

Towards Air Cargo Demand Forecasting for Southeast Asia

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Abstract

The demand for air cargo within ASEAN countries is influenced by a range of macroeconomic factors. The specific factors and their significance are not well understood. This has presented challenges for forecasting of air cargo demand in this region. Trade policies, such as tariffs or other barriers to trade as well as trading relationships, can affect the flow of goods between countries, and therefore the demand for air cargo. Overall, the demand for air cargo within ASEAN countries is influenced by a complex mix of economic and trade-related factors. Another key challenge is the identification of reliable open-source macroeconomic data. This study has sought to identify the key factors of significance that are available from open-source data, with a view to applying these in future forecasting research.

Keywords: Air Freight Demand; Air Cargo; Forecasting; Southeast Asia

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1 Introduction

1.1 Objective

This project is performed under the Undergraduate Research Opportunities Programme (UROP) at the Singapore University of Technology and Design (SUTD) and supervised through the Aviation Studies Institute (ASI). This programme provides university students with the opportunity to apply research techniques as part of their undergraduate studies for short duration projects (up to c. 3-months).

The project objective is to support the prediction of future air cargo demand within Southeast Asia by identifying the factors of significance and reliable open-source data. It leverages confidential historical air cargo demand data supplied by an external organisation (International Air Transport Association, [IATA]) who are collaborating with ASI.

The work would be the first step in developing applied insights of direct relevance to the air transport industry.

1.2 Motivation

Air Cargo has grown in relevance during the COVID-19 pandemic as a means to transport perishable goods in a timely manner. Despite extensive data on historical air cargo demand, predicting future demand remains poorly defined. Whilst passenger air transport demand is understood to have a general correlation with Gross Domestic Product (GDP) [Marazzo, Scherre, and Fernandes \(2010\)](#), several other macroeconomic factors are thought to play a pivotal role in air cargo demand. The specific factors are thought to vary in different geographical regions.

This project involved identifying factors of significance for predicting air cargo demand within the Southeast Asia region over long-time horizons.

The work uses extensive historical data related to air cargo demand (obtained from the IATA CargoIS platform), open-source macroeconomic data (historical) and data models to search for correlations.

A second challenge was to develop mathematical models that searched for correlations between the acceptable macroeconomic data and the historical air cargo demand. These were used to identify the factors of significance when predicting future air cargo demand in the region.

2 Analysis of Air Cargo Demand

After obtaining the relevant air cargo dataset from IATA in Comma Separated Values (CSV) format, DBeaver was used as a relational database management system (RDBMS) to manage the provided data. SQLite was used as our main language to query the required data.

The initial dataset provided by IATA's CargoIS platform ranged monthly from January 2015 to December 2018, and included each origin country's total weight and number of shipments to each receiving country.

2.1 Data Cleaning and Management

As the scope of our project involves analysis of air cargo demand within Asia, we have decided to focus on analysis between ASEAN countries within the Southeast Asia region. This significantly narrows down and reduces the size of the dataset, for easier identification of relevant correlations with macroeconomic data.

Due to data availabilities, we initially sourced and collated a multitude of macroeconomic and non-macroeconomic datasets for each country from open-source databases. Open-source datasets were generally available on an annual basis and we obtained these across ~ 60 years (1960 – 2021, provided by World Bank Data) to aid multi-year time series correlation analysis.

We subsequently obtained the historical air cargo data, which was provided on a monthly basis. However, we realised that this range was limited from 2015 to 2018. This meant that there would be only four available data points if analysing on an annual basis. As this would be insufficient for any meaningful analysis (low sample sizes would not produce credible results), we investigated the availability of further macroeconomic datasets. We were able to obtain quarterly datasets for GDP, from the central banks and monetary authorities (and their equivalents) of 6 ASEAN countries.

As a consequence, we aggregated each year's worth of air cargo data into quarterly totals. This would bring us to a total of 16 data points per country, which was enough to show potential trends and seasonality in the data.

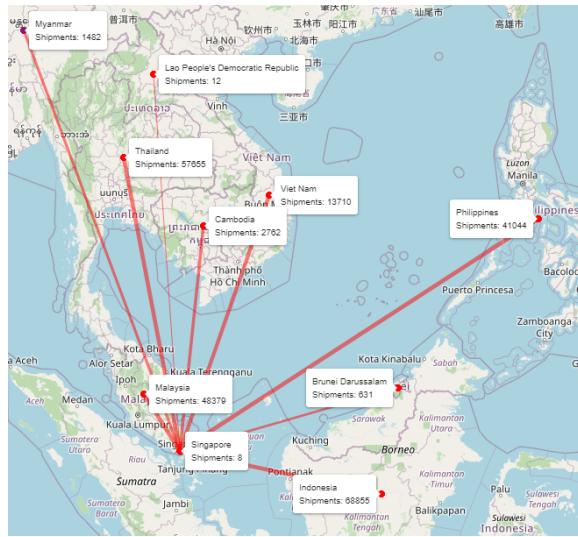
Our second challenge while working with the historical air cargo data was that the different countries had naturally vastly different number of shipments and monthly weights, by virtue of their differing levels of economic development. This resulted in a relatively high sample standard deviation across the ASEAN region, which made it difficult to perform comparative analysis of the raw data. To overcome this issue, we employed feature scaling techniques on the raw data, namely base 10 logarithmic scaling, to better visualise the data in maps and radar charts.

2.2 Exploratory Data Analysis

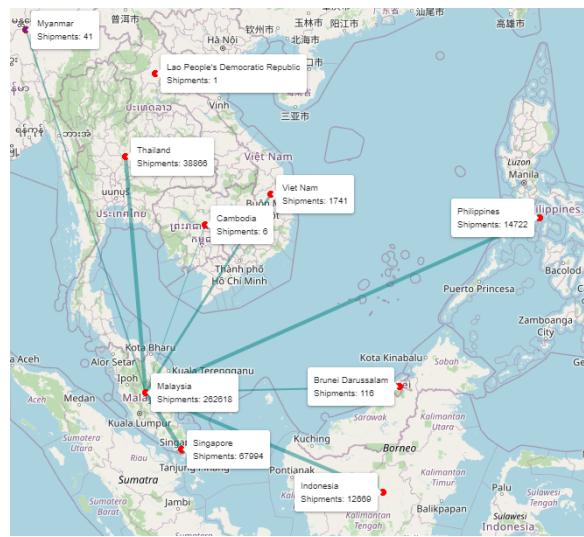
2.2.1 Air Cargo Trade Relations

Initial analysis was performed using *R* code in *RStudio* to visualise the key geographical flows of air freight between ASEAN countries. This was done by combining our current dataset with [open-source geospatial data](#) from Google, which contained longitude and latitude coordinates representing each country. Due to limitations of the dataset, this geospatial plot does not represent the exact take-off and landing coordinates of each flight, nor of the flight paths taken by aircraft.

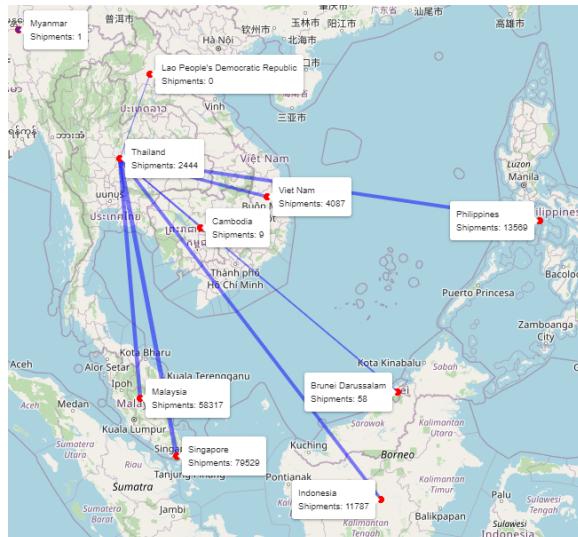
Air cargo shipment activity between each ASEAN state, aggregated from 2015 to 2018, is shown below. The thickness of each line indicates the relative number of exports from each country.



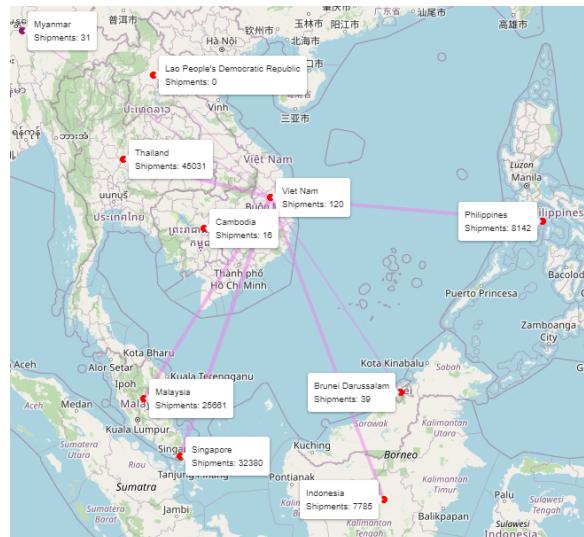
(a) Singapore's Aggregated Exports



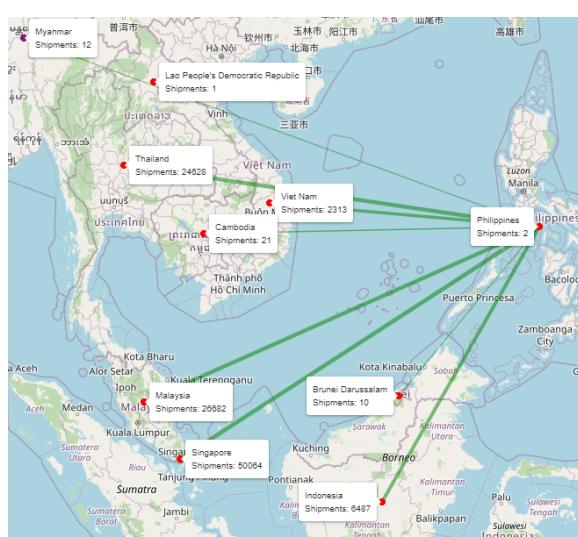
(b) Malaysia's Aggregated Exports



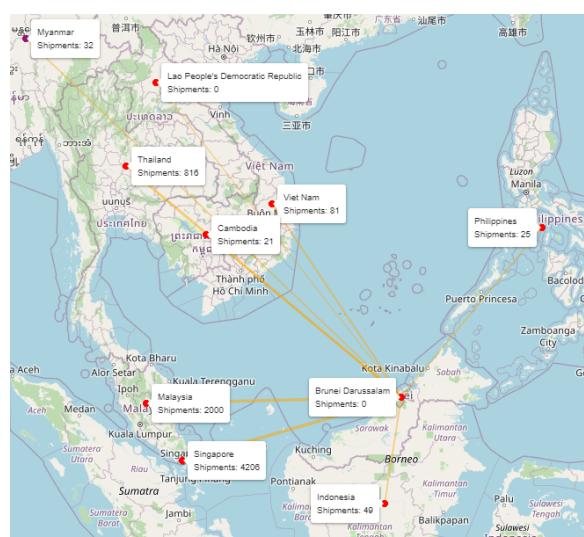
(c) Thailand's Aggregated Exports



(d) Vietnam's Aggregated Exports

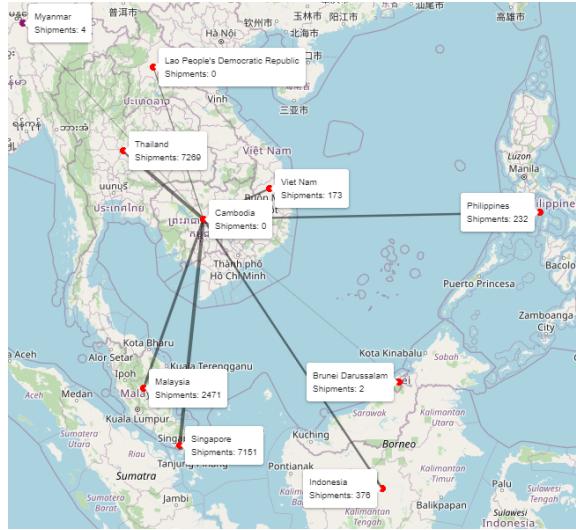


(e) Philippines's Aggregated Exports

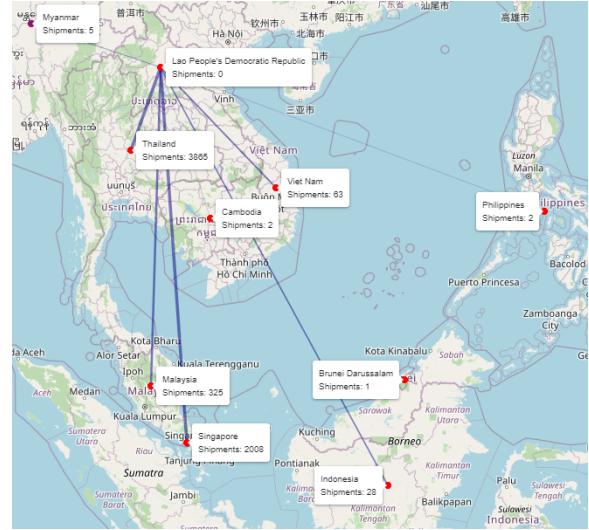


(f) Brunei's Aggregated Exports

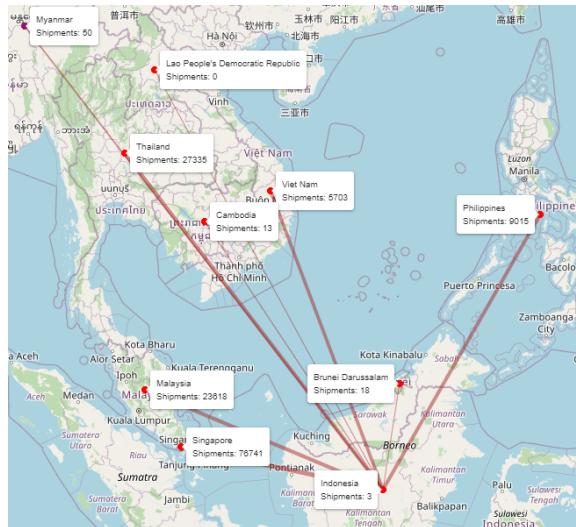
Figure 1a: Aggregated Exports to ASEAN (2015 to 2018)



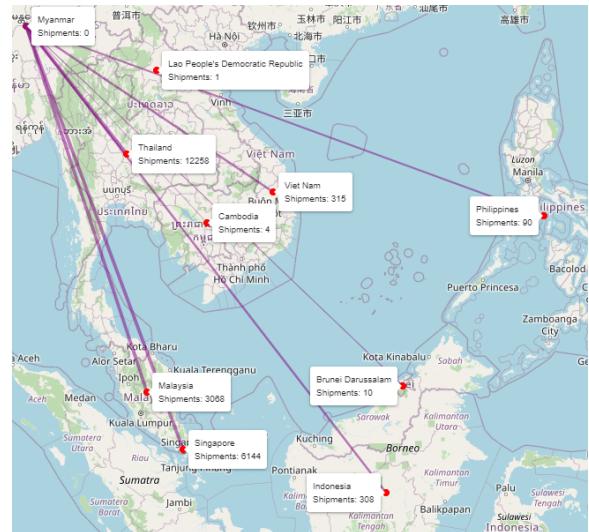
(a) Cambodia's Aggregated Exports



(b) Laos' Aggregated Exports



(c) Indonesia's Aggregated Exports



(d) Myanmar's Aggregated Exports

Figure 1b: Aggregated Exports to ASEAN (2015 to 2018)

Some key observations can be observed from the geospatial visualisation:

- Laos has one of the lowest air cargo activities amongst all the ASEAN countries. Despite exporting to many countries, it does not seem to receive a corresponding quantity of imports (interestingly, Laos is the only land-locked country in Southeast Asia).
- Different countries have different major trading partners for air cargo, although Singapore, Malaysia, and Thailand have particularly high proportions of air cargo shipment activity with other ASEAN countries regardless.
- Malaysia has a disproportionately large domestic air cargo shipment activity compared to other countries. The exact origin and destination of domestic air cargo is not known due to the lack of information in the dataset.

2.2.2 Annual Imports of Air Cargo Per Country

Interactive radar charts were generated in *Python* code, with options to display the years as coloured overlays. The radar charts give an additional overview of the interaction between the ASEAN countries, which in this case represents the total number of imports per year. The number of shipments have been log-scaled, and as such the axis represents the scaled value of shipments, i.e. number of shipments = 10^r , with r being the value on the axis.

We are also able to visualise and compare each country's internal shipments with that of other countries, as well as countries with no interaction between one another. The legend of the chart is as follows: blue representing 2015, red representing 2016, green representing 2017, and purple representing 2018.

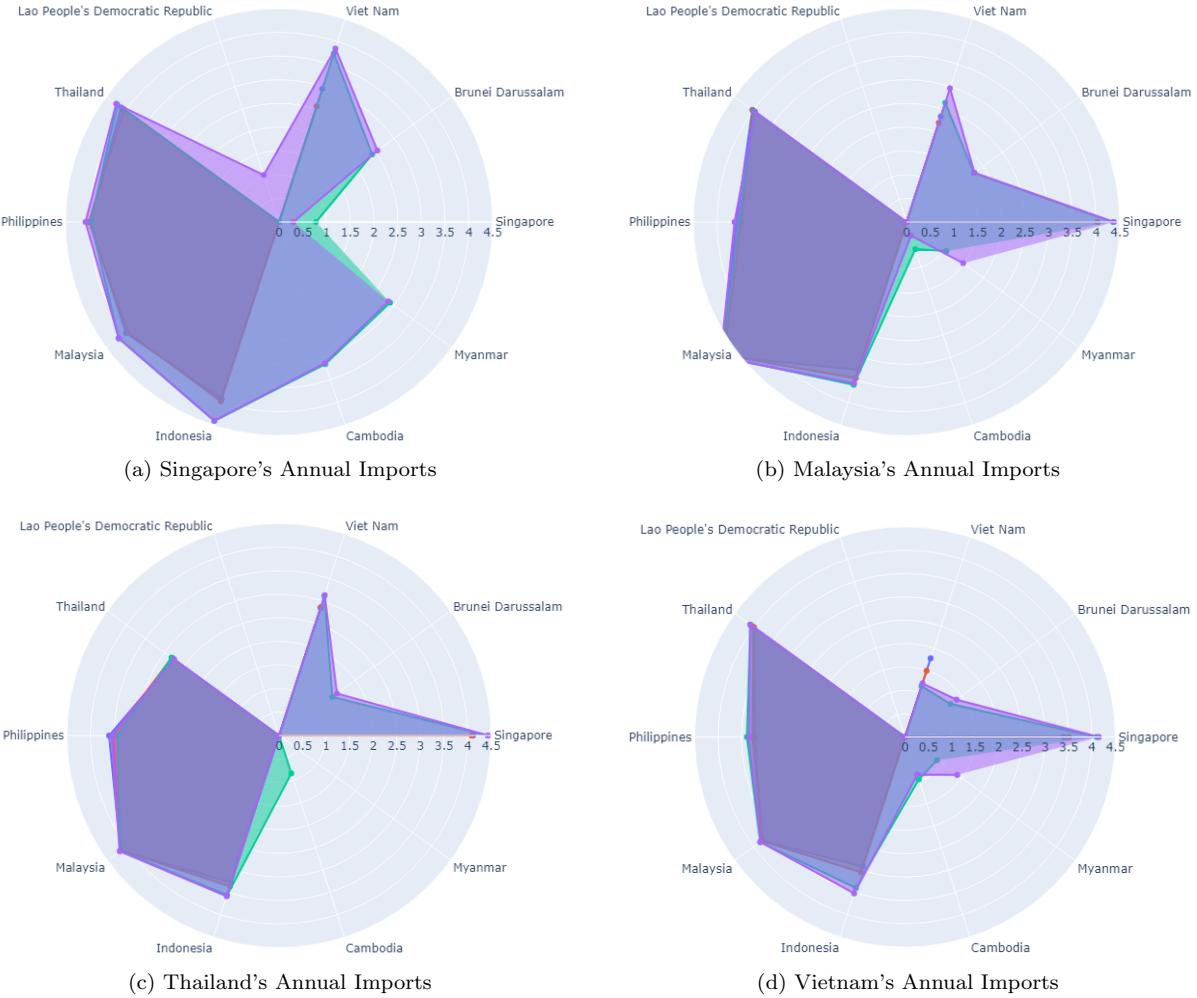
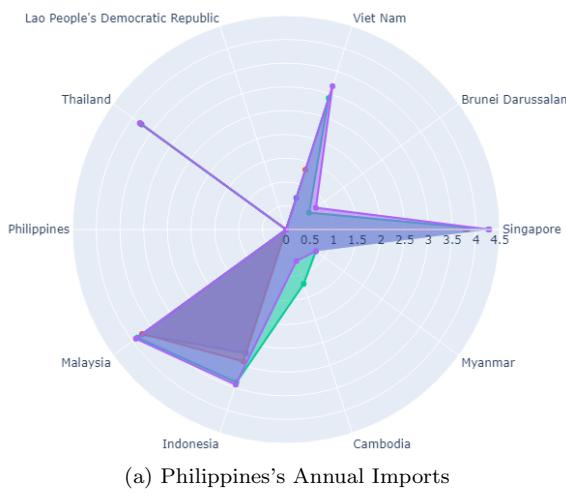
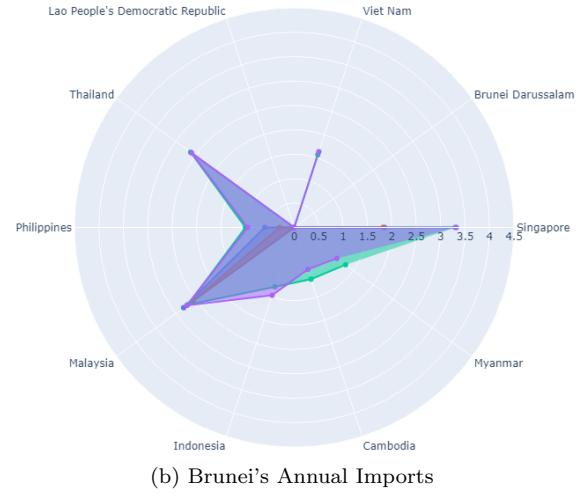


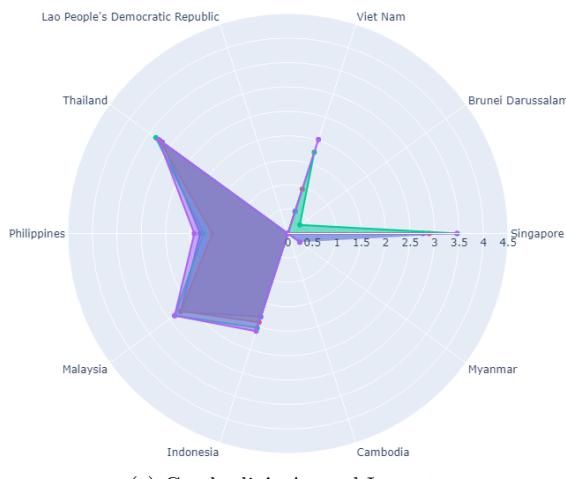
Figure 2a: Aggregated Imports to ASEAN (2015 to 2018)



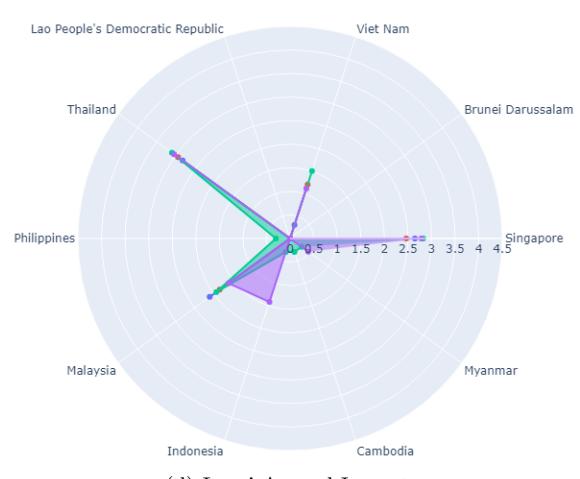
(a) Philippines's Annual Imports



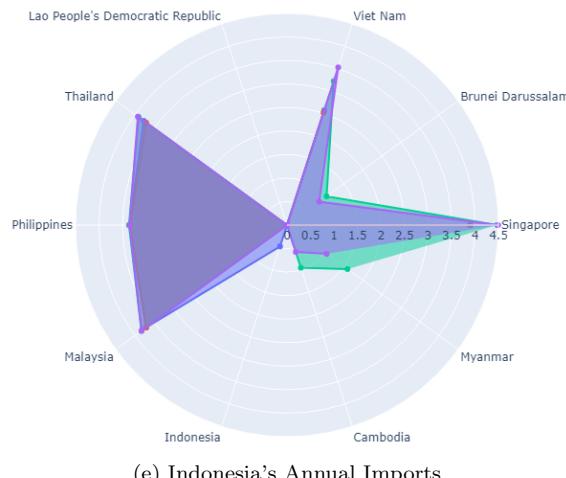
(b) Brunei's Annual Imports



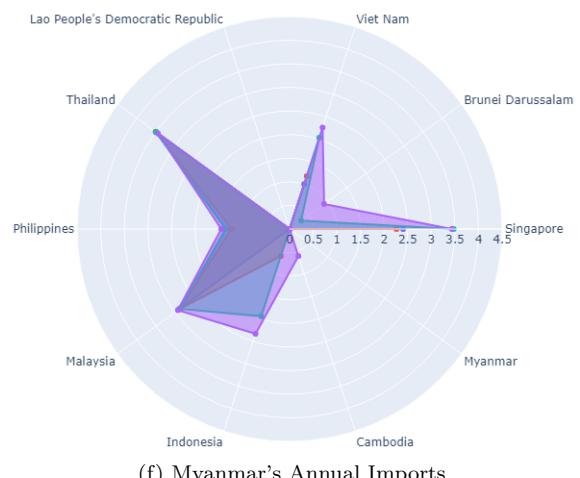
(c) Cambodia's Annual Imports



(d) Laos' Annual Imports



(e) Indonesia's Annual Imports



(f) Myanmar's Annual Imports

Figure 2b: Aggregated Imports to ASEAN (2015 to 2018)

Some interesting analysis to note:

- While most countries do not import from themselves, Malaysia seems to once again have a disproportionately high number of internal air cargo shipments.
- There seems to be a noticeable jump in the number of imports from 2016 to 2017, which is consistent for all countries. The number of imports from 2015 to 2016 and from 2017 to 2018 stays relatively consistent, however.
- The disproportionate increase in trade between countries from 2016 to 2017 might be due to the ASEAN Economic Community (AEC) Blueprint 2015 being achieved. Its objectives include the elimination and reduction of import duties, removal of Non-Tariff Barriers (NTBs), among many others, aimed at creating a single ASEAN market. Therefore, the elimination of tariffs and facilitation of trade would have promoted the growth of air cargo demand [ASEAN Secretariat \(2015\)](#).

2.2.3 Quarterly Air Freight Demand

The following figures depict line charts, displaying the amount of shipment activity (total imports and exports) for each country within the ASEAN region. The plots are separated into two, with one including the countries with higher shipment activity, and the other with lower shipment activity. This allows for better visual comparison between countries with vastly different shipment activity, to identify commonalities in trends.

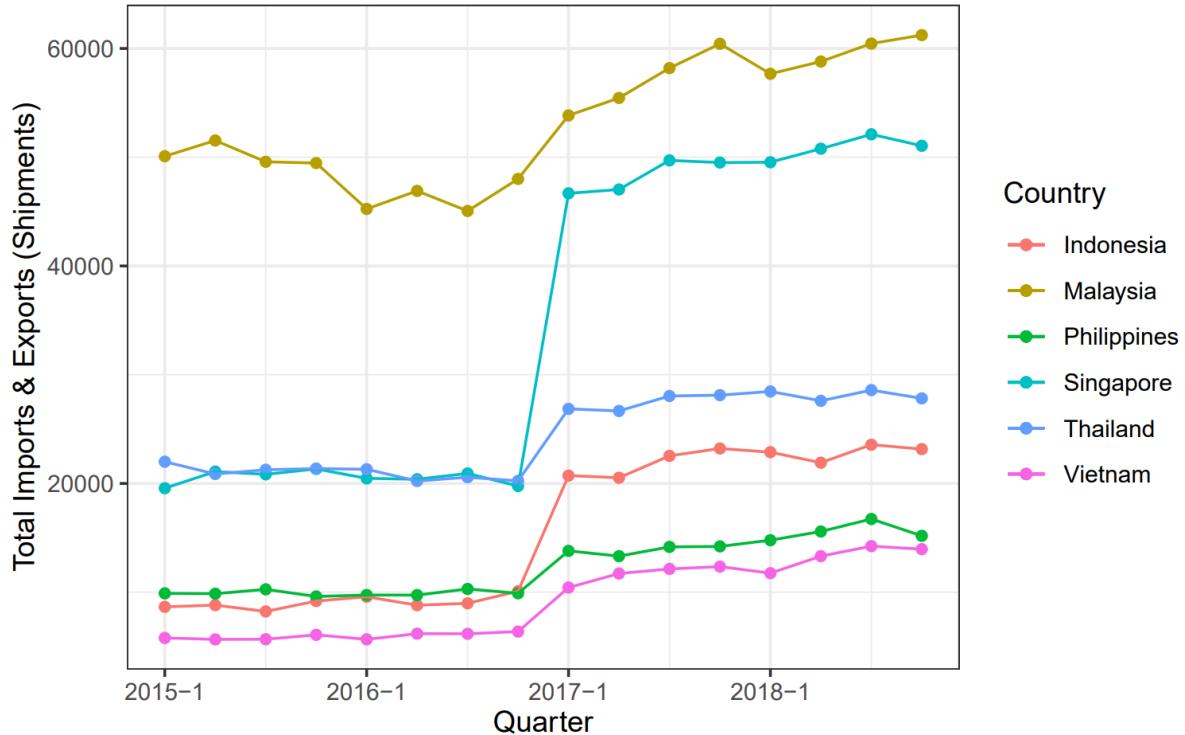


Figure 3a: Total Shipments for Larger Activity Countries

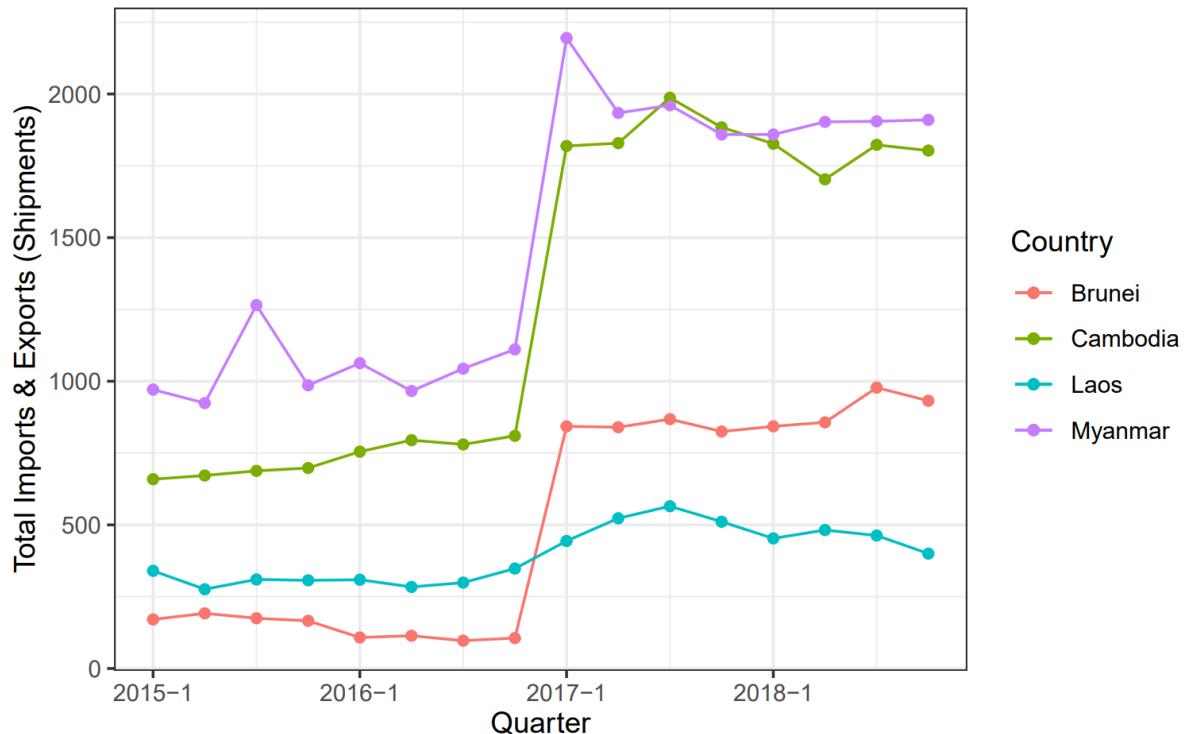


Figure 3b: Total Shipments for Smaller Activity Countries

Similarly, there is a large increase in the number of shipments from 2016 Q4 to 2017 Q1 for most countries. The only exception to this trend is Laos, where the change in shipment over time seems to be comparatively gradual rather than sudden.

2.2.4 Seasonal Trend Analysis

The line plots below depict the monthly data for the aggregated number of shipments (Imports and Exports) for each country, showing a slight seasonal trend during the months of March to April and October to November. We have included both the logarithmic-scaled plots and the raw data plots, as the raw data plots show a better visualisation of seasonal trends, but obscure the countries with lower activity. The scaled plots thus supplement the visualisation of the countries with lower air cargo activity.

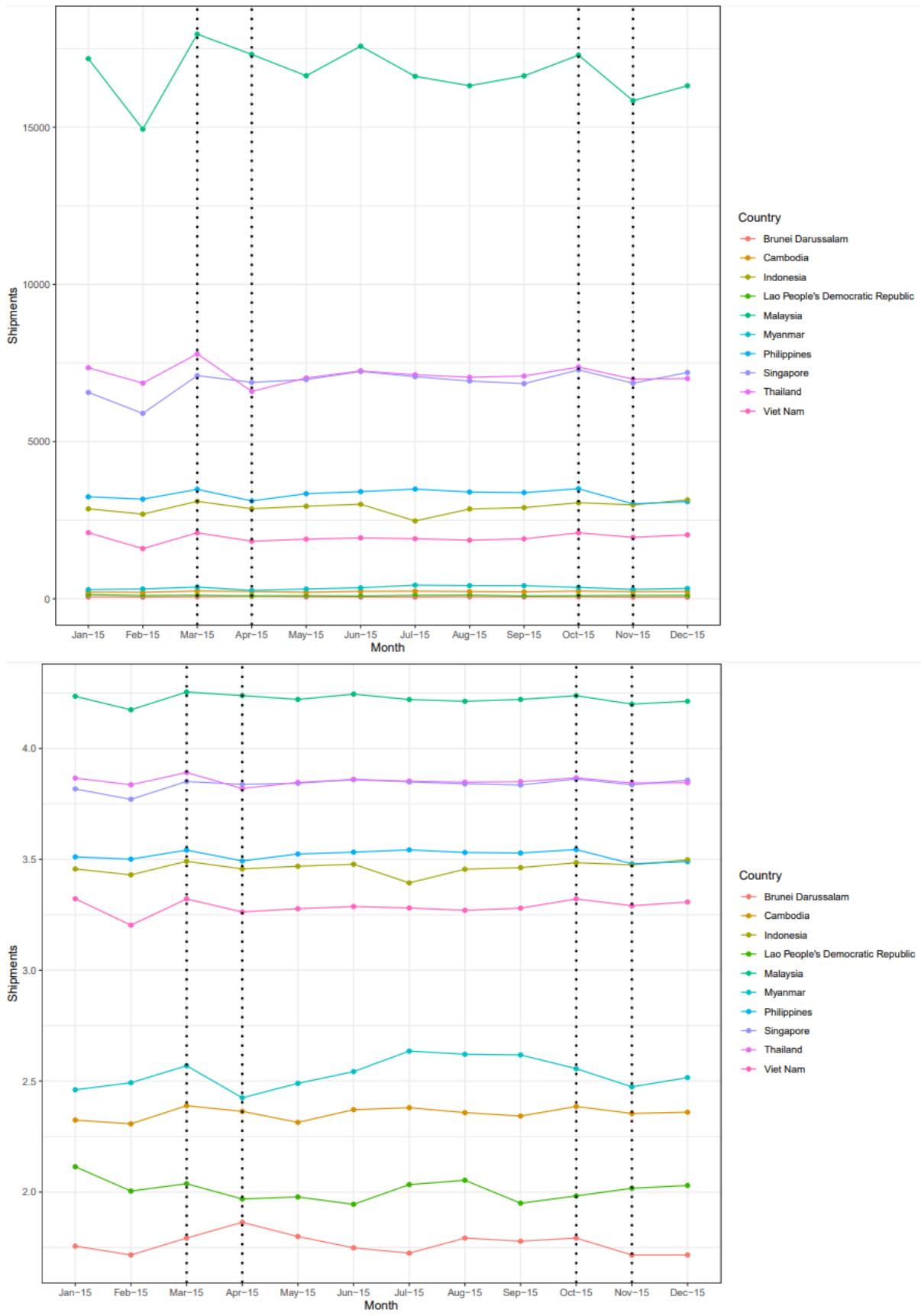


Figure 4: 2015 Monthly Shipments, regular and log-scaled (below)

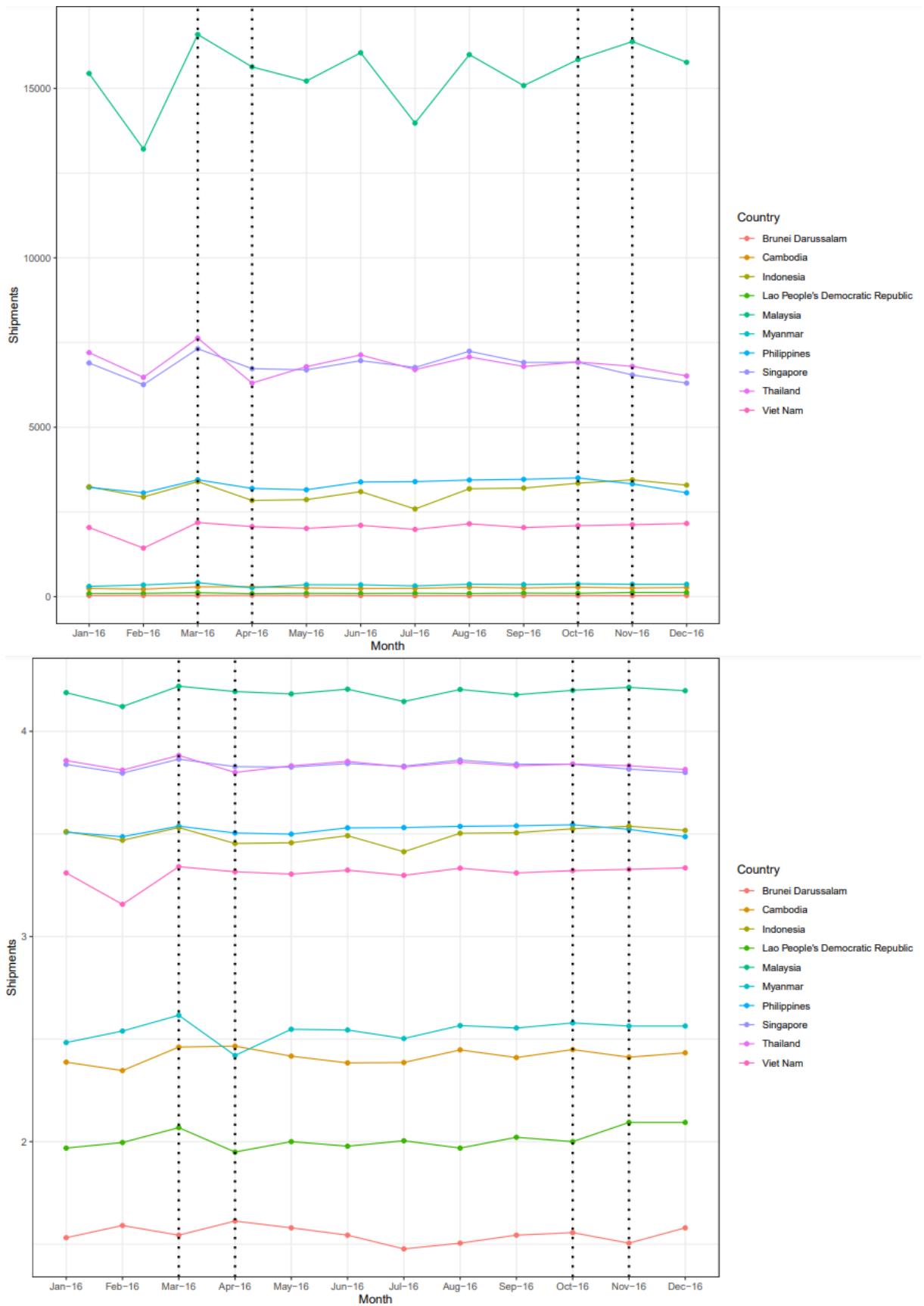


Figure 5: 2016 Monthly Shipments, regular and log-scaled (below)

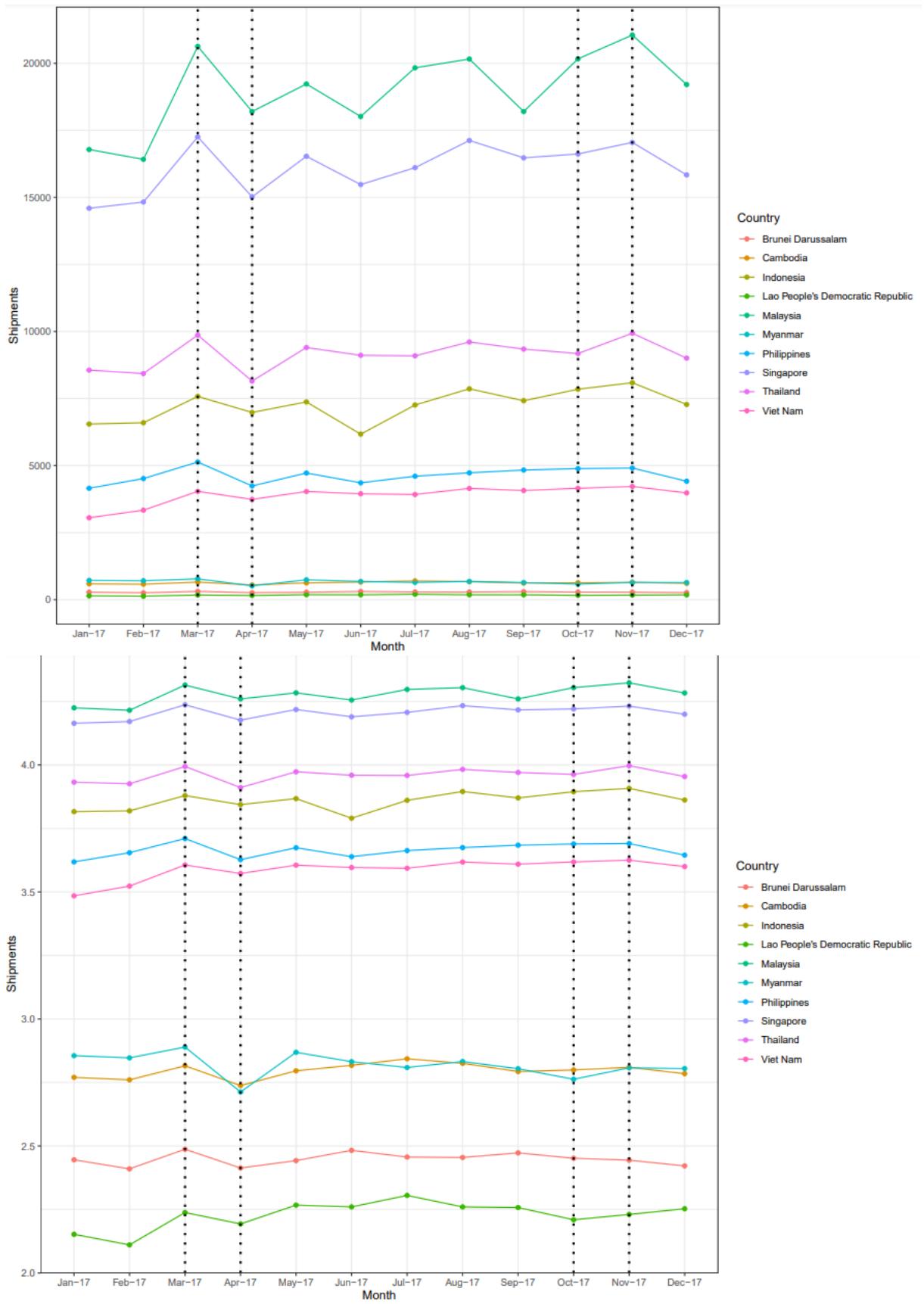


Figure 6: 2017 Monthly Shipments, regular and log-scaled (below)

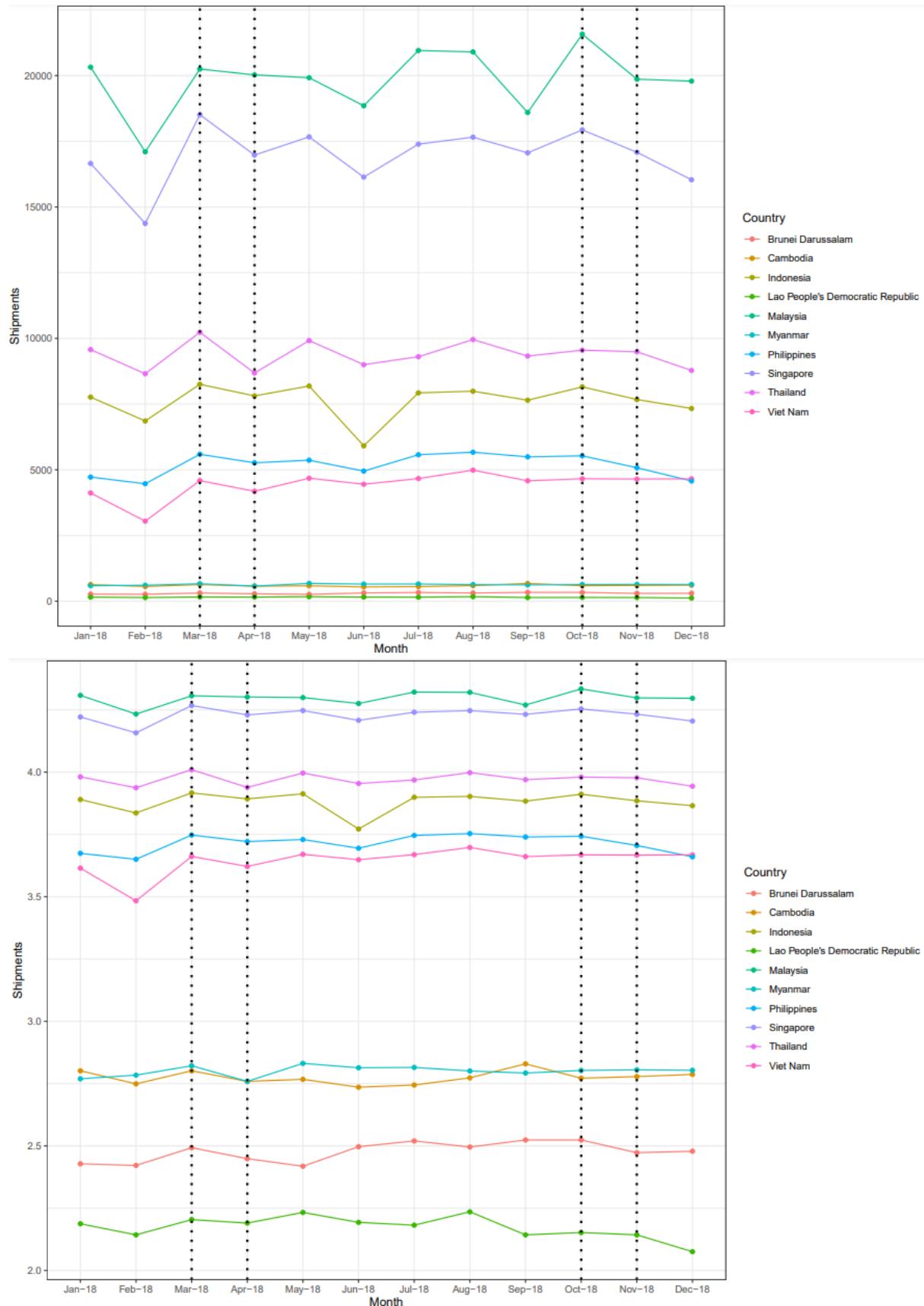


Figure 7: 2018 Monthly Shipments, regular and log-scaled (below)

The figures show the presence of a seasonal trend. In general, there is a temporary decrease in the number of shipments from March to April, and similarly from October to November, which is consistent throughout each year and each country analysed. This may be due to specific seasonal changes in consumer spending. Different countries and cultures may experience different patterns of consumer behaviours. Some examples of seasonal changes in consumer spending that could potentially occur during the March-April period include:

- New Year National Holiday: Thailand Songkran Festival, Lao, Cambodia and Myanmar
- Good Friday: Indonesia, Malaysia, Philippines, Singapore
- Ceremonial and Religious observance: Vesak day (Cambodia, Laos, Malaysia, Singapore), Anniversary of the Coronation of King Maha Vajiralongkorn (Thailand).

The demand for certain types of goods such as gifts and decorations during the holidays would increase, thereby increasing the demand for air cargo in those countries.

3 Assessing Macroeconomic Factors of Relevance

A key challenge of the project involves identifying suitable open-source macroeconomic data relevant to the ASEAN region. In the course of the project, we developed hypotheses about what macroeconomic factors could be of influence on air cargo demand, and how different sets of macroeconomic factors might be related to each other. This will be detailed in the following sections.

There exists a multitude of macroeconomic datasets online, many of which are paywalled or non-accessible to public use without proper licensing. Thus, our identification of relevant macroeconomic data was limited to open-source datasets and those available via existing university subscriptions. The datasets which we accessed were from the following, supplemented by some country's respective department of statistics:

- [World Bank Group](#)
- [International Monetary Fund \(IMF\)](#)
- [Statista \(Existing Subscription\)](#)
- [Trading Economics](#)
- [ASEANstats](#)

One noteworthy source of ASEAN data is from the ASEAN Statistics Division (ASEANstats). It is one of the divisions under the ASEAN Economic Community Department of the ASEAN Secretariat, in charge of providing statistical services to the ASEAN Secretariat, ASEAN bodies and ASEAN stakeholders. ASEANstats is also the technical arm of the ASEAN Community of Statistical System (ACSS). ASEANstats mainly provides annual statistical publications, an open-source online database which can be exported in .XLS (Microsoft Excel Binary File) format, and they also support further requests for data not included in their database [ASEAN Statistics Department \(2022\)](#). However, we were unable to obtain any data of relevance to the project on the database, as they were mostly aggregated annually. They were also unable to facilitate requests for data within the timescales of this project. Subsequent research conducted should consider the use of the ASEANstats portal to obtain reliable data on ASEAN countries.

3.1 Data Cleaning

Since we are working with open-source macroeconomic datasets, there is a significant inconsistency in the formatting of each country's datasets. Thus, we had to employ further data cleaning techniques to re-order the data for our use. As we were sourcing for quarterly data, the indicators for each country had to be manually collated into an Excel spreadsheet and reordered based on the given time range.

3.2 Macroeconomic Indicators

Our main source of macroeconomic data used is obtained from each country's respective department of statistics, whereby an online open-sourced repository of the country's data is stored. This usually includes the country's National Accounts, as well as data obtained from nation-wide surveys on various indicators such as mean household income.

Some of the macroeconomic indicators which we sourced for initially included the *Balance of Payments (BoP)*, *Gross Domestic Product (GDP)*, *Consumer Price Index (CPI)*, and others such as the *Percentage of Population with Internet Access*. However, due to the short time period of this project, as well as the lack of available open-source macroeconomic data that was aggregated quarterly, we were unable to conduct any meaningful analysis on BoP, CPI, as well as other non-macroeconomic indicators.

Each country's department of statistics' portal can be found in the links below:

- | | |
|---|--|
| <ul style="list-style-type: none">• Singapore• Malaysia• Thailand• Philippines• Indonesia | <ul style="list-style-type: none">• Vietnam• Brunei• Laos• Myanmar• Cambodia |
|---|--|

Where possible, the macroeconomic data sourced was aggregated in quarters, to align with the CargoIS data which was cleaned as aforementioned.

3.2.1 Gross Domestic Product

GDP, as defined by the IMF, is the monetary value of final goods and services purchased by the user, and produced in a country in a given period of time [Callen \(n.d.\)](#). The line plots of each country's raw GDP (at current prices) aggregated in quarters per year is given below, in contrast with their aggregated shipments. Figures are only produced for those countries that provided data on an aggregated quarterly basis (countries that only provided data on an aggregated annual basis are not shown).

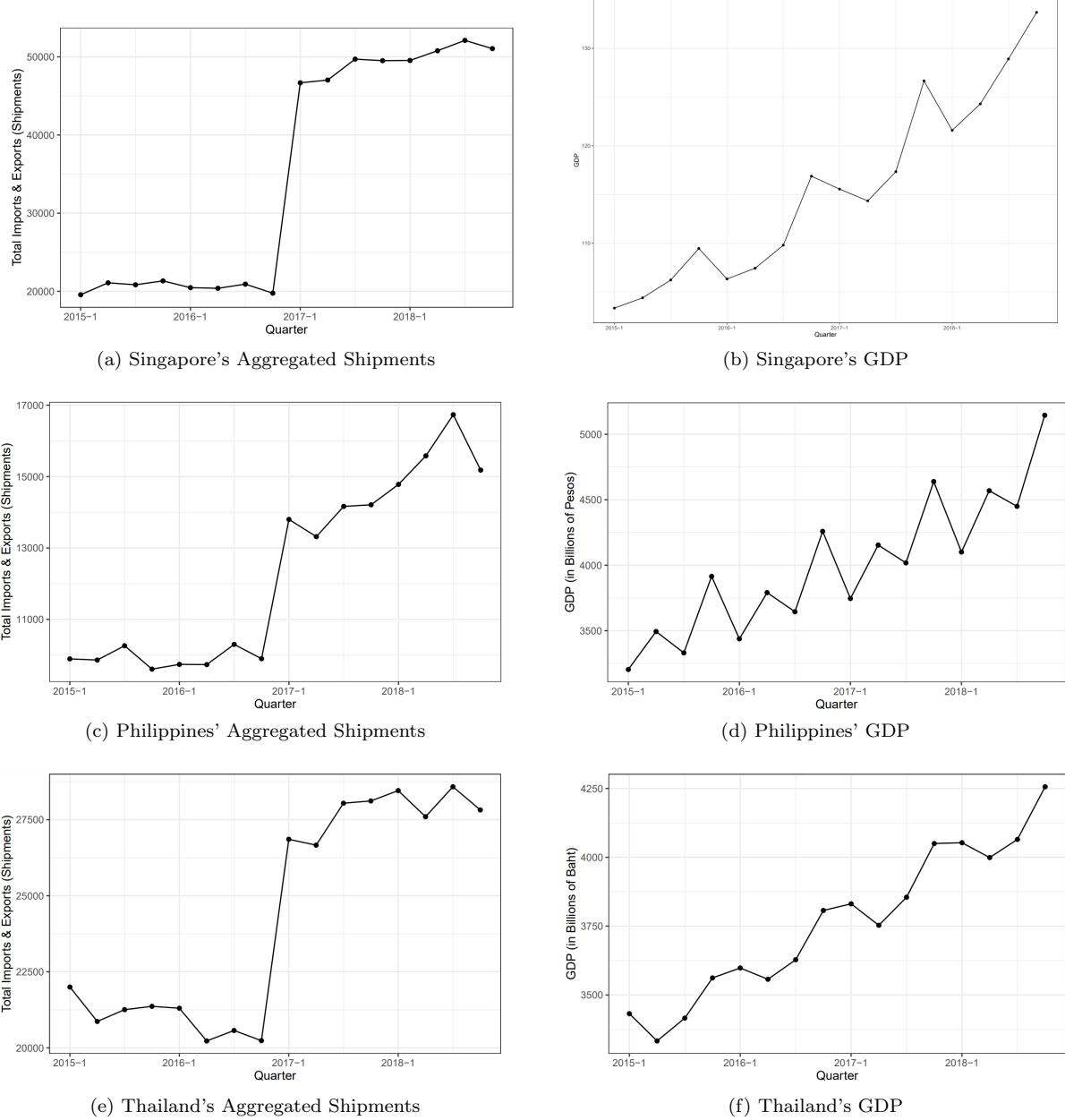
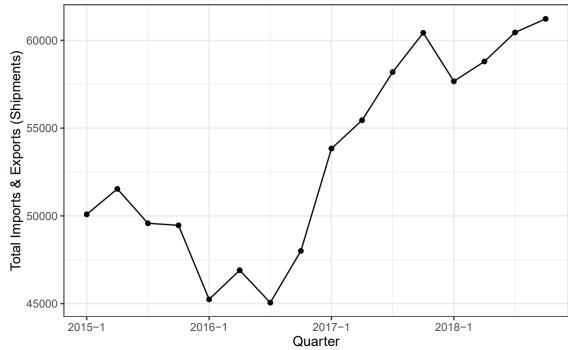
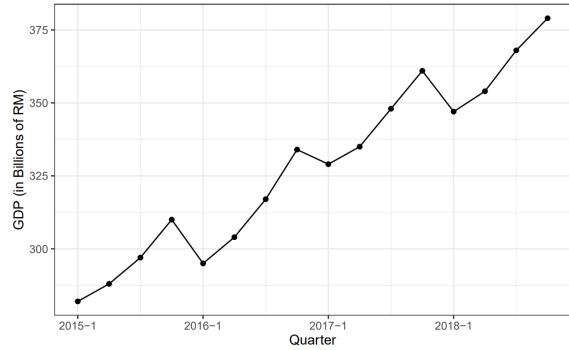


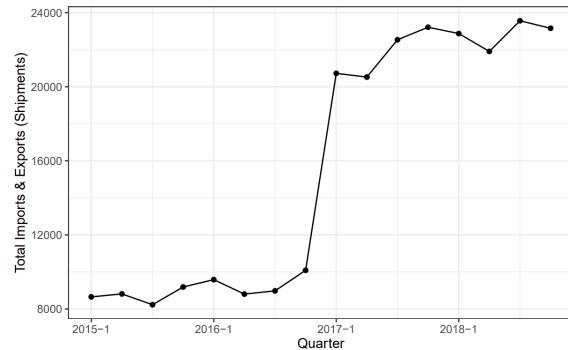
Figure 8a: Aggregated Shipments and GDP (2015 to 2018)



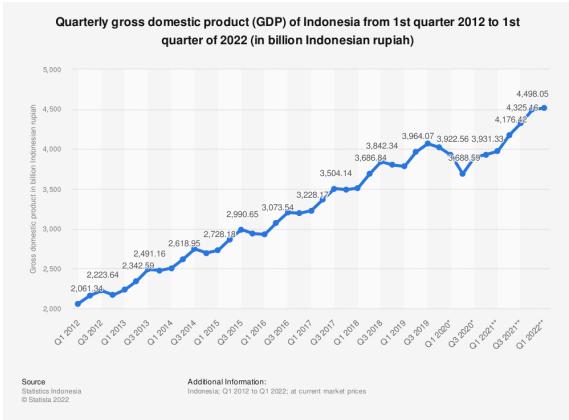
(a) Malaysia's Aggregated Shipments



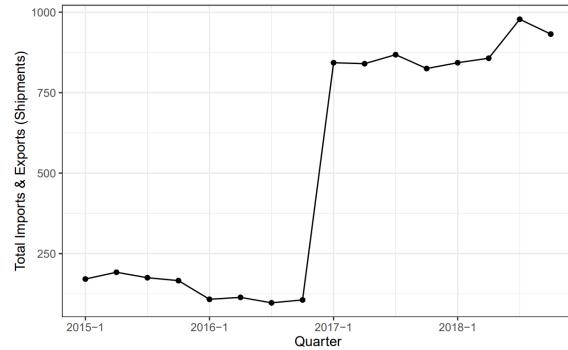
(b) Malaysia's GDP



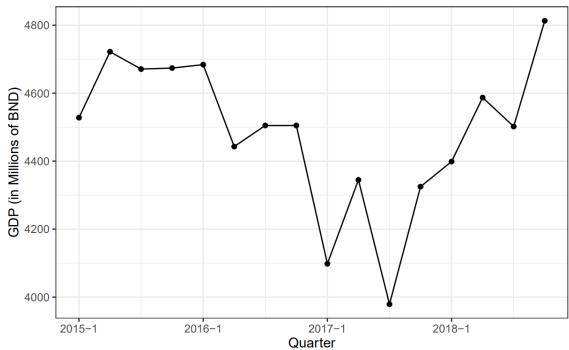
(c) Indonesia's Aggregated Shipments



(d) Indonesia's GDP (Statista)



(e) Brunei's Aggregated Shipments



(f) Brunei's GDP

Figure 8b: Aggregated Shipments and GDP (2015 to 2018)

It can be seen that for most countries, there is a general increase in the GDP over time, whilst the shipments for each country pre-2017 stayed relatively consistent or decreased slightly. Post-2017 however, there seems to be a slight increase over the quarters. Brunei is the only exception to this trend, where its GDP decreased from 2016 to 2017. We suspect this to be due to the oil price collapse in 2016, which largely affected the Brunei economy Stocker, Baffles, and Vorisek (2018). As a small, oil-rich country, Brunei is heavily dependent on the export of oil and natural gas Fox (2022). Changes in oil prices can therefore have a significant impact on the country's GDP.

3.3 Correlation of Air Cargo Data with Macroeconomic Data

As our dataset is too small to conduct meaningful forecasting and regression analysis, we decided to proceed with correlation analysis with the given 16 data points.

3.3.1 Pearson's Correlation Coefficient

The Pearson's Correlation Coefficient is a statistical measure of linear correlation between two sets of data. Mathematically, it is the covariance of the two variables divided by the product of their standard deviations. When applied to a sample with bivariate data of n pairs, the formula is given by

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (1)$$

The correlation coefficient ranges from -1 to 1 . An absolute value of exactly 1 implies that a linear equation describes the relationship between X and Y perfectly, while the sign denotes positive or anti-correlation. Values of r close to zero indicates little to no linear correlation.

Correlation plots (Pair Plots in R) are shown below, between the macroeconomic indicator and the number of shipments of each country, along with the Pearson's correlation value in the upper right matrix. The statistical significance of the correlation value will be expanded on in section 3.3.2. Plots along the diagonal represent the density distribution plot of the number of shipments or GDP correspondingly. These plots are obtained via kernel density estimates to show the probability density function of each variable and are essentially smoothed-out histogram plots. The peaks of the distribution displays where values are concentrated over the interval.

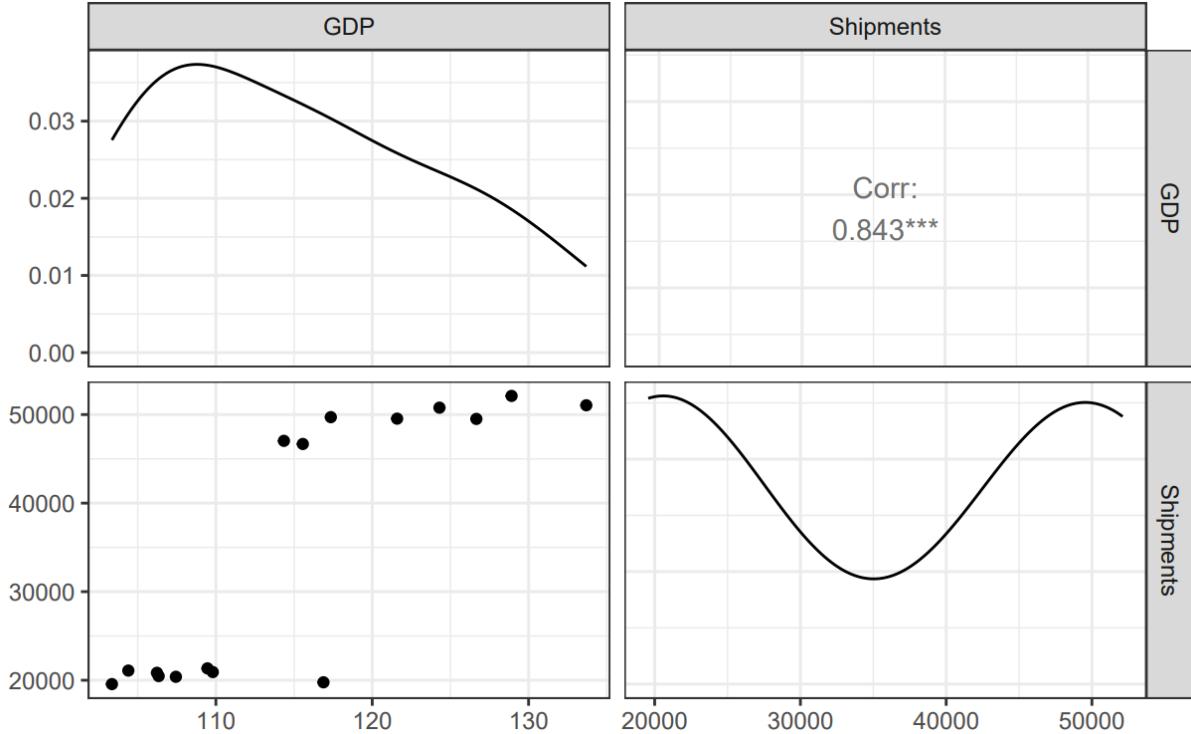


Figure 9: Singapore GDP Correlation Plot

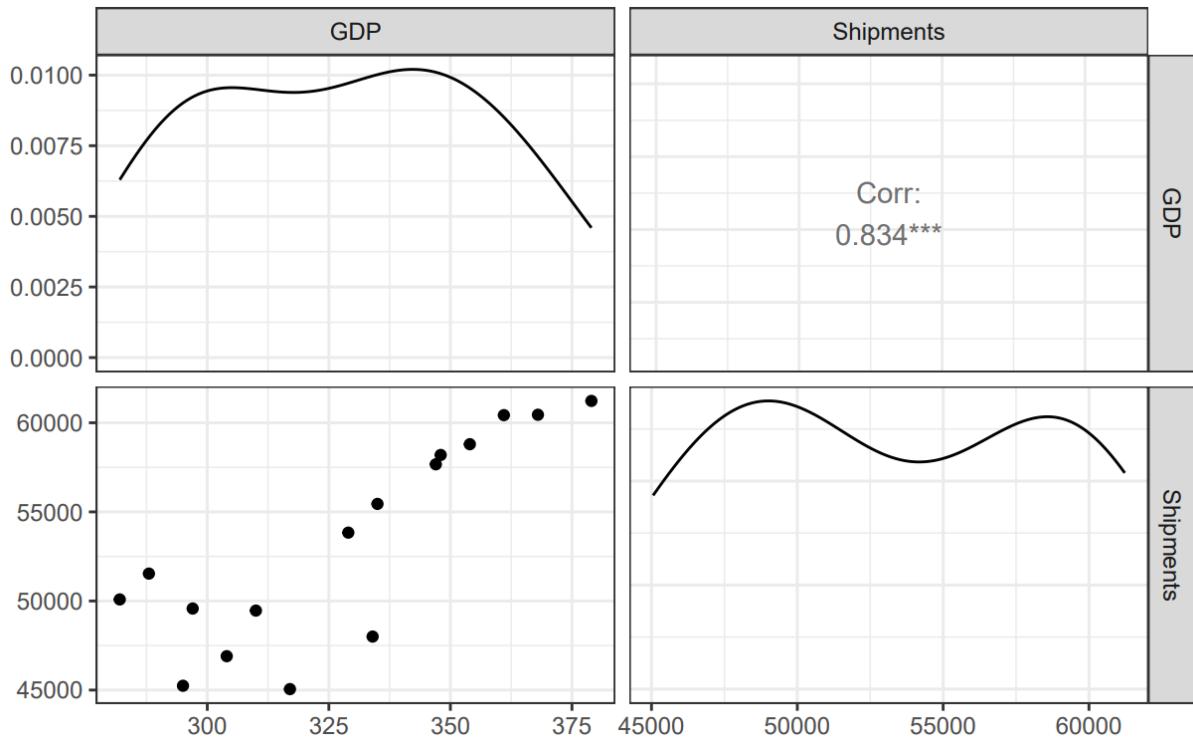


Figure 10: Malaysia GDP Correlation Plot

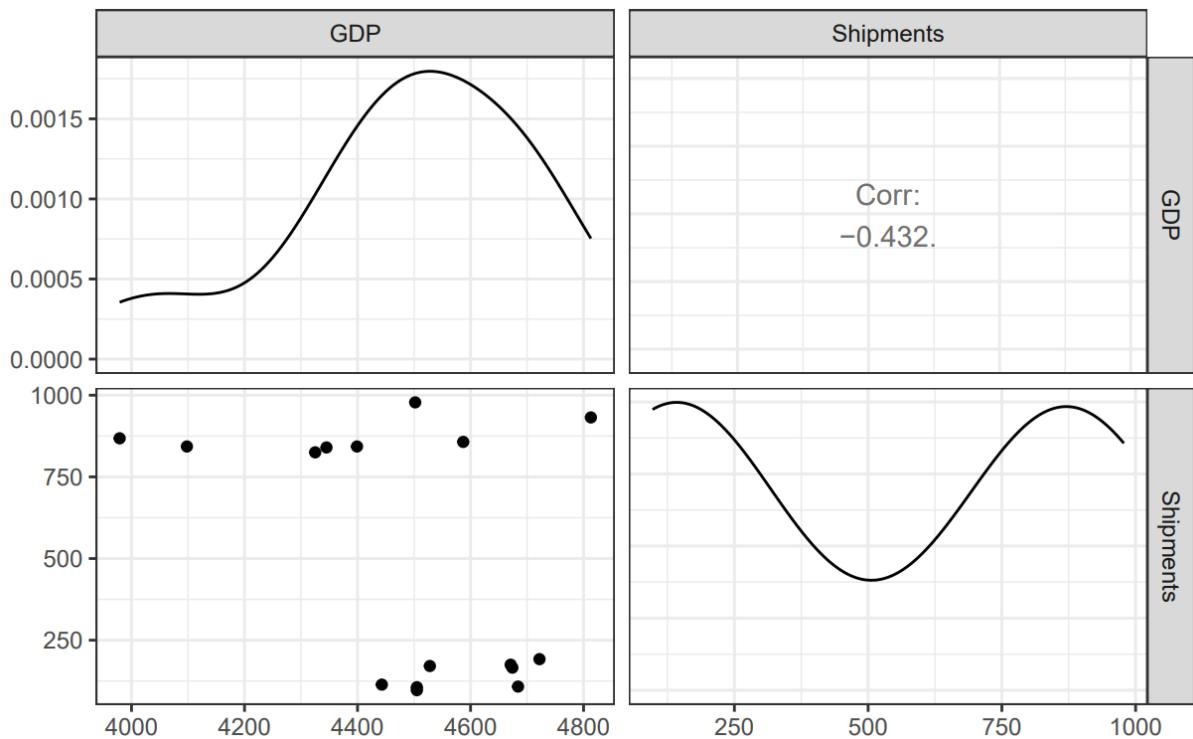


Figure 11: Brunei GDP Correlation Plot

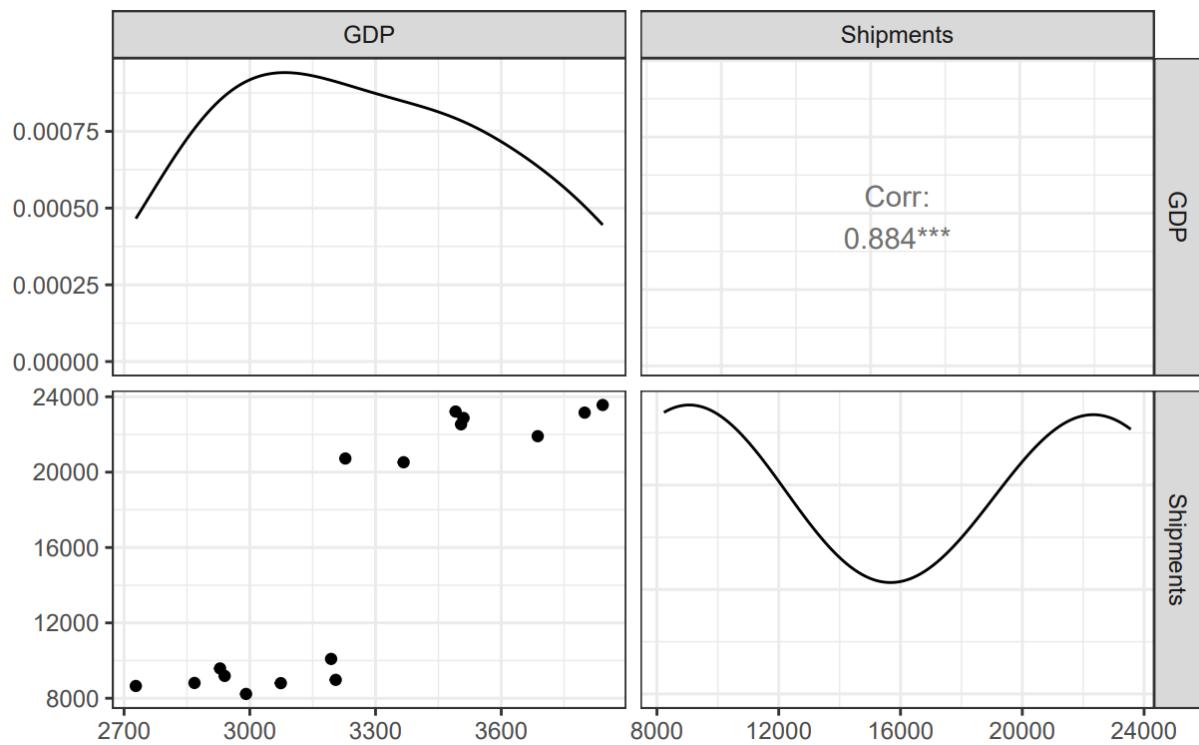


Figure 12: Indonesia GDP Correlation Plot

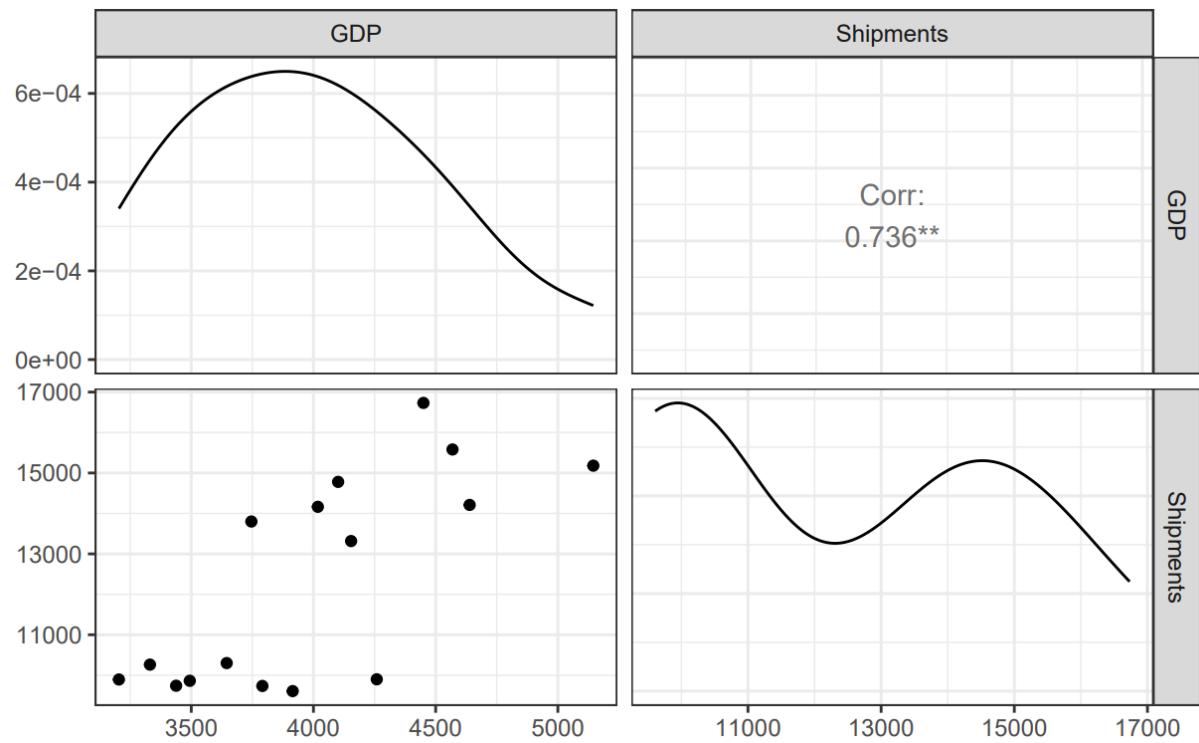


Figure 13: Philippines GDP Correlation Plot

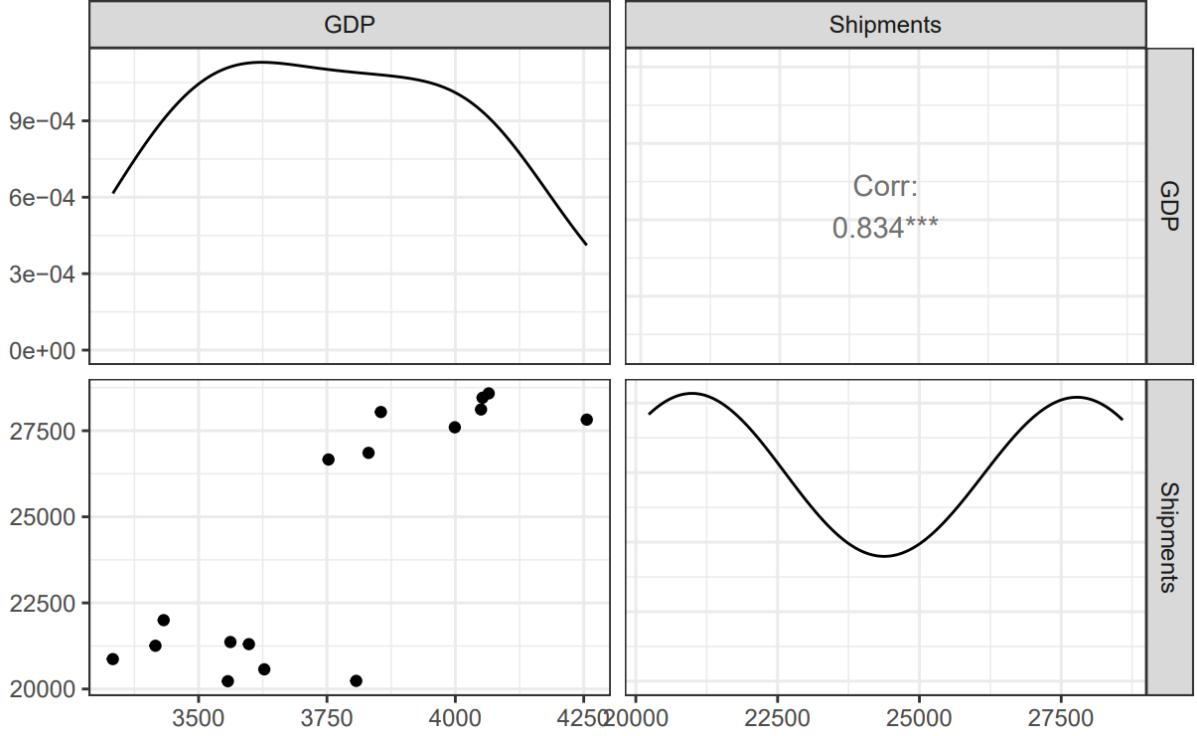


Figure 14: Thailand GDP Correlation Plot

Notable trends include the similar shape of each density distribution of the shipments for all countries, which indicates that most countries tend to either engage in trade with very large or small number of shipments, but little in-between.

Another interesting observation is the *relatively* high correlation values for each country (excluding Brunei), suggesting possibly a correlation between the GDP values of a country and its corresponding number of shipments, reemphasizing the observation found in section 3.2.1.

3.3.2 Hypothesis Testing

For us to determine whether the correlation values are statistically significant, we employed hypothesis testing on the correlation coefficient obtained. To measure the significance of our empirical analyses, we used the *p-value*, which is defined as the probability of obtaining results ‘as extreme’ or ‘more extreme’, under the assumption that the null hypothesis is true. The lower the p-value, the higher the significance of our obtained correlation coefficient. We used R’s in-built correlation test function with the standard significance level $\alpha = 0.05$ to determine the respective p-values of each observation, as shown below. The function returns a list of statistics: The *t* test statistic, degrees of freedom, p-value, and the correlation value.

<i>Country</i>	<i>t</i>	<i>d.o.f</i>	<i>p-value</i>	<i>Correlation Value</i>
Singapore	5.8576	14	4.163×10^{-5}	0.8427438
Malaysia	5.6571	14	5.917×10^{-5}	0.8340666
Brunei	-1.7915	14	0.09485	-0.4318419
Indonesia	7.0863	14	5.453×10^{-6}	0.8843
Philippines	4.0627	14	0.001164	0.7355751
Thailand	5.6467	14	6.027×10^{-5}	0.8336006

We can observe from the statistics obtained that the *p-values* of Singapore, Malaysia, Indonesia, Philippines, and Thailand, are lower than the significance level α . This indicates a strong evidence to reject our null hypothesis, which means that our results obtained for the correlation values are statistically significant. The *p-value* for Brunei however, is greater than α , which indicates a strong evidence for the null hypothesis, that there is no statistical correlation between Brunei’s GDP and the total number of shipments per quarter.

Despite most countries showing correlation between GDP and the number of shipments however, this does not necessarily imply direct causation, as air cargo demand is still influenced by many other factors. It is also important to note that although the *p-value* may be low, this does not immediately indicate that our null hypothesis is false. Rather, it means that the observed result is unlikely to have occurred by chance and warrants further investigation.

4 Conclusions

Throughout the course of this project, we have conducted exploratory data analysis on the provided air cargo dataset, as well as analysis on the various factors that can influence the demand for air cargo within ASEAN.

Through our exploratory geographical data analysis, there are differing levels of demand for air cargo within the ASEAN region, and different countries have different flows. Irrespective of these observations, the air cargo rates (number of shipments and weights) for the region has been increasing over the four-year period (2015 to 2018). When forecasting air cargo movements, domestic demand needs to be taken into consideration alongside international demand (Malaysia being a prime example). Furthermore, seasonal trends should be considered when implementing forecasting models (such as the Seasonal Autoregressive Integrated Moving Average [SARIMA] model), which support seasonal data.

Economic growth is a key factor that can affect the demand for air cargo within ASEAN countries. As economic activity increases, there is typically an increase in the demand for goods, which can similarly lead to an increase in the demand for air cargo to transport those goods. This trend however, generally applies only to ASEAN countries with diversified economies. Countries like Brunei for example, are heavily dependent on oil and gas exports for economic growth. In cases like these, the positive linear correlation between GDP and air cargo demand does not necessarily hold true, suggesting that economic diversity is a significant consideration when forecasting future air cargo demand.

Trade policies, such as tariffs or other barriers to trade, can also affect the demand for air cargo within ASEAN countries. Changes in trade policies can lead to changes in the flow of goods between countries and therefore the demand for air cargo. An important trend to note is that while GDP appears to indicate a general trend, trade policies on the other hand can have a short-term yet significant impact on the demand for air cargo. Trade policies are not particularly easy to forecast numerically, unlike macroeconomic factors such as GDP. As such, close attention should be paid when trade policies are being deliberated, and proper qualitative analysis of such policies can help to infer future trends for air cargo demand. As such, anticipation of various policy changes as a result of regional trends should be taken into account, when implementing models for the forecasting of air cargo demand.

4.1 Further Recommendations

We recommend that additional studies should be conducted to explore more factors that might influence air cargo demand within ASEAN countries, including non-macroeconomic indicators. These factors of significance should also be further tested for reliability before being employed for statistical analysis. Furthermore, unlike common data science pipelines used in the industry, one core limitation of our project involves the manual sourcing of open-source datasets online, which is generally time consuming and prone to human error. Further studies conducted, where possible, should consider the use of techniques such as web-scraping and APIs integrated within their pipeline to extract business insights. Lastly, another limitation of this project was the insufficient data used in conducting statistical analysis, which may affect the reliability of our obtained values. Further studies conducted should consider obtaining more data before embarking on any significant statistical analysis.

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