Analysis of 10 Years of T-Bill and Bond Yield Data (2014-2024): A Comprehensive Report

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Objective

The purpose of this exercise is to analyze 10 years' worth of Treasury bill (T-bill) and benchmark bond yield data using the Bank of Canada Valet API. The focus is on retrieving, cleaning, analyzing, and visualizing data to assess trends and relationships between different yield tenors. These include:

- **1-Year T-bill yields (TB.CDN.1Y.MID)**
- **2-Year Bond yields (BD.CDN.2YR.DQ.YLD)**
- **5-Year Bond yields (BD.CDN.5YR.DQ.YLD)**
- **10-Year Bond yields (BD.CDN.10YR.DQ.YLD)**

Summary

In this analysis, a comprehensive workflow was executed involving API connection, data retrieval, and data cleaning using **Power Query** in **Excel**. Following data preparation, fundamental descriptive statistical analyses were performed—calculating maximum, minimum, average, standard deviation, and variance for each of the four bond yields from 2014 to 2024.

The cleaned data was then imported into **Power BI**, where **DAX** was utilized to create advanced measures, and **Python** was employed within the **Python Script Editor (PowerBI)** to conduct further analysis. This included the development of dynamic visualizations, such as scatter plots comparing pairs of bonds, moving averages for each bond, a correlation matrix, seasonal decomposition of time series, rolling volatility, rolling correlation, principal component analysis (PCA). This approach enabled a thorough examination of bond yield dynamics and enhanced data visualization capabilities.

Technologies Utilized in This Assignment:

PowerBI (DAX), Power Query, Python (Pandas, Numpy, scikit-learn, Matplotlib, Seaborn), Excel (PivotTable, PivotChart, Formulas)

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1. Data Retrieval Process

Approach

The analysis commenced with a connection to the Bank of Canada Valet API to retrieve T-bill and bond yield data covering a 10-year period from January 2, 2014, to December 29, 2023. Data retrieval was executed programmatically using Power Query in Excel, with a focus on filtering the relevant tenors to align with the specific yields of interest.

This approach enabled the extraction of a time series for each tenor over the 10-year period.

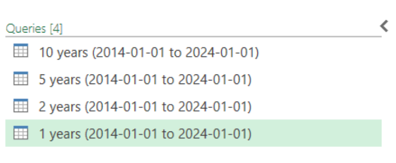
API Connection and Data Retrieving Request:

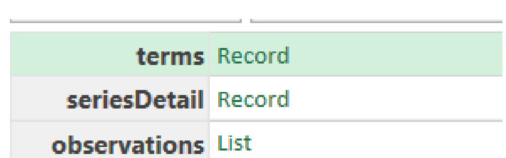
URL:
https://www.bankofcanada.ca/valet/observations/BD.CDN.10YR.DQ.YLD/json?start_date=2014-01-01&end_date=2024-01-01

Modified the highlighted section of the URL with the correct identifiers for the remaining securities and ran the URL again to collect the JSON file.

Findings:

The API connection is straightforward and involves downloading four JSON files for four bonds. The structure features clearly defined key-value pairs, with "terms" and "seriesDetail" as records containing metadata, and "observations" as a list of multiple data entries, where all yield values and their corresponding dates are stored.





****Please refer to Power Query for Data Retrieval Process (Excel)**

2. Data Cleaning and Formatting

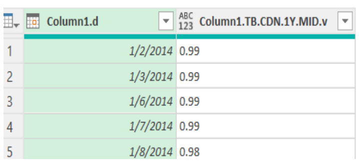
Approach

Data Exploration and Conversion of Required Data from JSON to Table

Once the JSON files were loaded into Power Query, the "observations" list was accessed to view all records (1). Converted this list of records into table format (2), and fully expand the column that hold these records to fully view all the data (3), repeat 3 step for all 4 JSON files resulting in four tables corresponding to each tenor.

	List
1	Record
2	Record
3	Record
4	Record
5	Record

	Column1
1	Record
2	Record
3	Record
4	Record
5	Record



	Column1.d	Column1.TB.CDN.1Y.MID.v
1	1/2/2014	0.99
2	1/3/2014	0.99
3	1/6/2014	0.99
4	1/7/2014	0.99
5	1/8/2014	0.98

(1) (2) (3)

Column Renaming, Data Format Conversion, and Missing Value Handling in Each Table

- **Column Renaming**: To enhance clarity and facilitate interpretation, the columns were renamed as follows:
  - Date
  - 1 years T-bill yields
  - 2 years bond yields
  - 5 years bond yields
  - 10 years bond yields
- **Data Format**: The Date column was formatted appropriately as a Date type, and all the Yield columns were formatted as Decimal number.
- **Handling Missing Values**: Using filter drop-down arrow in the header of the selected column to identify null and blank values. All 4 tables do not have any blank and null value so no action needed

Merge All Tables to Create the Final Dataset

Merge all 4 table on the share column (which is the date column), in the final merged table expand all column and remove unnecessary date columns. Here is the final table after all cleaning and merging steps.

This preview may be up to 2 days old. Refresh

```
= Table.RenameColumns(#"Changed Type1",{{"Column1.d", "Date"}, {"1 years T-bill", "1 years T-bill yields"}, {"2 year
```

	Date	1.2 1 years T-bill yields	1.2 2 years bond yields	1.2 5 years bond yields	1.2 10 years bond yields
1	1/2/2014	0.99	1.13	1.93	2.74
2	1/3/2014	0.99	1.14	1.94	2.75
3	1/6/2014	0.99	1.13	1.91	2.72
4	1/7/2014	0.99	1.11	1.87	2.67
5	1/8/2014	0.98	1.11	1.9	2.72
6	1/9/2014	0.97	1.1	1.87	2.68
7	1/10/2014	0.95	1.02	1.73	2.56
8	1/13/2014	0.95	1.04	1.72	2.54
9	1/14/2014	0.95	1.05	1.76	2.57
10	1/15/2014	0.96	1.06	1.76	2.57
11	1/16/2014	0.96	1.04	1.71	2.52
12	1/17/2014	0.95	1.02	1.69	2.5
13	1/20/2014	0.95	1.02	1.67	2.49
14	1/21/2014	0.95	1.03	1.7	2.5
15	1/22/2014	0.95	1.01	1.67	2.48
16	1/23/2014	0.94	0.97	1.6	2.41
17	1/24/2014	0.94	0.97	1.59	2.4
18	1/27/2014	0.95	0.99	1.63	2.44
19	1/28/2014	0.95	0.97	1.6	2.42
20	1/29/2014	0.94	0.96	1.57	2.36
21	1/30/2014	0.95	0.97	1.58	2.37
22	1/31/2014	0.94	0.95	1.55	2.34
23	2/3/2014	0.94	0.93	1.51	2.3
24	2/4/2014	0.94	0.96	1.55	2.34
25	2/5/2014	0.95	0.98	1.58	2.38
26	2/6/2014	0.95	0.98	1.61	2.43
27	2/7/2014	0.95	0.98	1.59	2.39

Findings:

The size of the data for this report is relatively small, consisting of 2,495 rows corresponding to a 10-year period (approximately 252 trading days per year). The structure of the clean data is straightforward, featuring one column for the date (formatted as a date type) and four columns for the corresponding yield values. These yields values already shown as percentages values, so the data type for these columns will be decimal type.

****Please refer to Power Query for Data Cleaning and Formatting (Excel)**

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3. Descriptive Statistics Analysis

Approach

To gain insights into the overall behavior of each bond tenor, a basic descriptive statistics analysis was performed, focusing on key metrics such as Average, Correlation, Standard Deviation, Variance, Minimum, and Maximum. These analyses were facilitated through the use of PivotTables and PivotCharts.

Additionally, basic line charts were generated in Excel to visualize the time series of T-bill and bond yields for the 1-year, 2-year, 5-year, and 10-year tenors. These visualizations provide valuable insights into the trends and fluctuations of yields over time.

Findings:

- Based on the yield analysis chart, we observe that from 2014 to early 2019, T-bills and bonds maintained a consistent yield hierarchy, with longer-term bonds yielding more than shorter-term ones. However, starting in 2019, this trend reversed, leading to higher yields for short-term bonds. The Covid-19 pandemic caused yields across all bonds to drop to historic lows.
- Following the pandemic, bond yields surged to their highest levels in a decade, with short-term bonds continuing to lead. This trend is supported by average, minimum, and maximum yield data, which highlight the significant decline during the pandemic and the subsequent rise in yields.
- All four bonds experienced their highest variance & standard deviation in 2022, reflecting significant market volatility, particularly for short-term bonds.
- Despite high yields persisting, variance and standard deviation across all bonds dropped significantly after 2022, indicating market stabilization. For instance, the variance of the 1-year T-bill fell by approximately 92%, from 1.39 to 0.11. This decline suggests increased investor confidence, even as yields reached all-time highs, driven by inflationary pressures and expectations of future interest rate hikes.
- The reduction in volatility, especially for short-term bonds, indicates a more stable economic outlook. The rise in yields amidst decreasing volatility suggests that while the market is stabilizing, the demand for higher returns persists, likely due to ongoing economic risks.

****Please refer to the Excel file for both data analysis and visual representations. (Excel)**
****Alternatively, please explore Pages 1 and 2 for interactive visualizations (PowerBI)**

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4. Yield Spread Analysis

Approach

For the calculation of yield spreads, basic Excel formulas were utilized to generate columns representing the spreads between various bond tenors.

Line charts were then created to visually represent the calculated spreads, focusing on the differences between the 2-year and 1-year yields, the 5-year and 2-year yields, and the 10-year and 5-year yields. These visualizations enhance the understanding of yield spread dynamics across different maturities.

To better understand the relationships between the different tenors, I calculated yield spreads as follows:

- **2Y-1Y Spread**: The difference between 2-year and 1-year yields.
- **5Y-2Y Spread**: The difference between 5-year and 2-year yields.
- **10Y-5Y Spread**: The difference between 10-year and 5-year yields.

Findings:

- **Early Stability and Divergence (2014 to Mid-2018):** (2Y-1Y) Spreads were stable, while (10Y-5Y) Spreads fluctuated between 0.4 and 0.9, and (5Y-2Y) Spread declined. This reflects mixed sentiment: stable short-term spreads signal confidence, while long-term volatility indicates uncertainty about growth and inflation, suggesting investor caution.

- **Flattening Yield Curve (2018-2020):** From mid-2018, all three spreads began to decline, with the spreads nearing zero or dipping slightly negative by the time COVID struck. This significant flattening or inversion of the yield curve could be reflected rising concerns about future economic growth, which is often interpreted as a precursor to recession

- **Post-Pandemic Spike in Spreads (2020-2021**): Both increased sharply, (5Y-2Y) Spreads reaching a peak at 0.75 in mid-2021 and (10Y-5Y) Spreads slightly lower at 0.55. While (2Y-1Y) Spreads remained relatively subdued, increasing more slowly than the others, peaking at 0.55 in mid-2022. The rapid rise in spreads during the post-COVID recovery phase reflected strong economic optimism, higher inflation, and expectations of future interest rate hikes.

- **Rapid Decline After Mid-2021**: After mid-2021, both the 5Y-2Y Spreads and 10Y-5Y Spreads began to drop sharply, suggesting that the post-pandemic recovery momentum was fading, and the market was beginning to price in economic slowdowns and potential recession risks.

- **Inversion of the Yield Curve (2022-2023**): By early 2023, all three spreads had fallen into negative territory, with both the 2Y – 1Y and 5Y - 2Y spreads hitting -0.75, marking a clear yield curve inversion, is a classic signal of recessionary fears. The steep declines in spreads reflect market concerns about future economic contraction.

- **Ongoing Economic Uncertainty:** The persistence of negative spreads through 2023 indicates that the bond market continues to price in significant risks to future economic growth, possibly tied to inflationary pressures, monetary tightening, or geopolitical uncertainties.

****Please refer to the Excel file for both data analysis and visual representations. (Excel)**

****Alternatively, please explore Pages 1 and 2 for interactive visualizations (PowerBI)**

****All analyses beyond this point will be conducted in Power BI. After being prepared in Excel, the final cleaned dataset and relevant tables have been loaded into Power BI for further analysis.**

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5. Scatter Plot Analysis

Approach

To explore the relationships between various bond yields, scatter plots were created to compare the yields of different assets across short- and long-term maturities. These visualizations facilitate the examination of correlations and trends between short- and long-term interest rates, providing insights into the shape and movement of the yield curve. Analyzing these plots allows for the identification of potential shifts in market sentiment, interest rate expectations, and risk perceptions across different maturities.

For this analysis, a new table named **BondYieldComparison** was created in Power BI using the following DAX code:

```
BondYieldComparison = DATATABLE(
    "Comparison", STRING,
    {{"1-Year T-Bill vs 5-Year Bond"},
     {"2-Year vs 10-Year Bond"},
     {"1-Year T-Bill vs 10-Year Bond"},
     {"5-Year vs 2-Year Bond"}}
)
```

The table contains a single column called Comparison, which is of type STRING. This column includes four entries representing specific bond yield comparisons.

- "1-Year T-Bill vs 5-Year Bond"
- "2-Year vs 10-Year Bond"
- "1-Year T-Bill vs 10-Year Bond"
- "5-Year vs 2-Year Bond"

This Comparison column will be used as Value for a Slicer in PowerBI to give viewer the ability to toggle different scatter plots.

Two new DAX measures were created to facilitate the analysis of bond yield comparisons for scatter plots.

1. **SelectedXValue**: This measure retrieves the average yield for the specified bond on the x-axis based on the user's selection from the BondYieldComparison table. It uses a SWITCH statement to return the average yield for the appropriate bond based on the comparison selected, providing a dynamic x-axis value for the scatter plot.
2. **SelectedYValue**: Similarly, this measure retrieves the average yield for the specified bond on the y-axis. It also employs a SWITCH statement to return the average yield for the corresponding bond based on the selected comparison, enabling a dynamic y-axis value for the scatter plot.

Together, these measures allow for a clear visualization of the relationships between different bond yields, enhancing the ability to analyze yield dynamics across various maturities effectively.

Findings:

- **Positive Correlation**: All scatter plot indicates a consistent upward trend over 10 years period. The consistent upward trend across all these scatter plots reinforces the idea of a positive correlation between the yields of different bonds.
- **Economic Indicators**: These trends may reflect broader economic conditions, such as expectations for rising interest rates, inflation, or improved economic growth.
- **Investor Sentiment**: An upward trend can lead investors to adjust their strategies based on expectations of how these yields will affect their portfolios.

****Please refer to Page 2 for visualization and "BondYieldComparison" table for the technical DAX code (PowerBI)**

6. Moving Average (30 days) Analysis

Approach

To analyze bond yield trends, a function was created to visualize both the raw data and their 30-day moving averages. This method generates line plots that smooth short-term fluctuations, revealing underlying trends. By examining these visualizations, users can identify yield patterns, assess market trends, and gain insights into long-term movements, aiding informed investment decisions across various maturities.

For this analysis, like previous step, a new table named **MovingAverage** was created in Power BI using DAX code:

The table contains a single column called TimePeriod, which is of type STRING. This column has four entries, each representing a different type of moving average corresponding to the respective bond yields value:

This TimePeriod will give viewer the ability to toggle and plot the bond yields value and its Moving Average of the bond they want to view.

Two new DAX measures were created to analyze bond yields through current and moving average calculations:

1. **SelectedBondValue**: This measure retrieves the average yield for the selected bond type from the MovingAverage table using a SWITCH statement, providing a clear view of current yields.
2. **SelectedMA**: This measure calculates the 30-day moving average of the selected bond yield, employing a SWITCH statement with AVERAGEX and DATESINPERIOD to assess the average yield over the last 30 days. It helps identify trends in bond yields, enhancing market insights.

Together, these measures enable effective analysis of both current and historical yield data, supporting informed decision-making in bond investment strategies.

Findings:

Observation

- From 2014–2016, the MA line is flat along with the raw yield values.
- From 2017 – 2019, Yields begin to increase and the MA line shows a smooth, upward slope, indicating a period of prolonged rate hikes.
- At the first quarter of 2020 where the raw yields drop significantly below the MA line, signaling a major reversal from previous trends.
- From 2022 to 2023, both the raw yields and the MA line are clearly trending upwards, with the MA line following the yield values very closely, although it smooths out some of the sharper peaks and dips.
- 2023 Peak and Decline: In mid-2023, you can see the yields hit a before starting to cross down below the MA line in late 2023.

Insights:

- From 2022 to 2023, This strong upward trend in both the raw yields and the MA line confirms a bullish sentiment in the bond market for 1-year T-bill yields, particularly in response to inflationary pressures and the Fed's aggressive rate hikes to control inflation. The alignment of the MA and yield values indicates that this is not a short-term spike but a sustained upward trend. This can give investors confidence in a strong underlying trend, supporting higher yield expectations over this period.

- From 2014–2016, the MA line is flat along with the raw yield values. The alignment of both suggests low volatility and trend stability, confirming that the prevailing trend was one of very low yields with no significant expectation of change.
- This massive drop around the start of 2020 is a reversal signal, where the raw yields fall below the MA, indicating a sharp downturn in yields. This massive drop around the start of 2020 is a clear indication of the Fed's emergency rate cuts in response to the economic crisis. This sharp divergence (crossing below the MA) signals that market conditions have fundamentally shifted.
- In late 2023, you can see the yields hit a peak before starting to cross down below the MA. This signals a potential reversal in the yield increase, indicating that the rapid rate hikes may have ended and yields are now either stabilizing or starting to decline

****Please refer to Page 2 for visualization and "MovingAverage" table for technical DAX code (PowerBI)**

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7. Rolling Volatility Analysis

Approach

To assess the volatility of the yields and their respective spreads, the 1-year rolling standard deviation (252 trading days) was calculated for each tenor to capture fluctuations over time, compare risk across different bond maturities, and identify periods of heightened market uncertainty or instability. This analysis provides insights into the risk profile and sensitivity of each bond to market conditions, guiding better investment and risk management decisions. The results were visualized through line charts, highlighting periods of increased or decreased market volatility over a longer time horizon.

For this analysis, the procedure is similar to previous analysis, a new table named **RollingVolatility** was created in Power BI using DAX code. The table contains a similar column with similar functionalities called TimePeriod. This column has four unquie rows, each representing a different type of rolling volatility.

A new DAX measure was also created to calculate and dynamically display the rolling volatility based on the selected time period from the slicer. The measure, named **SelectedRollingVolatility**, is designed to compute the rolling standard deviation (volatility) for each bond yield over a 252-day window.

The measure works as follows:

1. The measure dynamically calculates the rolling volatility for the selected bond yield over the past 252 days using **STDEVX.P**, which computes the population standard deviation.
2. The measure adjusts for the selected time period and applies the volatility calculation to the corresponding bond yield.

Findings:

1-Year T-Bill Rolling Volatility:

- The chart shows periods of low volatility, particularly in 2015 and 2019, where the rolling volatility (RV) was close to 0.03%.
- There are significant spikes in volatility, notably in 2020 with a peak near 0.66%, and in 2022 where it reached as high as 0.94%. These increases could be tied to major economic or monetary policy changes, such as the COVID-19 pandemic and subsequent fiscal responses.
- In general, the 1-year T-bill appears to have relatively stable periods with occasional sharp jumps, indicating that short-term yields are usually less volatile but can respond dramatically to macroeconomic shocks.

10-Year Bond Rolling Volatility:

- The rolling volatility for the 10-year bond shows higher baseline levels of volatility compared to the 1-year T-bill. In 2016 and 2018, the RV hovered between 0.20% and 0.32%.
- There are also notable peaks, such as in 2020 (0.44%) and in 2022 (0.61%), which could correlate with periods of increased economic uncertainty, inflation concerns, or changing interest rate expectations.
- Longer-dated bonds like the 10-year are generally more sensitive to expectations about inflation and future interest rates, explaining the higher and more frequent volatility compared to the 1-year T-bill.

Specific Insights:

- **Short -Term Bonds (1-Year, 2-Year):** The rolling volatility is generally lower with fewer fluctuations. Investors tend to view short-term bonds as safer, and their yields are more influenced by central bank policy than by market uncertainty.
- **Long-Term Bonds (5-Year, 10-Year)**: Longer-term bonds show higher and more frequent volatility, as they are more exposed to shifts in inflation expectations, interest rate changes, and overall economic sentiment. This indicates a higher level of uncertainty and risk compared to short-term bonds.

****Please refer to Page 2 for visualization and "RollingVolatility" table for the technical code (PowerBI)**

8. Correlation Analysis Heatmap

Approach

Using Pandas, Seaborn, and Matplotlib, the correlation matrix of the dataset was calculated and visualized. This analysis highlights the relationships between different bond yields, aiding in the understanding of how various maturities interact and informing investment strategies based on yield dynamics.

In building the correlation heatmap, Pandas, Seaborn, and Matplotlib were utilized to visualize relationships between variables:

1. **Data Encoding**: Categorical variables in the dataset were converted into dummy/indicator variables using pd.get_dummies(). This step ensures that the correlation matrix includes both numerical and categorical data for a complete analysis.
2. **Correlation Matrix Calculation**: The correlation matrix was computed using dataset.corr(), calculating pairwise Pearson correlation coefficients between all numerical variables. This step is critical for quantifying the linear relationships between variables, with values ranging from -1 to 1.
3. **Heatmap Visualization**: The correlation matrix was visualized using Seaborn's heatmap() function. A color gradient (cmap='BuPu') was applied, and the correlation coefficients were annotated on the heatmap (annot=True), making the relationships between variables easy to interpret.

Findings:

- The heatmap ranges from deep purple (strong positive correlation) to light blue (strong negative correlation), representing how closely related the yields and spreads are to one another.
- **Strong Positive Correlations:**
  - 1-year T-bill yields and 2-year bond yields: Correlation of 0.99 (near-perfect positive correlation). This implies that changes in the 1-year T-bill yield are almost perfectly mirrored by changes in the 2-year bond yield.
  - 5-year and 2-year bond yields: 0.98, indicating a strong positive relationship.
  - 10-year bond yields and 5-year bond yields: 0.96, showing a strong correlation between longer-duration bonds.

- **Negative Correlations:**
    - 2Y-1Y Spreads and 1-year T-bill yields: -0.72 (moderate negative correlation), implying that as the spread between 2-year and 1-year bonds increases, the 1-year yield tends to decrease.
    - 5Y-2Y Spreads with 1-year T-bill yields: -0.88, indicating a strong negative relationship.
    - 5Y-2Y Spreads with 2-year bond yields: -0.83, showing that the spread tends to rise when yields on 2-year bonds drop.
- The correlation heatmap shows that yields are strongly correlated across maturities, with negative correlations between yields and spreads. Spreads shrink as yields rise.

Specific Insights:

- **Yields vs. Spreads:** As yields increase, the spreads between different durations (e.g., 5Y-2Y, 10Y-5Y) tend to become more negative, indicating that spreads shrink when overall yields rise.
- **Spread Interactions:**
    - Spreads themselves (like 2Y-1Y, 5Y-2Y, 10Y-5Y) have positive correlations with one another (e.g., 5Y-2Y Spreads and 10Y-5Y Spreads: 0.84), showing that changes in the spread between one pair of maturities often correlate with changes in spreads across other pairs.

****Please refer to Page 3 for visualization and Python Script Editor below chart for the technical Python code (PowerBI)**
****Please refer to Correlation Sheet if only the table is required (Excel)**

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9. Volatility Heatmap

Approach

For this analysis, a new empty table with 4 new DAX measure were created, these DAX were used to calculate the rolling volatility of all bonds and T-Bill over a 252-day window. The measures are designed to assess the standard deviation of yield fluctuations to provide insights into market risk and stability.

The measure works as follows:

1. It uses **STDEVX.P** to compute the population standard deviation over a defined period of 252 days, capturing the variability of yields.

2. The measure calculates the difference between the average yield on the most recent date and the average yield from the previous month, normalizing this difference by the average yield from the previous month to reflect changes relative to historical performance.

After 4 new measures were created, create a Python visual chart and drop all 4 new measure and the Date to the Values field. Using Python's Seaborn and Matplotlib libraries in Python Script Editor, a volatility heatmap was generated to visualize the volatility of different bond yields using Python's Seaborn and Matplotlib libraries . The dataset was prepared by selecting relevant columns (4 volatility measure in Values field) that represent the volatility of various maturities.

Findings

1. **Observation:**
   - The color scale ranges from light yellow (low volatility) to deep blue (high volatility). This indicates the variation in bond yields over time, with yellow areas showing stable periods and blue areas indicating more volatile periods.
   - The volatility heatmap reveals that longer-term bonds (5-year, 10-year) exhibit more volatility over time, with notable periods of market instability affecting their yields. Short-term bonds (1-year T-bill) are relatively stable.
   - **General Trend:**
     - The 1-year T-bill has experienced lower volatility overall, with only a few isolated blue patches indicating periods of high volatility.
     - The 2-year bond yield volatility is more spread out, with patches of blue (higher volatility) occurring intermittently.
     - The 5-year and 10-year bonds exhibit relatively more volatility over time, with more significant portions of blue in the heatmap.
2. **Specific Insights:**
   - **Volatility Across Time:**
     - There is a clear pattern of increasing volatility for the longer-term bonds (5-year and 10-year), as represented by the more frequent and larger blue patches in the heatmap, suggesting that longer-duration bonds are more sensitive to market fluctuations.

- Recent Volatility Spikes: Towards the right side of the heatmap (representing the later years), there are significant volatility spikes in the 10-year bond yields, implying increased uncertainty or market reactions to macroeconomic events during this period.

****Please refer to Page 3 for visualization, "VolatilityHeatmap" table for DAX code and Python Script Editor below chart for the Python code (PowerBI)**

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10. Principal Component Analysis (PCA)

Approach

To evaluate the relationship between bond yields and market dynamics, Principal Component Analysis (PCA) was employed on the yield data. This analysis aims to reduce the dimensionality of the yield dataset while retaining the most significant variance, thereby simplifying the examination of yield interactions. By visualizing the principal components, underlying trends and common factors that influence bond yields can be identified, facilitating a better understanding of overall bond market behavior.

In Principal Component Analysis, Pandas, Matplotlib, Scikit-learn, NumPy were utilized to analyze bond yields:

1. **Data Selection**: The dataset was filtered to include only the relevant columns for bond yields: 1-Year T-bill yields, 2-Year bond yields, 5-Year bond yields, and 10-Year bond yields.
2. **Standardization**: The data was standardized using the StandardScaler from sklearn.preprocessing, which transforms the data to have a mean of 0 and a variance of 1. This step is crucial in PCA because it ensures that all features contribute equally to the analysis, preventing features with larger ranges from disproportionately influencing the results.
3. **PCA Transformation**: PCA was applied using PCA(n_components=2) from sklearn.decomposition, reducing the dimensionality of the dataset from four bond yield variables to two principal components (PC1 and PC2). This transformation captures the most variance in the data while simplifying it for visualization.

Findings

- **Principal Component 1** and **Principal Component 2** (on the x and y axes) represent the most significant directions of variation within the bond yield data. These components are derived from a linear combination of the original yields.

Observations:

- **2014-2017:** Scattered data may indicate a period of recovery and market adjustments post-financial crisis. Bond yields were likely responding to gradual policy normalization and less predictable economic growth.
- **2018-2020:** Tighter clustering during this period may point to a period of stabilization where central bank policy was more predictable, and economic conditions were steadier. Yields across different tenors moved more in sync as the yield curve may have flattened.
- **2021-2023:** Stronger variations toward the end of the dataset likely capture economic shocks, including pandemic-induced volatility**.** The spread in components suggests bond yields across different maturities responded unevenly to this period of rapid change.

Insight: PCA reveals that there's a temporal evolution in bond yields, where the trends are not static. You might infer from the clusters and shifts that external economic shocks and central bank policies had an impact at different periods.

This suggests that bond yields were relatively stable or less dispersed in the earlier part of the decade (2014–2017), whereas in more recent years (2020–2023), the yield curve likely steepened or experienced more volatility.

**Please refer to Page 3 for visualization and Python Script Editor below chart for the technical Python code (PowerBI)

11. Rolling Correlation Analysis

Approach

To analyze the interrelationships among bond yields, the 1-year rolling correlation (252 trading days) between various maturities was calculated. This analysis aids in understanding the co-movement of yields, which is crucial for risk assessment and investment strategy. A significant correlation may indicate a shared response to macroeconomic events, while a decline in correlation could suggest diverging market behavior. These insights can guide portfolio diversification strategies, helping investors make informed decisions about allocating assets across different maturities.

Utilized Python Script Editor, The Python analysis begins with a dataset that includes historical yields for various maturities. This dataset is loaded into a pandas DataFrame for manipulation.

1. **Rolling Correlation Calculation**:

To assess the interrelationships among different bond yields over time, the rolling correlation is computed using the following steps:

  - The correlation between different bond yields (1-Year T-bill vs. 2-Year bonds, 2-Year vs. 5-Year bonds, and 5-Year vs. 10-Year bonds) is computed over a rolling window of 252 days. This allows for capturing how the relationship between these yields evolves over time.
  - The .rolling(window=252).corr() function computes the correlation coefficient for each pair of bond yields, providing a dynamic view of their interdependence.

2. **Visualization**:
    - A line plot is generated to visualize the rolling correlations. Each line represents the correlation between a specific pair of bond yields over time, helping to identify trends and fluctuations.

Findings

Observation:

1. **High Correlation Levels:**
    - Correlations are generally near 1.0, especially between 1Y-2Y and 2Y-5Y, indicating that short- to medium-term bond yields typically move together, driven by similar factors like central bank policies.
2. **Periods of Divergence:**
    - **Correlations dip significantly during key periods:**
        - **2016-2017:** The 5Y-10Y correlation falls below 0.5, likely due to differing expectations about interest rates and inflation.
        - **2020 (COVID-19):** A sharp drop in correlations across maturities reflects market disruptions.
        - **2022-2023:** The 2Y-5Y correlation declines amid inflation concerns and rate hikes, indicating short-term bonds reacted more strongly.
3. **Correlation Stability:**
    - 1Y-2Y remains stable (rarely below 0.8), while 2Y-5Y and 5Y-10Y show more volatility, as longer-term bonds are more sensitive to macroeconomic factors like inflation and growth expectations.

4. **Recent Trends (2023-2024):**
    - A sharper decline in 2Y-5Y correlations suggests yield curve flattening or inversion, often signaling economic slowdown fears. The 1Y-2Y correlation remains relatively stable.

Specific Insights:

- **Strong Correlations Overall**: Throughout most of the period, bond yields across maturities remain highly correlated, reflecting the influence of broad market factors.
- **Longer-Term Bond Sensitivity**: Longer-term bonds (5Y-10Y) show greater sensitivity to market changes, evidenced by more frequent and deeper dips in correlation, suggesting that investor expectations about future economic conditions can cause divergences in these yields.

**Please refer to Page 3 for visualization and Python Script Editor below chart for the technical Python code (PowerBI)

12. Technical Summary and Conclusion

This analysis involved a comprehensive examination of 10 years of Treasury bill (T-bill) and benchmark bond yield data from the Bank of Canada. The following technical steps were undertaken:

1. **Data Retrieval and Cleaning**: The Bank of Canada Valet API was accessed to retrieve historical T-bill and bond yield data, followed by data cleaning to ensure accuracy and consistency.
2. **Statistical Analysis**: Statistical analyses were performed to identify yield trends, volatility patterns, and yield spreads, providing insights into market sentiment.
3. **Yield Spread Calculation**: Yield spreads between different tenors were calculated to evaluate economic signals and fluctuations in investor confidence.
4. **Correlation Analysis**: The correlation between adjacent yield tenors was analyzed to understand their relationships and movement patterns over time.
5. **Advanced Analytical Techniques**: Principal Component Analysis (PCA) was employed to uncover underlying factors influencing bond yields, and rolling volatility assessments were conducted to examine fluctuations across different maturities.
6. **Visualization**: Visual representations, including yield curves and volatility heatmaps, were created to effectively communicate findings and facilitate the interpretation of data trends.

The analysis of the T-bill and benchmark bond yield data highlights key insights into the bond market's behavior. Longer-term bond yields, such as the 10-year bond, displayed greater stability, while shorter-term yields, like the 1-year T-bill, were more volatile and sensitive to economic changes. Yield spreads indicated economic sentiment, with a flattening curve signaling pessimism during uncertainties and wider spreads reflecting confidence in growth. Correlation analysis showed that yields tend to move in tandem, while advanced techniques, such as PCA, provided deeper insights into yield dynamics. Overall, this analysis emphasizes the importance of monitoring yield trends for informed investment decisions amid evolving economic conditions. This technical framework supports a robust understanding of bond yield dynamics and aids in navigating the complexities of the financial landscape.