%	22.3%	-0.001
Estados Unidos	0.3%	30.3%	14.0%	-0.008
Sudáfrica	-0.2%	39.2%	19.3%	-0.022
China	-0.8%	48.2%	20.0%	-0.032
México	-4.8%	26.5%	9.3%	-0.056
Rusia	-2.8%	48.1%	24.5%	-0.062

Asia



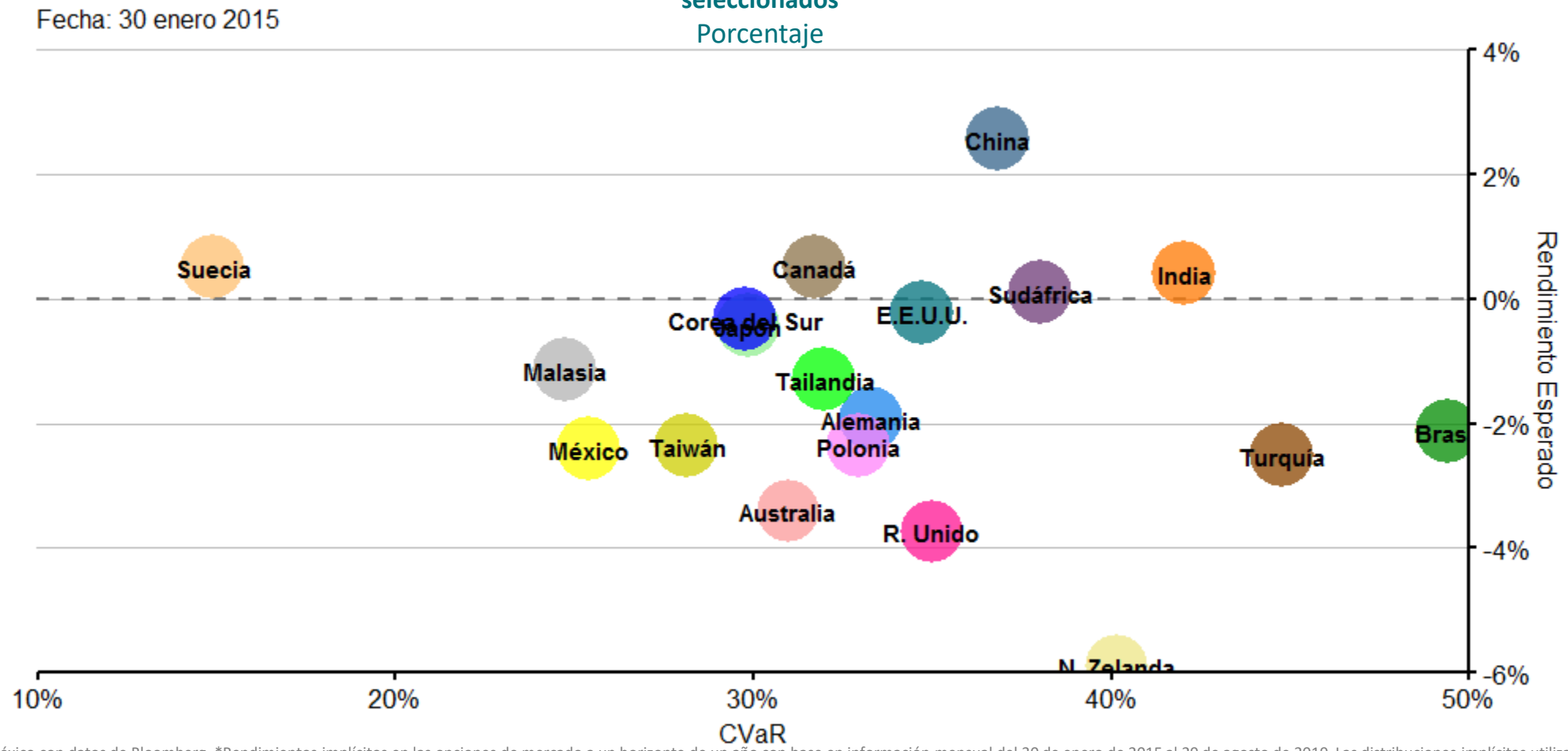
País	Media	CVaR 95%	Volatilidad	Eficiencia*
Estados Unidos	0.3%	30.3%	14.0%	-0.008
Corea	-0.3%	30.3%	15.0%	-0.015
Tailandia	-1.3%	23.0%	11.5%	-0.020
Taiwán	-2.1%	30.0%	13.0%	-0.030
Indonesia	-1.0%	50.1%	26.1%	-0.047
México	-4.8%	26.5%	9.3%	-0.056

Fuente: Banco de México con datos de Bloomberg. *Rendimientos implícitos en las opciones de mercado a un horizonte de un año. Las distribuciones implícitas se obtienen con base en el modelo de Breeden-Litzenberger y kernels Epanechnikov. La eficiencia está medida como el valor esperado de la utilidad de la riqueza asociada a cada elemento del soporte. La función de utilidad que se utiliza es el logaritmo natural de la riqueza.

UNA PERSPECTIVA HISTÓRICA DE LA EFICIENCIA RELATIVA: RENDIMIENTO DE RENTA VARIABLE LOCAL CON EXPOSICIÓN AL TIPO DE CAMBIO

- La eficiencia relativa en el mercado de renta variable es relativamente estable a lo largo de las economías y del tiempo. Asimismo, resalta que es un mercado con niveles de volatilidad muy elevados, en el que el riesgo y el rendimiento esperado muestran un alto grado de dinamismo en el tiempo.
- En el caso de México, resalta que, de mediados de 2016 a la fecha, el rendimiento esperado de la distribución se ubica en el nivel más bajo de la muestra. Por otra parte, el nivel de CVaR permanece relativamente estable en un rango de entre 25% y 30%.

Evolución de la eficiencia relativa de la distribución de los rendimientos anuales de renta variable medidos en dólares de países seleccionados



Fuente: Banco de México con datos de Bloomberg. *Rendimientos implícitos en las opciones de mercado a un horizonte de un año con base en información mensual del 30 de enero de 2015 al 29 de agosto de 2019. Las distribuciones implícitas utilizan la metodología de Breeden-Litzenberger, el modelo Ho-Lee y kernels Epanechnikov.

This document has been prepared exclusively for its use as supporting material for the XIII Meeting on International Reserves Management in Lima, Perú , in September, 2019.

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