US Automotive Trade - The Critical Influence of GDP and Tariffs

Executive Summary

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Background

Automobiles represent the **second-largest consumer expenditure**, highlighting the significant role of the automotive industry in global economies. This study focuses on analyzing the **United States' automotive trade relationships** with various international partners. It aims to evaluate the trade balance of passenger vehicles, trucks and parts, while also examining the **influence of Gross Domestic Product (GDP) and tariff rates** on these trade dynamics.

External References

US President has declared **increase in tariffs** on all goods imported into the US from different countries. This could cause significant damage to the economies of all nations involved. Below **articles** played a critical role in our selection of the idea for this project. (links on References page)

1. Seven Charts Showing How Canada/Mexico Tariffs Would Harm the US Auto Industry (and American Car Buyers)
2. What does it mean for the US to have a half a trillion-dollar trade deficit?
3. Who are the US' top trade partners?
4. Automobile tariffs by country 2025

Motivation

The automotive sector **influences numerous stakeholders** from consumers to manufacturers to international policy makers.

This analysis is driven by the critical need to comprehensively evaluate the United States' automotive trade balance with its global partners providing essential insights for diverse group of stakeholders.

Given the **recent dynamic shifts in global trade policies**, particularly variations in tariffs, understanding their direct impact on import and export flows is paramount for automotive manufacturers and governments negotiating trade agreements.

Furthermore, discerning the **correlation between the economic output of partner countries and their automotive trade** with the US is crucial for investors assessing market potential and for policy makers formulating effective economic strategies.

Data Sources

➢ **Primary data:** US International Trade Administration (ITA) data for automotive imports/ exports by category and country (2008 - 2024)

➢ **Secondary data:**

    1. World Bank Group GDP data by country and year (1960 - 2024)

    2. World Integrated Trade Solution (WITS) MFN simple average tariff rates for imports and exports with respect to US by country and year (1991 - 2023)

Key research questions

1. What are the year-on-year trends in US automotive trade balance?

2. Who are the primary trade partners for exports and imports and how have these patterns evolved?

3. Is there a correlation between country's GDP growth and its automotive trade volume with the US?

4. What is the effect of varying tariff rates across years on export to those countries and import into the US?

Data Sources

Name	Description	Size	Links
US International Trade Administration (ITA) data from trade.gov	The primary dataset comes from the International Trade Administration (ITA) and includes multiple tables, each covering a specific category of automotive trade (parts, new passenger vehicles/light trucks, and medium/heavy-duty trucks). Each table provides yearly import or export values by country or region from 2008 to 2024. **Key columns :** 1. Automotive Trade Category – Parts, passenger vehicles or light trucks, medium or heavy trucks 2. Name of the Country 3. Calendar Year in which import/ export values are reported 5. Trade Value (in USD) 6. Trade Type (Export/Import)	2MB ~ 27000 rows	CSV download – Automotive parts CSV download – Passenger vehicles CSV download – Medium and heavy trucks
GDP data from World Bank Group	This secondary dataset is from the World Bank Group which contains GDP data of different countries from years 1960 to 2024. This shows the numbers in US dollars year on year for different countries. **Key columns:** 1. Name of the country 2. GDP in USD 3. Calendar year	1MB ~ 15000 rows	CSV download – GDP data
Tariff data from World Integrated Trade Solution (WITS)	This secondary dataset is from the WITS (World Integrated Trade Solution) which contains 'Most favored nation simple average' i.e., average Tariff rate for import of goods from different countries into USA from years 1991 to 2023. This shows the numbers in MFN (most favored nation) Simple Average in % year on year for different countries. **Key Columns:** 1. Name of the country 2. MFN simple average % 3. MFN weighted average % 4. Calendar year	0.6MB ~ 8000 rows	CSV download – MFN data

Primary and Secondary Datasets – Extraction and Cleaning

Primary dataset

The primary dataset was constructed from **six separate files** containing **export and import values in USD** across three automotive categories: **parts**, **passenger vehicles**, and **medium/heavy trucks**.

We began by loading the **passenger vehicle export data** into a DataFrame and appended a 'Category' column to distinguish between the three segments. A **reusable preprocessing function** was then developed to:

- ✓ Standardize country names

- ✓ Retain only relevant columns

- ✓ Reshape each dataset into a **long format**

This function was applied across all six datasets. We then **merged the three export datasets** into a unified export DataFrame and did the same for the three import datasets.

To create the final dataset, we performed an **inner join** between the export and import Data Frames. This join retained only rows with matching values across key columns—ensuring that each record includes **complete trade data**. The resulting dataset contains five columns: Country Name, Category, Calendar Year, Import Value and Export Value

An **inner join** in Pandas is very useful to maintain data integrity by excluding incomplete or unmatched records, allowing for robust analysis across consistent trade entries.

Secondary datasets

GDP dataset - We downloaded CSVs for **GDP and Inflation Adjusted GDP**, removed non-data footer rows, and standardized country names using country_converter to ensure merge consistency. After filtering for **2008–2022**, we dropped rows with missing data or unresolved country names, retained only relevant columns, and reshaped each dataset to long format using melt(). Finally, we merged the cleaned Real and Nominal GDP frames to produce a unified dataset with columns: **year, country, GDP, GDP_adjusted**.

MFN dataset - We downloaded four CSVs covering **MFN tariffs**: simple and weighted averages **imposed by the U.S.** and **faced by the U.S.** from partner countries. For each file, we standardized country names using country_converter, filtered for **2008–2022**, dropped incomplete or unstandardized rows, retained relevant columns, and reshaped the data to long format. The cleaned datasets were then merged into a unified frame with columns: **year, country, tariff_by_us_simple, tariff_by_us_weighted, tariff_on_us_simple, tariff_on_us_weighted**.

Combining GDP and MFN DataFrames - We performed an **outer join** on the cleaned GDP and MFN tariff datasets using **year and country** as keys, ensuring each row includes GDP, adjusted GDP, and all tariff metrics. This approach preserves maximum data coverage, even when values are missing in one source. To handle gaps, we applied **linear interpolation**, ideal for time series data with gradual year-over-year changes—yielding smooth, reliable estimates that maintain trend continuity for downstream analysis.

Tools and techniques used

- ➢ **Pandas library**: Used for loading, cleaning, and transforming datasets.

- ➢ **country_converter library**: Applied to standardize country names across all files.
  - ◦ Example inconsistency: 'Sri Lanka' vs. 'Sri Lanka (Colombo)'.
  - ◦ Standardization ensured accurate merging between primary and secondary datasets.

- ➢ **Data reshaping**:
  - ◦ Used .melt() in Pandas to convert column headers into row values i.e., unpivoted the DataFrames.
  - ◦ Transformed year-based columns into a unified 'Year' column.
  - ◦ Simplified structure for downstream analysis and visualization.

- ➢ **Data filtering**:
  - ◦ Removed rows with zero export or import values.
  - ◦ Focused on top trading partners with consistent data from **2008 to 2022**.
  - ◦ Ignored intermittent gaps for low-volume countries to maintain analytical integrity.

Combining Primary and Secondary Datasets

Preparatory steps before merging

1. Import and export values are string format with thousand separators. We removed those separators and **converted these amounts to integers.** These columns are absolute values in billion or trillion US Dollars.

2. **GDP** values are also in billion or trillion US dollars, but with up to 5 decimal places. We converted them to the nearest integer and 'Int64' format using **.to_numeric() and .astype('Int64')** functions. This format can store very large whole numbers, uses less memory as compared to floating-point types and is compatible with most of the data science libraries.

3. **MFN tariff** rates are floating point numbers, specifically a 64-bit float. We rounded off MFN tariff values to 2 decimal places using **.round() function** for ease of analysis.

4. Converted all **column labels to lowercase** using .lower() function.

5. **Dropped countries** from primary and secondary data frames that could not be standardized

Handling missing values -

- **Interpolation** for GDP and MFN columns - Interpolation is a way to **fill in missing values between known data points especially while analyzing time series or numerical data.** We used 'linear' interpolation to fill in missing values for GDP and MFN tariffs by estimating them from nearby data. Some minor volume countries did not GDP or MFN values at all. We ignored those countries as they are less significant for studying trade balance.

Creation of a final data frame -

We combined primary and secondary data frames on country and year columns using '**left outer join**'.

We chose 'left outer join' because our primary data frame has no missing values, but secondary data frame has missing values. Left join allowed us to retain all the rows from export/import data frame even if there is no matching entry in the GDP/MFN data frame. It **preserves primary data and at the same time helps in handling missing values** in right data frame gracefully.

2008 to 2022 are the common years in primary and secondary data frames. Hence, we restricted our final data to this range of years.
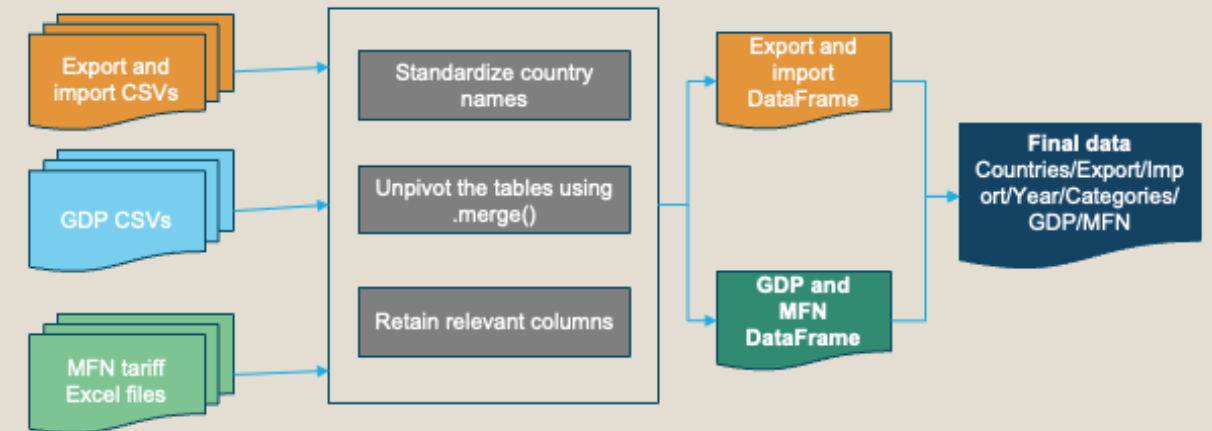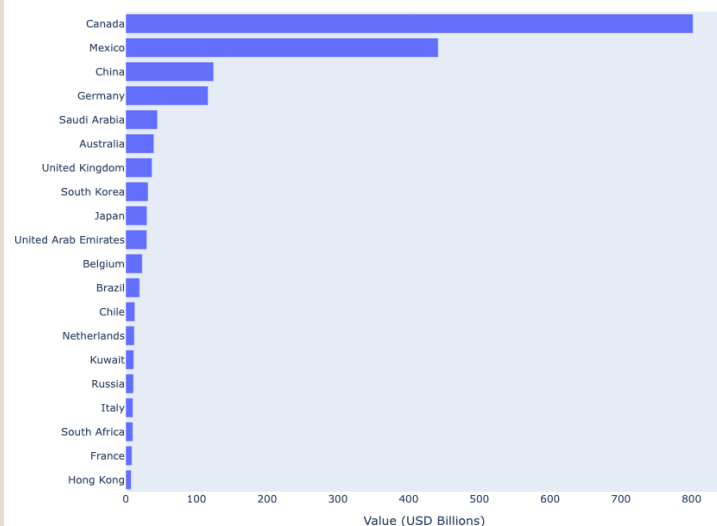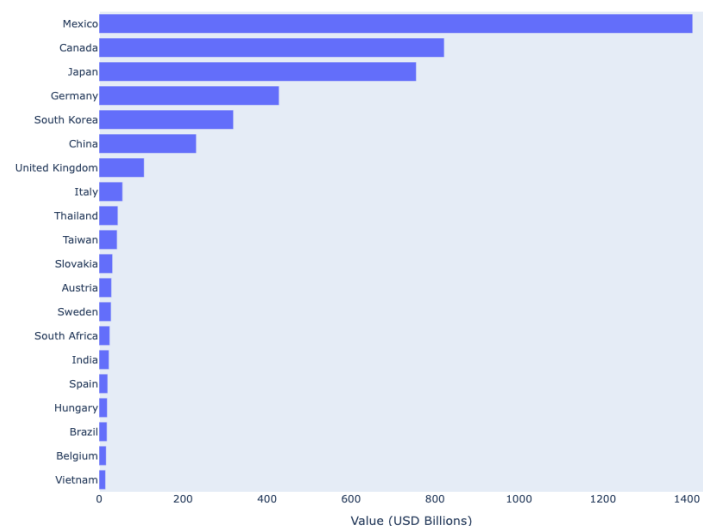

Important terminologies -

1. **MFN** - Most favored nation average tariff rate imposed by a country on other countries while importing goods from those countries. Tariff rates increase the cost of goods for consumers as well as manufacturers. We have used simple average MFN rates for all our analysis.

2. **GDP** - Gross Domestic Product is a total value of everything (goods and services) a country produces in a certain period. It can be a nominal value or inflation adjusted value. We have used inflation adjusted value in all our analysis.

Trade Balance across Countries and Categories

Exports by Country from 2008 to 2022 (Top 20)

Canada, Mexico, China, Germany, Saudi Arabia, Australia, United Kingdom, South Korea, Japan, United Arab Emirates, Belgium, Brazil, Chile, Netherlands, Kuwait, Russia, Italy, South Africa, France, Hong Kong

Value (USD Billions)

Imports by Country from 2008 to 2022 (Top 20)

Mexico, Canada, Japan, Germany, South Korea, China, United Kingdom, Italy, Thailand, Taiwan, Slovakia, Austria, Sweden, South Africa, India, Spain, Hungary, Brazil, Belgium, Vietnam

Value (USD Billions)

Top countries for automotive trade with the US

We aggregated export and import values across parts, passenger vehicles and trucks for all years for each country for preliminary analysis.
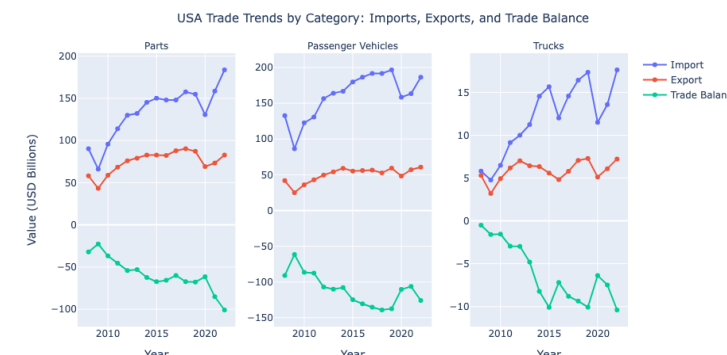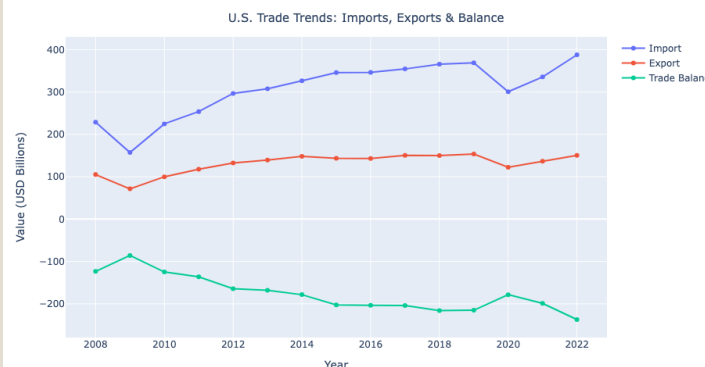
Key takeaways for export : Canada dominates as top importer, with total value nearing $800 billion. This reflects deep trade ties, geographic proximity and integrated supply chains between the US and Canada. Mexico ranks second, slightly above $200 billion due to USMCA trade agreement. China, Germany and Saudi Arabia are next, representing major global markets with strong demand for the American automotive brands.

Key takeaways for import : Mexico leads the pack with almost $1350 billion in exports to the US; Canada is second with $700 billion and Japan stands at #3 reflecting long-standing industrial ties and tech collaboration. China's position is lower than expected, possibly due to trade tensions, tariffs and shift toward nearshoring/reshoring.

Trade balance between different categories

U.S. Trade Trends: Imports, Exports & Balance - Blue line shows steady upward trajectory for overall automotive imports into the US. Exports shown in red line also reveal an upward trend, but still consistently lower than the imports. Trade balance in green line is persistently negative, indicating a trade deficit for the US. This means the US imports more automotive goods than it exports every year.

USA Trade Trends by Category: Imports, Exports, and Trade Balance - Import of passenger vehicles is consistently higher than exports, reflecting strong consumer demand for foreign brands. Parts and trucks also show a widening gap between import and export over time. All categories show a dip in import and exports values in 2009 and 2020, possibly due to recession and Covid pandemic, respectively.

U.S. Trade Trends: Imports, Exports & Balance

Import, Export, Trade Balance

Value (USD Billions) — Year

USA Trade Trends by Category: Imports, Exports, and Trade Balance

Parts, Passenger Vehicles, Trucks

Import, Export, Trade Balance

Value (USD Billions) — Year

# Trade Balance for Different Countries

After independently analyzing export and import values across countries and categories, we shifted focus to the **trade balance** by constructing a **dumbbell plot**. This visualization displays paired markers for U.S. exports (blue) and imports (pink) in billion USD, connected by lines to highlight the trade gap for the **top 20 trading partners**.

To ensure comparability across countries with varying trade volumes, we narrowed the scope to **calendar year 2022**. The data was first grouped by country, and aggregate sums of export and import values were computed. We then applied .sort_values() to identify the top 20 countries by export value and top 20 by import value, ensuring a comprehensive view of major trade relationships.
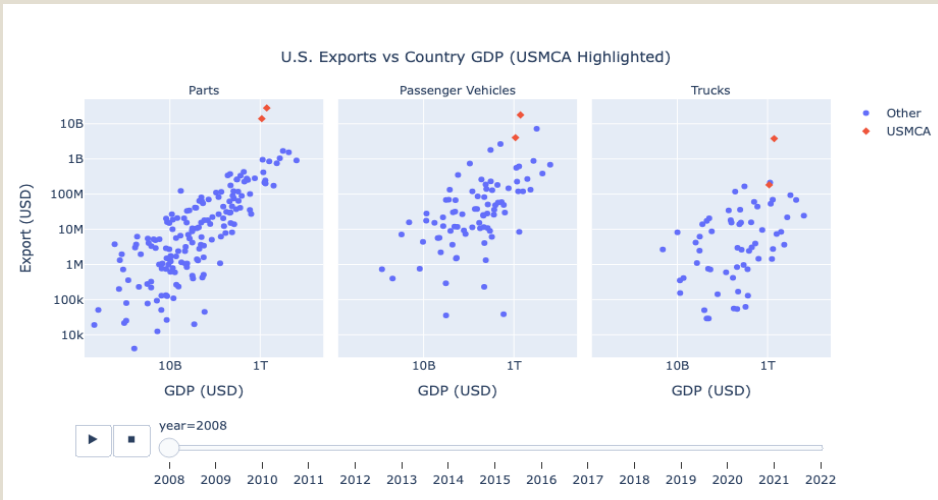
After filtering for 2022 and converting values to billions, the dumbbell chart was plotted by placing distinct markers for exports and imports per country, with connecting lines visually representing the magnitude and direction of trade imbalance.

Key takeaways :

✓ Blue dots indicate export value from the US and pink dot indicates import value to the US.
✓ The length of the line between blue dot and the pink dot represents the trade imbalance - the wider the gap, the larger the deficit or surplus.
✓ **Mexico shows massive import** value to the US, with exports from the US trailing significantly. This is potentially because of high volume of parts exports from the US to Mexico.
✓ **Canada is also a top trading partner** but with the difference of higher exports from the US than the imports.
✓ Apart from these two close allies, **Japan shows a strong trend** of high imports into the US compared to the exports. This trend is dominated by vehicle imports and parts especially from manufacturers like Toyota, Honda and some Tier-1 automotive parts suppliers.
✓ Other notable countries - UK, Italy, Brazil, Belgium, France, Chile, Australia etc. countries show balanced trade.
✓ Out of top 5 trade partner countries, US imports are much higher than the exports for top 4 resulting in possible trade deficit. Canada is an exception.

U.S. Exports and Imports with Top Trade Partners in 2022
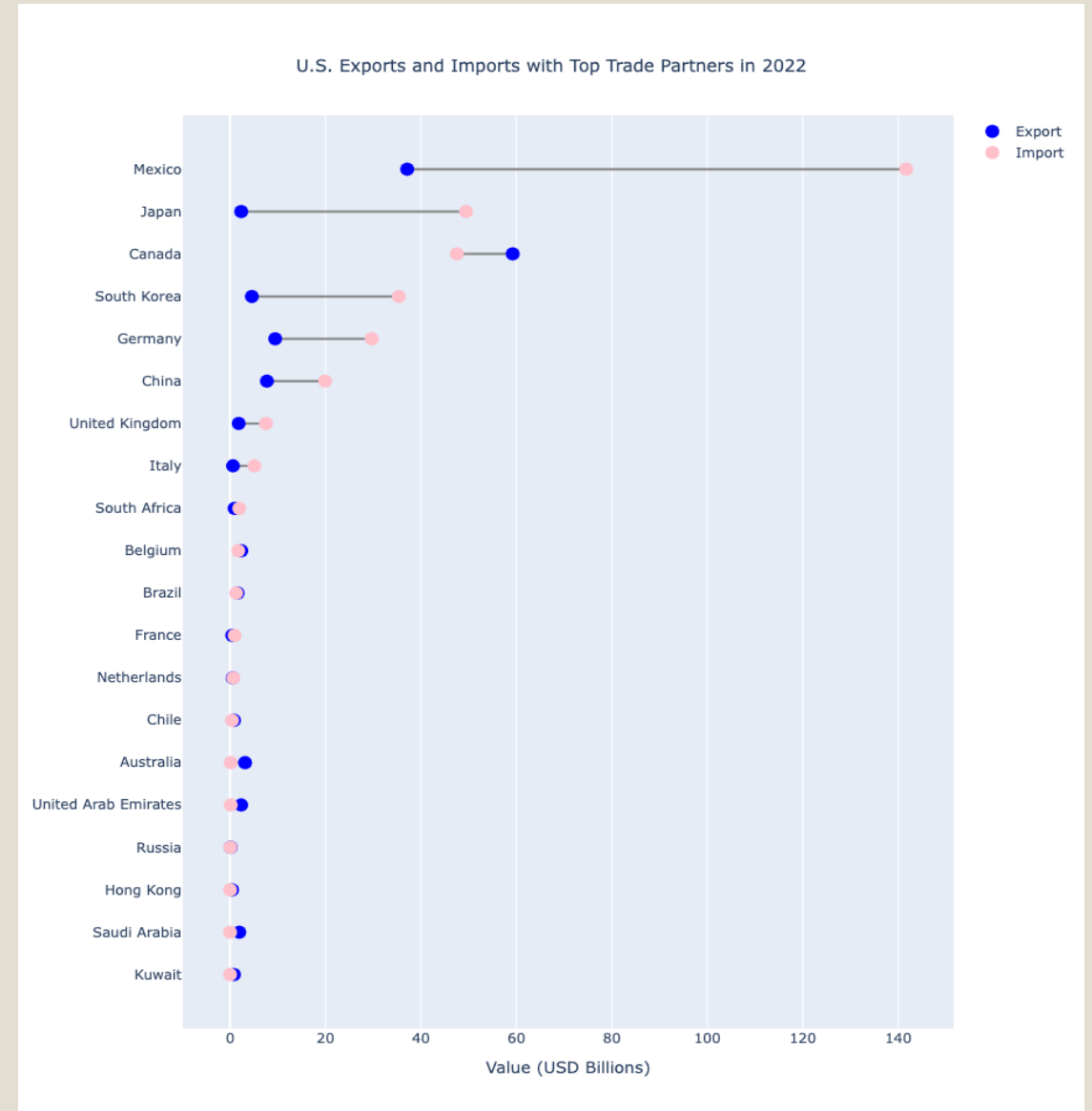
Analysis of Exports From the US vs GDP of the countries

U.S. Exports vs Country GDP (USMCA Highlighted)

U.S. Exports vs. country GDP (USMCA highlighted)

After the preliminary trade analysis, we expanded our attention to identifying correlations between GDPs of different countries and the export value from the US to them. We began by plotting **exports versus GDP** across all countries, using facet charts to separate Trucks, Parts, and Passenger Vehicles, with **USMCA** countries highlighted. The initial scatter plots revealed **Canada and Mexico as statistical outliers**, driven by disproportionately high export volumes.

Validation of outliers : To validate this, we computed **percentiles**, which confirmed extreme values: Canada and Mexico above 99th percentile meaning, these countries are higher than 99% of all other countries. These outliers were excluded to avoid skewing the analysis and to better capture the underlying global trend. (Percentile function is used to understand distribution and detecting outliers)

USMCA - US, Mexico, Canada Trade agreement (previously known as NAFTA)

U.S. Exports vs GDP of Top Non-USMCA Countries (2008–2022)
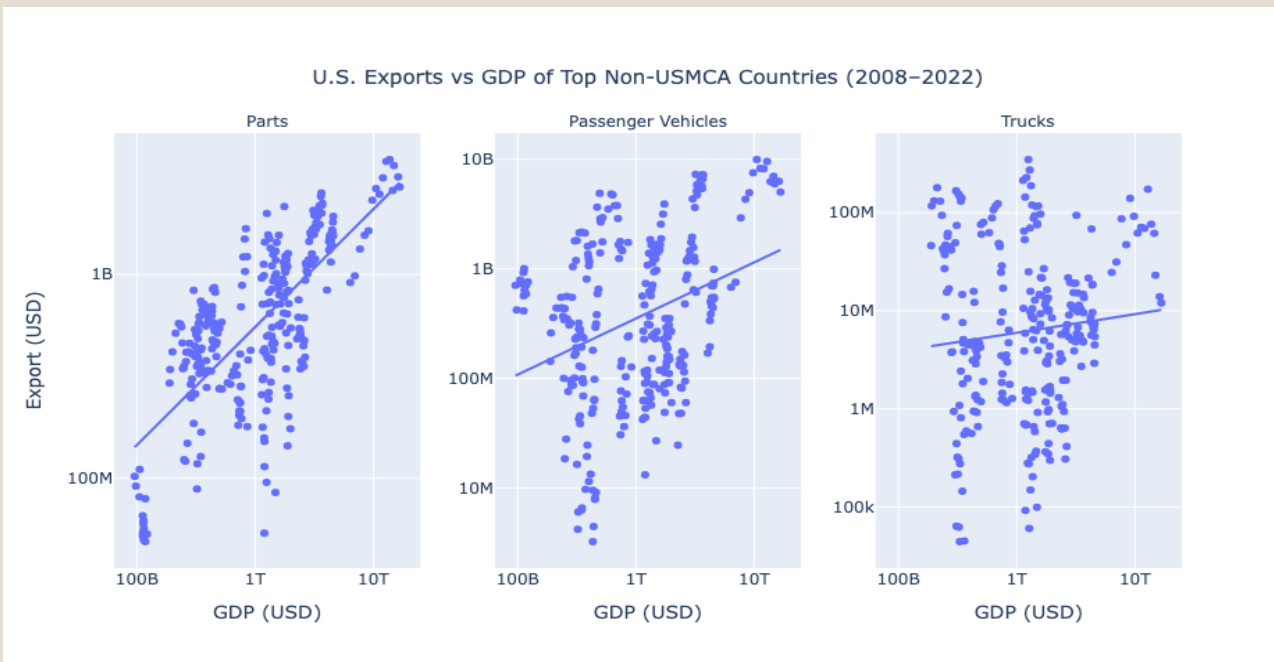
U.S. Exports vs. GDP of top Non-USMCA countries (2008 - 2022)

Focusing on the **top 20 trade partners from 2008 to 2022**, we examined the distribution of GDP and export values. Histograms indicated non-normality, prompting the use of **Spearman correlation** to assess monotonic relationships. (Spearman's correlation helps to identify how consistently one variable increases or decreases with the other, regardless of their distribution.)

**Parts**: ρ = **0.68**, indicating a strong positive association
Passenger Vehicles: ρ = **0.29**, suggesting a weak correlation
Trucks: ρ = **0.06**, showing no meaningful relationship

To further quantify the trend, we applied **Ordinary Least Squares (OLS)** regression on log-transformed GDP and export values. It fits a line to data by minimizing the differences between observed and predicted values. The resulting positive slope reflects a multiplicative relationship—as GDP increases, export volumes tend to rise, with higher-GDP countries importing disproportionately more. The fitted trendline reinforces the observed correlation patterns and provides a concise summary of the overall trade dynamics for parts, passenger vehicles and trucks.

Analysis of Tariffs on the US and Exports

To examine how U.S. trade flows relate to MFN tariff rates, we focused on the **top 8 trading partners**, aggregating **export and import values by category and year**. We visualized the trends using an **animated scatter plot**, where **bubble color represents country** and **size reflects export value**. Given the wide range of export volumes, we applied a **log transformation** to normalize scale and improve comparability across countries. Like the GDP analysis, the MFN plots revealed **Canada and Mexico as clear outliers**, driven by disproportionately high trade volumes. Below plots show Export value and tariff rates for specific years 2008, 2015 and 2022 -
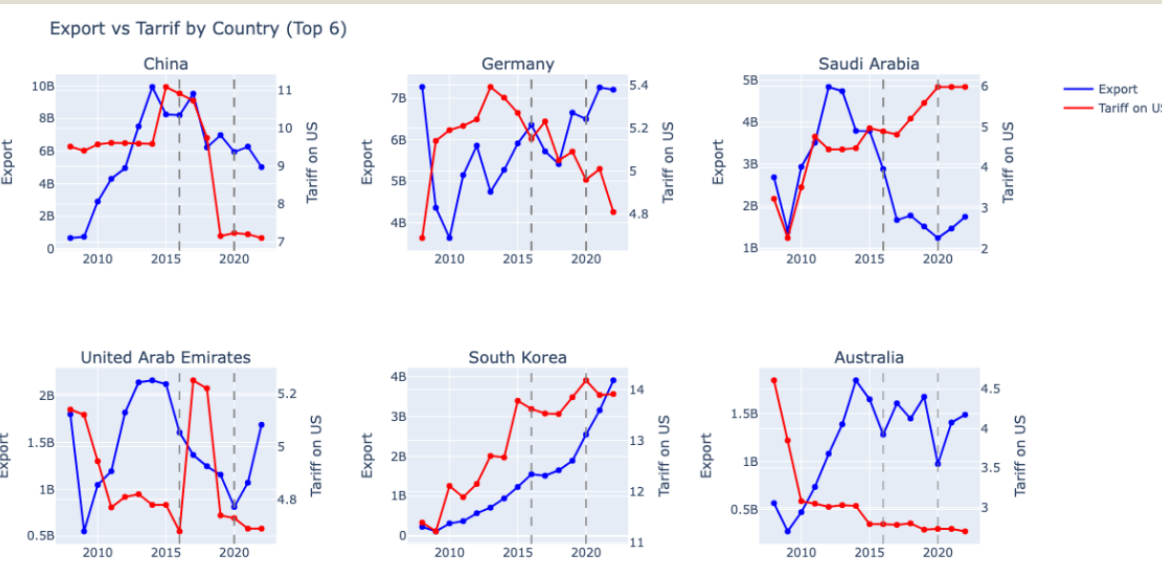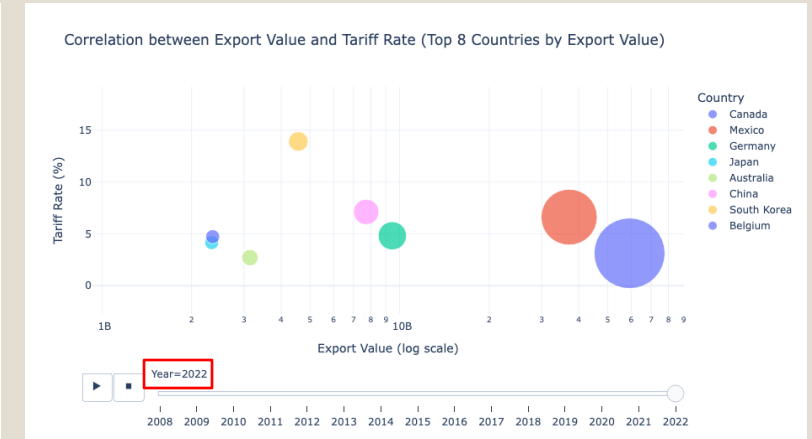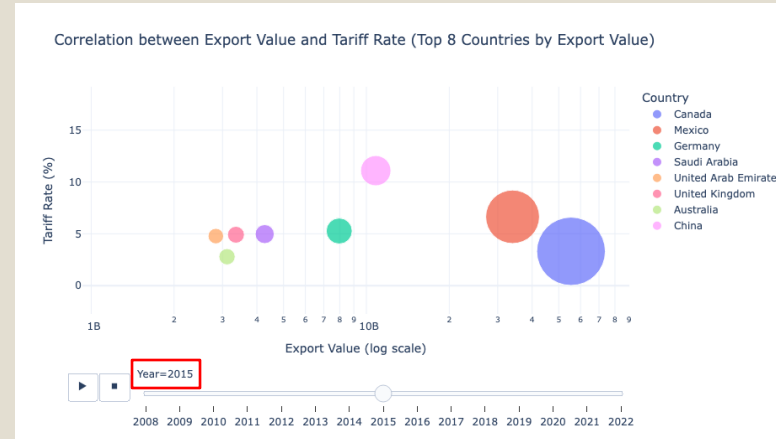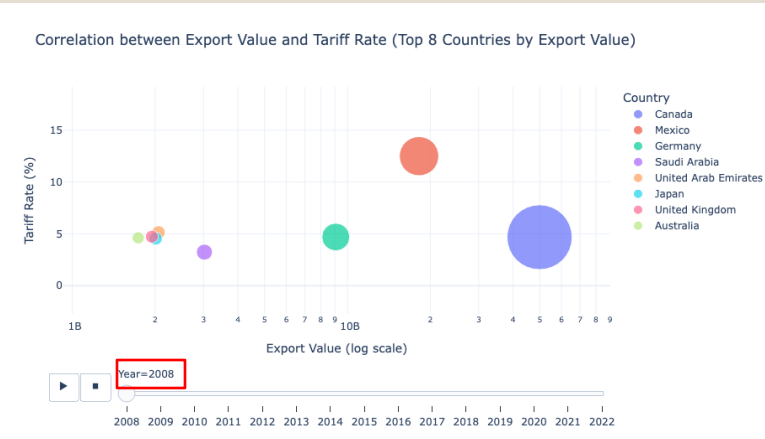

For further analysis, we filtered export values for 'Passenger vehicles' for top 6 countries and plotted grid line plots with two-Y axes for each plot - left Y showing Export value in billion USD and right Y showing the % tariff on the US.

➢ **China** shows a strong exports from the US trend until 2018, followed by a sharp decline in 2019, 2020. This is paired with tariff spike in 2018 showing inverse relationship.

➢ **Germany**, on the other hand shows fluctuating trend for the exports from the US as well as tariff rates. Trade between Germany and the US is most likely influenced by demand cycles.

➢ **Saudi Arabia and United Arab Emirates** importing from the US peaked around 2012, followed by steady decline. Apparently, there is a sharp increase in tariff rates in 2018, which might have contributed to export decline in Gulf countries.

➢ **South Korea and Australia** show steady rise in their imports from the US. Tariffs rates do not appear to have significant influence on the trade value

Analysis of Tariffs by the US and Imports

We extended our analysis to **U.S. automotive imports** and the **tariffs imposed by the U.S.** on partner countries, using the same animated scatter plot function developed for exports. Visualizing trends for the **top 8 exporters**, **Japan, Canada, and Mexico** consistently led in automotive shipments to the U.S. In **2008**, import values from all three were nearly equal. By **2015**, **Mexico** had become the dominant exporter, and by **2022**, it stood out as a clear outlier—**surpassing $100 billion** in total imports. Notably, the **U.S. tariff rate** on these top exporters remained **stable between 3% and 4%** throughout the period, suggesting that trade volume shifts were driven more by supply chain dynamics than tariff policy.
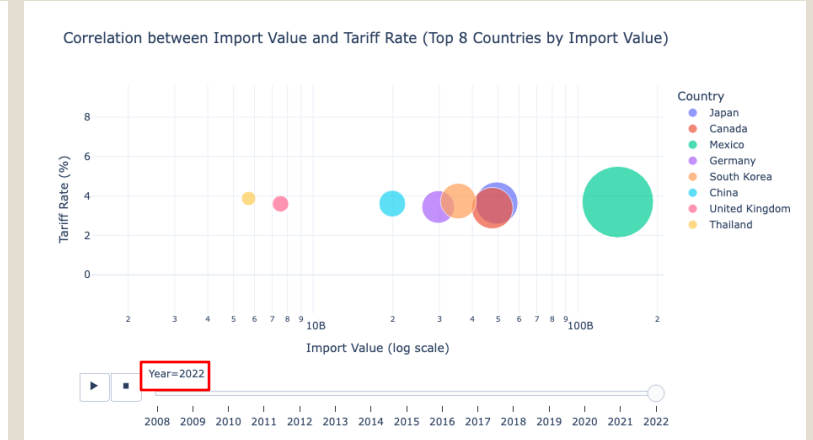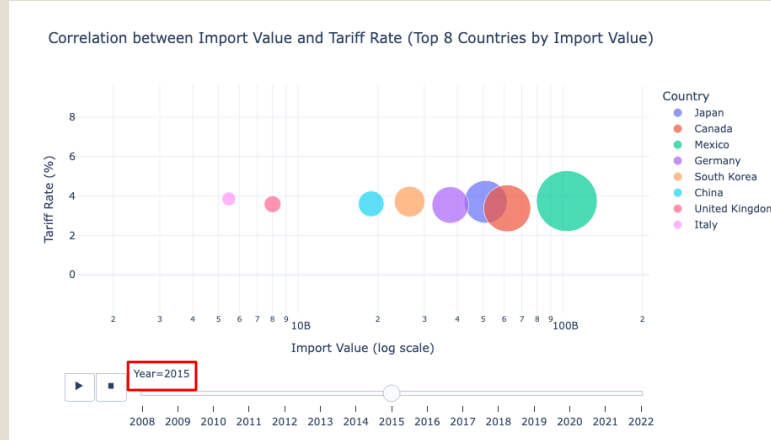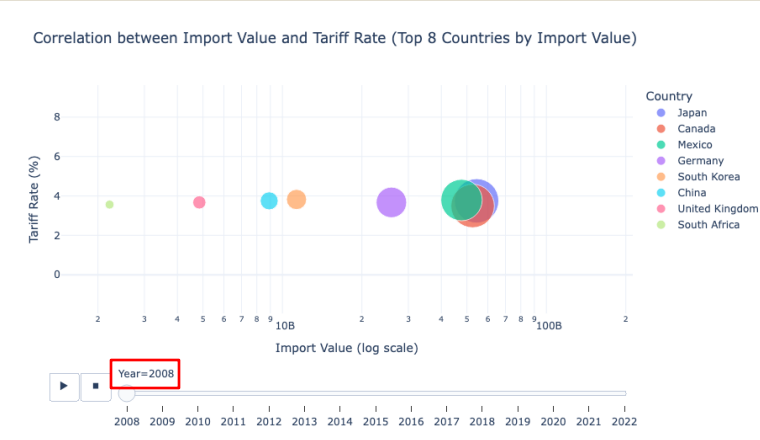
Building on our export-side analysis, we conducted a deep dive into **U.S.-imposed tariffs** on countries exporting automotive goods to the U.S. To capture potential policy-driven shifts, we marked **2016 and 2020** with dotted vertical lines—highlighting a period where **tariff rates spiked across multiple trade partners**, signaling possible election-linked trade policy impacts.

➢ Imports from **Japan** show a stead growth until 2018, then a dip in 2019 and further decline in 2020.
➢ Import rend from **Germany** is rising steadily until 2014, then there is a gradual decline.
➢ **South Korea** and other countries exportin to the US also show consistent growth until 2018, followed by decline in the after years.
➢ Tariff by US shows a common pattern across most of the countries. US' **tariff rate was between 3.5% to 3.8% until 2018 and it suddenly spiked to over 4.5% in 2018** and then reduced back to pre-2018 range. This sudden short-term policy change and then COVID-19 pandemic in 2020 show decline in US' import values of passenger vehicles.
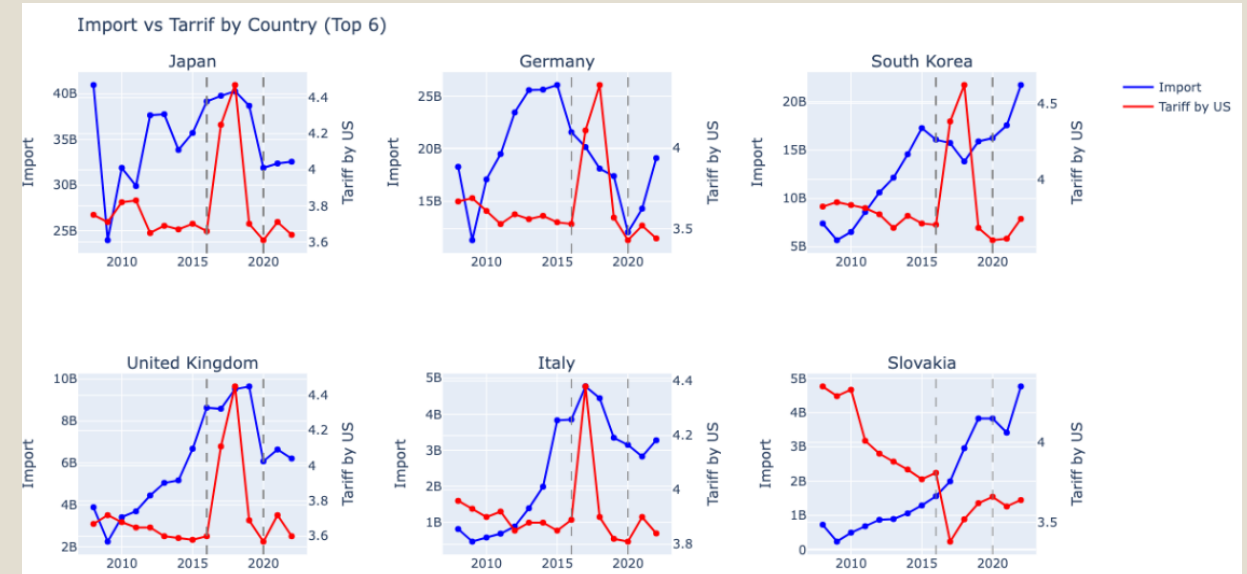
Conclusion, Next Steps, Limitations and References

Conclusion

Circling back to our key research questions mentioned in the beginning of this executive summary, we conclude that -

- **U.S. imports consistently exceed exports** across automotive parts, passenger vehicles, and trucks.
- **Parts exports** from the U.S. surpass those of passenger vehicles and trucks in total value.
- **Canada and Mexico** remain the U.S.'s most critical automotive trade partners.
- **Japan, Germany, China, and Gulf countries** represent key global markets engaged in automotive trade with the U.S.
- **Strong GDP growth** in partner countries correlates well with increased **U.S. parts exports but** shows **weaker correlation** for passenger vehicles and trucks.
- **Tariffs imposed by partner countries on U.S. exports** are significantly higher than **U.S. tariffs on imports**, creating an asymmetry in trade policy.
- **Tariff increases in 2018** by the U.S. led to a **notable decline in import volumes**, indicating an inverse relationship between tariffs and trade flow.
- **Economic downturns in 2008–2009 and the COVID-19 pandemic in 2020** caused broad declines in export/import values, independent of GDP or tariff levels.

Limitations

- We excluded several countries from our analysis to focus on the main trends, which may limit the generalizability of our findings.
- GDP may not be the only factor explaining high exports, as other factors such as trade agreements, tariffs, industrial capacity, exchange rates, etc. could also play a role.
- MFN tariffs are average rates for trade across all types of goods. It is not 100% accurate for automotive products.

Next steps

- In future work, we could assess the quality of the trendline fit more rigorously using measures such as R-squared or other goodness-of-fit metrics.
- Quantify import values over export values across different categories and countries to calculate the trade deficit.
- Calculate difference between value generated by parts exports vs. passenger vehicles and trucks exports.
- We could also include additional datasets such as consumer demands, brand loyalty, parts pricing and availability etc. to analyze future trends in automotive trade.

Ethical Considerations

- **Data accuracy and integrity:** Limitations posed due to missing trade data for some partners, GDP revision methodologies and the broad nature of MFN (Most favored nation) tariff rates. Mitigation includes transparent reporting and careful handling of missing data
- **Privacy:** Datasets are aggregated at country level, eliminating risk of privacy concerns. We are using publicly available datasets with no explicit consent from agencies.

References

1. https://www.cato.org/blog/seven-charts-show-how-us-tariffs-would-harm-american-auto-industry
2. https://usafacts.org/articles/what-does-it-mean-for-the-us-to-have-a-half-a-trillion-dollar-trade-deficit/
3. https://usafacts.org/articles/who-are-the-uss-top-trade-partners/
4. https://worldpopulationreview.com/country-rankings/automobile-tariffs-by-country

Statement of Work

Collaboration:

We established a cadence of regular check-ins to align on progress, address challenges, and plan next steps. While each team member handled data processing independently, we collaborated closely to define the most effective analytical approaches and visualization strategies, then divided the execution accordingly. To streamline our workflow, we set up a shared Git repository for version control and code exchange and integrated it with Deepnote to enable live notebook execution and real-time insight sharing. This setup fostered efficient collaboration and allowed us to capitalize on each other's strengths throughout the project lifecycle.

Mugdha's Contributions

◦ Contributed to identifying datasets and defining the project scope.

◦ Handled cleaning, aggregating, and transforming the primary dataset related to export and import across different product categories and years.

◦ Developed a portion of the visualizations used in the analysis.

◦ Drafted the project proposal and project report and summarized key findings.

Divya's Contributions

◦ Contributed to identifying datasets and defining the project scope.

◦ Handled processing and manipulation of secondary data, including economic indicators such as GDP and MFN tariffs.

◦ Developed another portion of the visualizations used in the analysis.

◦ Set up the Git repository and integrated it with Deepnote for collaborative work. Cleaned and organized the codebase, integrating contributions from both team members to ensure a modular structure, adherence to PEP 8 standards, and a cohesive workflow.