Why does New Zealand export sawn timber to some markets and logs to others?

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Abstract

New Zealand's annual log harvest has increased rapidly from 2009 to 2017. This increase in harvest has been mostly exported as logs, rather than being processed in New Zealand into sawn timber and other products. Previous industry strategy studies have identified the need for the sawn timber processing sector to be internationally competitive, as it is both an important processing industry, and a supplier of residue to downstream manufacturers.

Studies that compare New Zealand's export log and sawn timber markets have shown that most markets import either sawn timber or logs, but rarely an even mix of both. However, most export logs are processed into sawn timber or plywood at the destination. This research uses econometric analysis to identify the drivers of these differences in market behaviour.

A seven-country export demand panel model was used to analyse the effects that different variables had on demand for sawn timber and logs. Real GDP and real prices were used to explain demand for log and sawn timber imports from New Zealand. Variables for tariffs and tariff wedges (the difference between the tariff for a processed good and the tariff for its raw material), non-tariff barriers (NTB), competition effects, and local resources were used to test their effects on demand.

Tariff wedges and the local harvest of softwood timber were found to have a significant negative effect on demand for sawn timber, while only a softwood harvest was found to negatively affect demand for logs. The presence of tariff wedges was found to be negatively correlated with the sawn timber demand, but did not fully explain the difference in demand between logs and sawn timber. Research suggests that NTBs have a large impact, but they are difficult to measure and therefore analyse in this context. The existence of a softwood timber resource was found to be negatively correlated with demand for softwood imports. There was no significant negative effect found for competition effects.

1. Introduction

1.1 Background

This study analyses the different characteristics of New Zealand's sawn timber export markets and export log markets, with the purpose of understanding why some markets prefer log imports to sawn timber imports from New Zealand.

The forestry industry contributes 1.6% of New Zealand's annual Gross Domestic Product (GDP) and forest product exports were $4.8 billion in 2015 (Forest Owners Association, 2016). Around 78% of the annual harvest ends up being exported, with export logs accounting for over half of the annual harvest (Ministry for Primary Industries, 2017e). Almost all forest products are produced from plantations, the majority of which are *Pinus radiata,* a softwood forest type (Forest Owners Association, 2016). The forests are grown on a 25-30 year rotation, for both structural and appearance grade wood regimes, and pulp wood (Edgar, Lee, & Quinn, 1992).

The annual harvest from plantation forestry has increased rapidly over the past 8 years. It increased by nearly 60% in just 5 years from 2009 to 2014 from 18.9 million m^3 to 30.3 million m^3 (Ministry for Primary Industries, 2017b). This is forecast to increase further in coming years, potentially reaching 32-35 million m^3 between 2020 and 2030 (Ministry for Primary Industries, 2010).

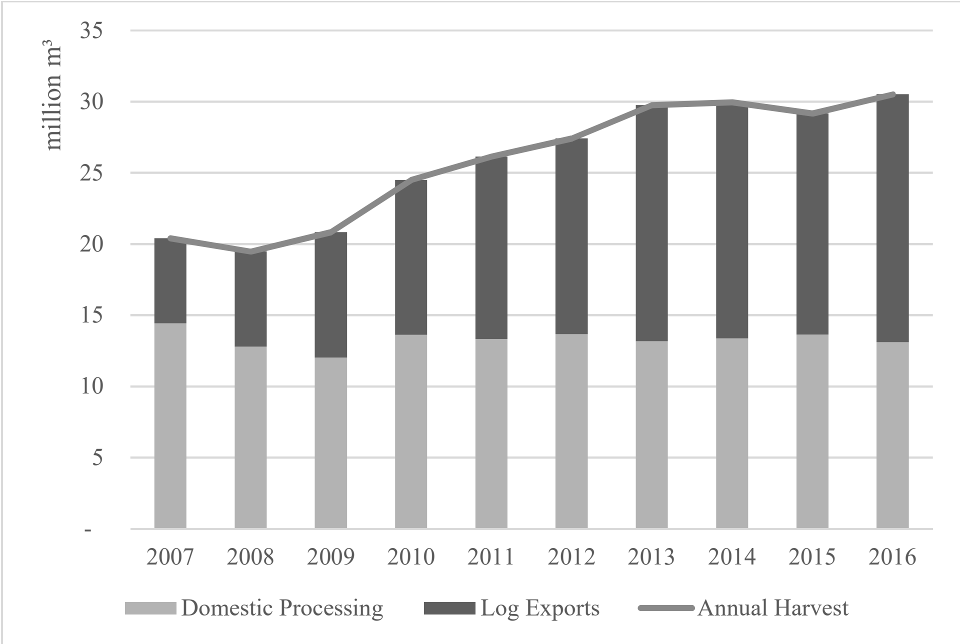


Figure 1 Use of log production from annual harvest 2007-2016 (Ministry for Primary Industries, 2017b)

The Woodco Strategic Action Plan of 2012 outlined two potential paths for the forestry sector to utilise an increasing harvest:

- the current path of increased reliance on log exports and a declining solid wood processing sector that constrains residue availability, or
- alternative paths with increasing domestic processing sector, diverse export markets and high-value wood-based manufacturing streams.

The report gave estimated export expectations in 2022 of $6.1 billion for the current path, and $12 billion for the alternative path (Woodco, 2012). The alternative path would bring the benefit of increasing forestry's ability to be a contributor to New Zealand's economic and environmental well-being (Woodco, 2012).

Currently over half of the annual harvest is exported in log form, without further processing (Ministry for Primary Industries, 2015). This has increased as the annual harvest has grown, up from 30% in 2008 (Ministry for Primary Industries, 2015). Without an increase in the level of domestic processing, New Zealand will continue to travel down the ‘current path’ outlined by Woodco, and the ‘alternative path’ will be a lost opportunity.

1.2 Domestic Policy Environment

New Zealand is an open economy where the primary industries contribute over 10% of GDP, and over 60% of economic activity comes from trade (New Zealand Treasury, 2016). New Zealand, in general, operates on free market principles and is committed to a reduction of trade barriers domestically and abroad (New Zealand Treasury, 2016). The Government takes a ‘hands-off’ approach to business and there are low levels of subsidies (New Zealand Treasury, 2016). New Zealand was ranked first by the World Bank (2017) for ease of doing business, where it ranked highly in ease of paying tax, dealing with construction permits and getting credit. The World Bank report also mentioned the government’s “Business Growth Agenda” (BGA) as having a positive impact on the ease of business. The BGA seeks to lower barriers to doing business in New Zealand. New Zealand also ranks as having the lowest corruption in the Corruption Perception Index (Transparency International, 2017).

2. Rationale for Research

2.1 Rationale

Industry strategies and studies in New Zealand have highlighted the importance of the domestic processing sector (Edgar et al., 1992; Woodco, 2012). Although recent studies have investigated the profitability of domestic processing (Hall, 2016; Jack, Hall, Goodison, & Barry, 2013) in New Zealand, studies of markets have been less common. Evison (2016) stated that in order for the sector to reach its full economic potential it would need:

- a shared view of the processes and products that would increase export receipts;
- a shared view of the significant barriers to achieving the strategy and action to mitigate these barriers; and
- engagement by the sector with government.

The objective of this study is to quantify the demand for New Zealand's sawn timber, to answer the question of why we export logs to some markets and sawn timber to others. This study will make a contribution to providing a view of the barriers in export markets. The study expands on previous work into econometric analysis of New Zealand's wood product trade by using panel data to estimate demand parameters, in econometric analysis. This study also brings a more specific approach to the analysis of tariffs and non-tariff barriers. Previous international studies have used a computable general equilibrium model approach to study the effects of tariffs and non-tariff barriers to trade (Sun, Bogdanski, Stennes, & van Kooten, 2010; Zhu, Buongiorno, & Brooks, 2000). However, the model specification is usually not detailed enough to quantify the effects of New Zealand exports at a product level.

2.2 Scope of Project

The scope of this project is limited to studying the demand for industrial sawn timber and logs. This constitutes the Harmoised System (HS) codes with the general description of –

sawn or chipped lengthwise, sliced or peeled, thicker than 6mm, (not planed or sanded or end-jointed). Although some logs are exported for use in higher value end uses, the majority are used in industrial end uses such as construction or packaging lumber. The opportunity for sawn timber exporters to increase output is in the same end uses as the industrial logs that are exported, and so exports of structural and appearance grade sawn timber are not included.

The study is focussed on demand models. As the focus of the project is in the differences between the export markets for logs and sawn timber, the focus is on the importing markets.

2.3 Research Questions

The research questions that this study will attempt to answer are:

1) Why does New Zealand export logs to some markets and sawn timber to others?
2) What are the characteristics of these markets that lead to this behaviour?
3) What effect would the removal of tariff barriers have on this behaviour?

2.4 Thesis Outline

This analysis uses global trade and economic data to show the difference between demand for New Zealand's export sawn timber and export logs. The study uses two econometric demand models, for sawn timber and for logs, to characterise the differences, and explain why New Zealand exports the two products to very different markets.

- Chapter 3 provides a review of the existing literature about this subject.
- Chapter 4 outlines the methodological approach taken and the econometric models that are used in the study.
- Chapter 5 goes through the results of the econometric analysis.

- Chapter 6 discusses the results and outlines the implications of the results for the processing sector in New Zealand, and the implications for policy makers in New Zealand.

3. Literature Review

3.1 The Solid Wood Processing Sector

The solid wood processing sector, including sawn timber processing, has faced challenging conditions (Woodco, 2012). The importance of a successful solid wood processing sector was highlighted in previous industry strategy studies (Edgar et al., 1992). New Zealand planted forests are grown on a 25-30 year rotation with structural, appearance and pulp wood produced jointly. Without a strong and competitive wood processing sector, there are fewer options for solid wood products other than log exports. There are also fewer opportunities for downstream processors that rely on the residues produced as a by-product of solid wood processing (Edgar et al., 1992; Jack, Hall, et al., 2013; Woodco, 2012).

Sawn timber production has been relatively stable in recent years, despite the increasing harvest. In 2003, 4.4 million m^3 of sawn timber was produced, but this had shrunk to 4.1 million m^3 by 2016 (Ministry for Primary Industries, 2017d). Domestic sawn timber use is stable, with a steady market share in the residential construction market (Woodco, 2012). This means that the growth opportunities are in exports, mostly to Asian nations (Woodco, 2012).

Many smaller saw mills have closed in recent years, and there is a trend towards a greater share of production coming from larger scale mills. The Woodscape study of 2013 (Jack, Hall, et al., 2013) identified that saw mills in New Zealand lack economies of scale, and that many current mills were likely to be uncompetitive. The study showed that some configurations of mills would be profitable, depending on the size and location. However, the study assumed that all product would be consumed in export markets, and there was enough demand to meet 100% of the production (Jack, Barry, Hall, & Goodison, 2013). It also found that the profitability of sawn timber production was highly sensitive to changing commodity prices (Jack, Barry, et al., 2013).

3.2 Sawn Timber Markets

Exports of sawn timber were stable between 2004-2010, despite the increasing harvest (Ministry for Primary Industries, 2017c). Since 2011, however, exports declined. Overall production has remained constant, but domestic consumption increased in recent years (Ministry for Primary Industries, 2017d).

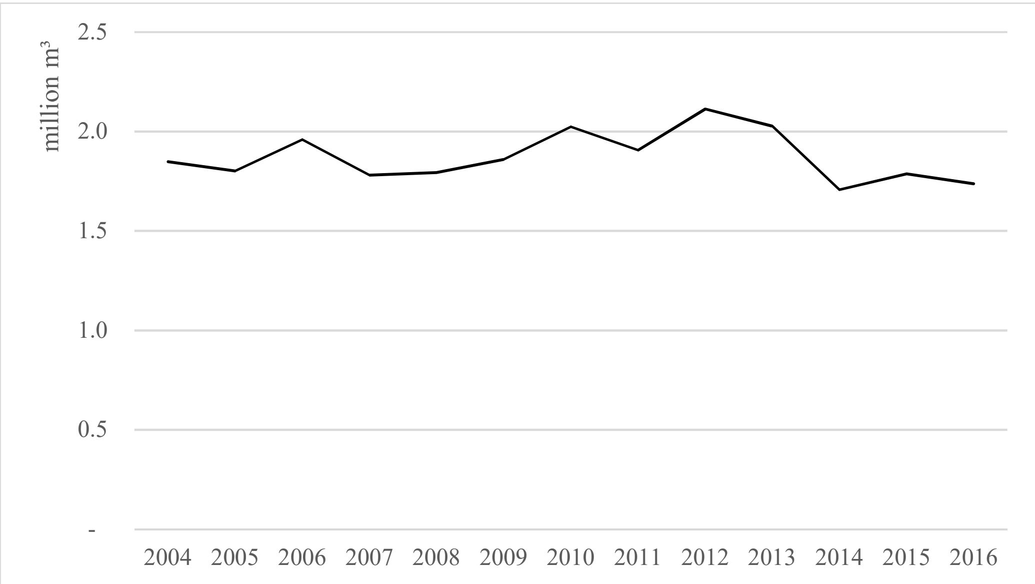


Figure 2 Sawn timber exports 2004-2016 (Ministry for Primary Industries, 2017c)

During this time the markets that products are exported to have changed. In 2004, 45% of export sawn timber went to USA and Australia, with 11% going to China. By 2016 China was the largest market, taking 22% of exports, while USA and Australia combined made up 21% of exports (Ministry for Primary Industries, 2017c). Although the total volume going to

North Asian countries stayed level, the volume to China has increased, and the volume to Japan has decreased (Ministry for Primary Industries, 2017c).

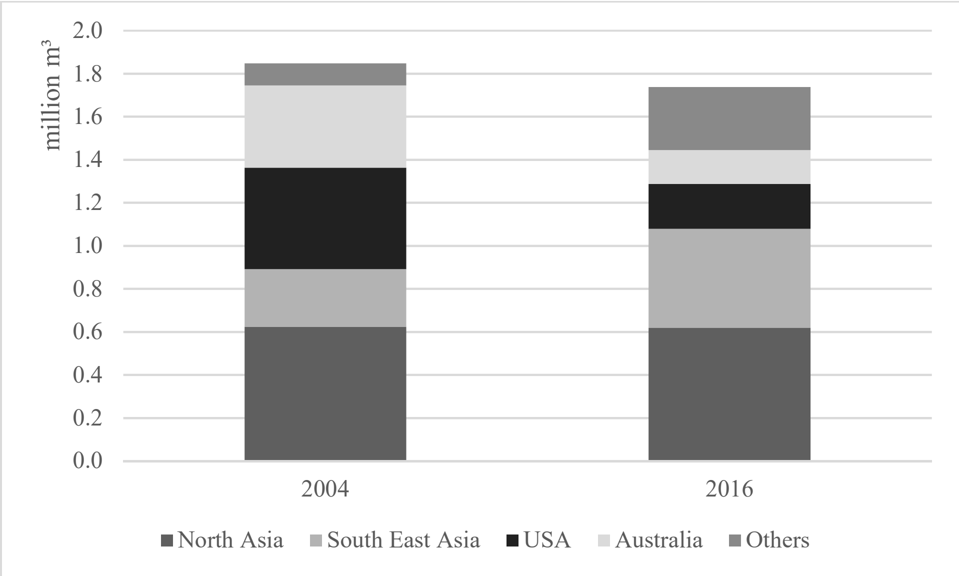


Figure 3 Sawn timber exports by destination 2004, 2016 (Ministry for Primary Industries, 2017c)

Some markets are differentiated by the products that they purchase. In particular many of the Asian markets import industrial timber from New Zealand, while USA and Australia import more appearance and structural grade timber (Jack, Barry, et al., 2013). The different Harmonised System (HS) codes used by exporters show this distinction. The HS codes do not differentiate by end use, rather, by the level of processing, which means assumptions can be made about the type of product that the HS codes represent, but they may not always be accurate. The majority of exports are assumed to be industrial grade, while structural and appearance grade timbers make up about a third of the sawn timber exported (Statistics New Zealand, 2016).

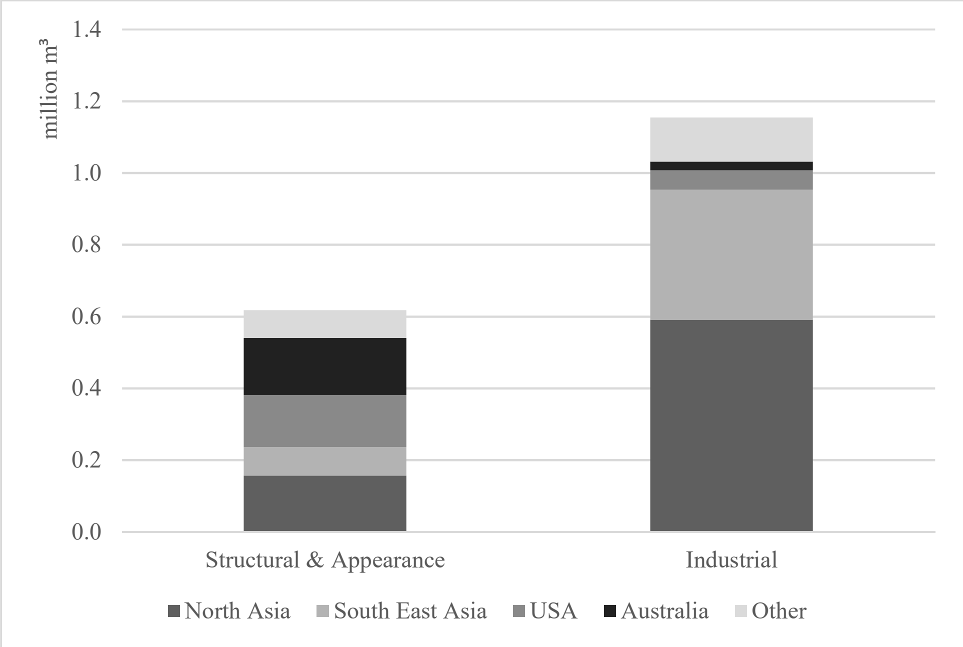


Figure 4 Sawn timber exports by product and destination (Statistics New Zealand, 2016)

Most timber exported can be grouped into a heading for industrial timber. This constitutes the HS codes with the general description of – sawn or chipped lengthwise, sliced or peeled, thicker than 6mm, (not planed or sanded or end-jointed):

- 4407105900 (Douglas fir)
- 4407109913 (Radiata Pine)
- 4407109915 (Radiata Pine)
- 4407109919 (Other Coniferous)

The appearance and structural sawn timber group consists of HS codes containing any of – end-jointed, planed, square-dressed, or structural, in the description:

- 4407104101 (Douglas fir)
- 4407104109 (Douglas fir)

- 4407104900 (Douglas fir)
- 4407108121 (Radiata Pine)
- 4407108125 (Radiata Pine)
- 4407108129 (Other wood)
- 4407108131 (Radiata Pine)
- 4407108135 (Radiata Pine)
- 4407108139 (Other wood)
- 4407108901 (Other coniferous)
- 4407108905 (Other coniferous)

3.3 Global Markets

New Zealand is a relatively small player in international sawn timber markets, but is a much more significant log supplier. In 2015, New Zealand was the eleventh largest sawn timber exporter, and the ninth largest softwood sawn timber exporter (FAO, 2017). For roundwood (logs) however, New Zealand was the second largest global supplier by volume, behind Russia, and the largest softwood roundwood exporter in 2015 (FAO, 2017). New Zealand supplies just over 30% of global log trade, most of which is exported to China (FAO, 2017).

Softwood volume traded is much larger than hardwood for both logs and sawn timber. According to FAO (2017) softwood sawn timber trade in 2015 was 90 million m^3 while hardwood trade was just 12 million m^3. Logs were traded more than sawn timber for hardwoods, with 29 million m^3 traded in 2015, while it was the opposite for softwoods, with 49 million m^3 traded (FAO, 2017).

The largest softwood suppliers are from Pacific North West and Europe, while the largest hardwood sawn timber suppliers (excluding USA) are from South East Asia (FAO, 2017). Canada is the largest player when it comes to softwood sawn timber trade, making up 30% of global supply (FAO, 2017). Russia also supplies 18% of softwood sawn timber, while New Zealand makes up just 2.5% of trade (FAO, 2017).

China is the dominant softwood log importer, importing 24% of global export supply (FAO, 2017). USA is by far the largest softwood sawn timber importer, though this trade is mostly imports from Canada (FAO, 2017). Russia and Canada dominate supply of sawn timber in China, New Zealand’s largest market for sawn timber and logs. Together these two supply about 82% of China’s softwood sawn timber imports (FAO, 2017). This is the case in most North Asian markets, including Japan and South Korea, while in South East Asian markets Canada and Russia are not major suppliers (FAO, 2017). These North Asian markets tend to be where New Zealand exports more logs than sawn timber, while in the South East Asian markets New Zealand tends to supply more sawn timber than logs (FAO, 2017).

3.4 Logs vs. Sawn Timber

A significant volume of the logs that are exported are processed into sawn timber in their destinations (Jack, Barry, et al., 2013; Manley & Evison, 2016). Manley and Evison (2016) estimate that 68% of export logs to China are sawn into timber, mostly for construction lumber, the rest is peeled for plywood. There were similar estimates for other log export countries. This means that the market is for the end use of sawn timber, which could be either sent as logs and processed, or processed and sent as sawn timber. However, export markets are often split between logs or sawn timber. Data from Ministry for Primary Industries (2017c) shows that in 2015 the top three log export markets took 95% of the product exported, but the top 21 sawn timber export countries took 95% of the sawn timber exported. The major importing countries are not the same either, the top three export destinations for logs are Northern Asian nations, while only around a half of the industrial timber exported is sent to Northern Asian nations (Statistics New Zealand, 2016). This means that there is no guarantee that sawn timber would be exported to the same country as logs were exported to if log processing was increased.

The sawn timber and log markets have had very different fates in the past 10 years. There have been significant increases in log exports, compared to sawn timber exports (Ministry for Primary Industries, 2017a). The differences in the trade of the different products may have occurred for many reasons, including market differences and a lack of capacity to supply sawn timber. This study will investigate the differences between these markets and why sawn timber and log exporters favour different markets. This will help to explain why export log volumes have increased significantly and sawn timber exports have not. The following sections introduce some of the economic drivers that are expected to be influencing the difference between sawn timber and log markets.

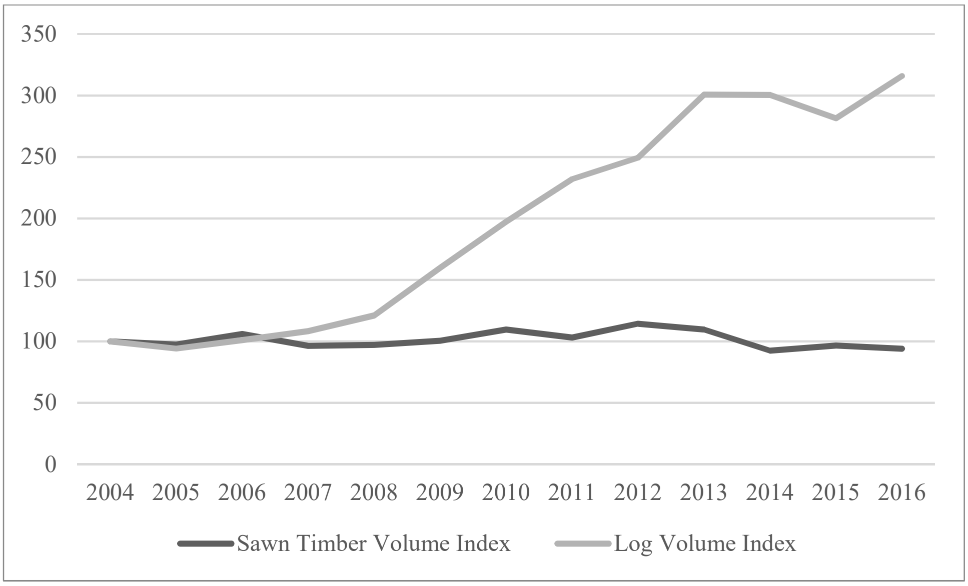


Figure 5 Sawn Timber and Log export volume indices (2004=100) (Ministry for Primary Industries, 2017a; Statistics New Zealand, 2017)

3.5 Tariffs

Tariffs are taxes that are levied at the border on imported goods, usually to protect a domestic industry from imported competition (Reinert, Rajan, Glass, & Davis, 2009) Tariffs have distortionary effects on trade, and in the case of a country without market power, free trade is considered the best policy (Reinert et al., 2009). Developed countries have been steadily reducing tariffs since the end of World War 2, and developing nations have also substantially reduced tariffs since the 1980s (WTO, 2017b). In 1947 the General Agreement on Tariffs and Trade (GATT) was signed by 23 nations with the purpose of reducing or eliminating trade barriers (WTO, 1994). This was signed by 123 nations in Marrakesh in 1994, where the World Trade Organisation was formed (WTO, 1994).

If tariffs are applied to the finished good, then competition for domestic producers is lowered, however, if the raw imported good has a tariff applied, then the price for domestic processors is raised (Reinert et al., 2009). Many countries impose higher tariffs on finished goods than the raw product, which is an approach known as tariff escalation, where tariffs increase, or escalate, with the degree of processing (Reinert et al., 2009). Tariff escalation can cause increased processing in importing countries and reduced processing in exporting countries (Reinert et al., 2009).

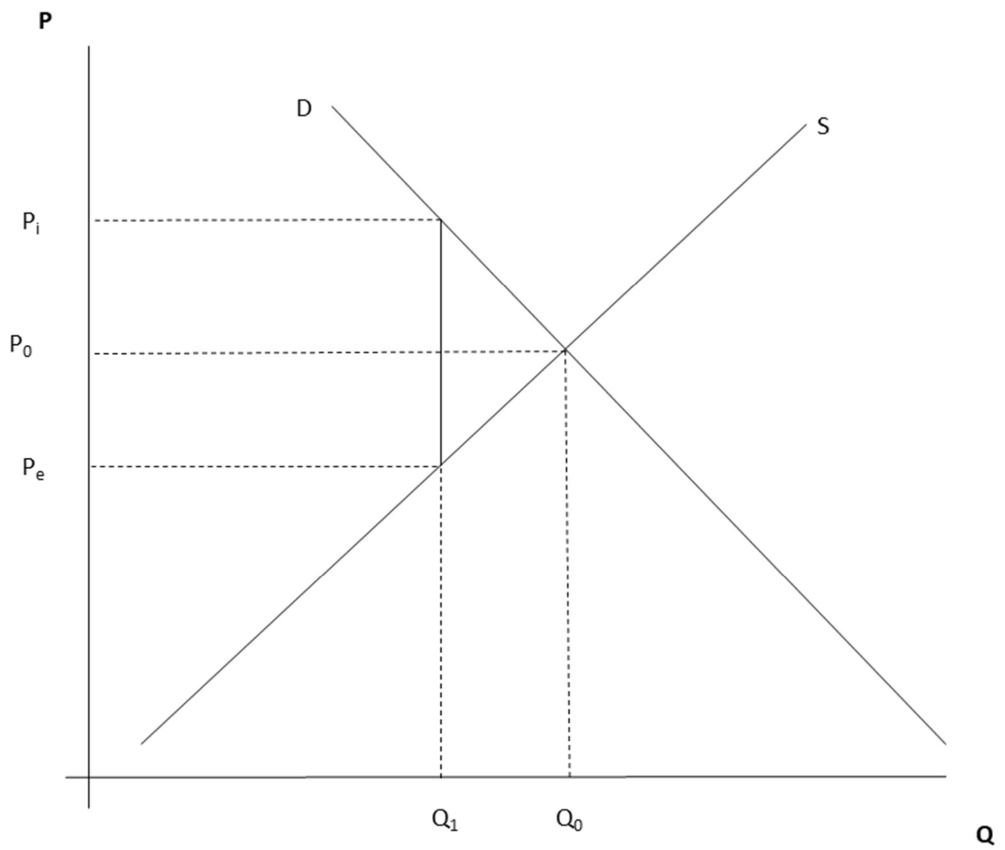


Figure 6 Graphical representation of the price and quantity effect of import tariffs (Gans, King, & Mankiw, 2012)

In Figure 6 above the effect of an import tariff on the supply and demand of an import product is shown. The tariff is represented by the vertical distance between the supply and demand curves from P_i to P_e. When it is imposed, the effective price faced by the importer increases from P_0 to P_i and the effective price received by the exporter falls from P_0 to P_e. This results in a fall in the quantity exported from Q_0 to Q_1. Consumer and producer surplus both fall, and there is a deadweight loss of taxation.

New Zealand faces tariffs and tariff escalation in many of its export markets. New Zealand as a small exporting nation is dependent on trade, 60% of New Zealand's total economic activity is made up by international trade (Ministry of Foreign Affairs and Trade, 2017). New Zealand actively pursues Free Trade Agreements (FTA), and is a member of the World Trade Organisation (WTO), the Organisation for Economic Cooperation and Development (OECD), and Asia Pacific Economic Cooperation (APEC) (Ministry of Foreign Affairs and Trade, 2017). New Zealand has successfully concluded FTAs with 16 WTO members;

- China
- Australia
- South Korea
- Hong Kong
- Myanmar
- Laos
- Thailand
- Viet Nam
- The Philippines
- Brunei
- Malaysia
- Singapore
- Indonesia
- Cambodia
- Chile
- Taiwan

FTAs usually result in tariffs being removed or lowered. They are not all encompassing, however, as some tariffs remain on certain products, have quotas introduced on the lower tariff rates, or have long phase-out periods.

3.6 Non-tariff barriers

Non-tariff barriers (NTB) or non-tariff measures (NTM) distort international trade flows through barriers such as policies, rules, regulation and practices other than tariffs (Reinert et al., 2009). Knowledge of NTBs is limited, due to a lack of data or poor quality of the data available (OECD, 2005). NTBs can take four general forms:

1. tax-like non-tariff measures,
2. cost-increasing measures,
3. quantitative trade measures, or
4. government procurement policies.

Many NTBs are imposed for reasons other than trade protection (Maplesden & Horgan, 2016). In these cases it could be health or environmental standards, or for traceability, but the overall effect is a barrier to trade (Maplesden & Horgan, 2016). OECD (2005) surveyed exporters and governments on their concerns about market access. They found that technical measures that increased costs were the most common NTB mentioned, followed by internal taxes or charges, customs rules and procedures and competition-related restriction on market access. Often NTBs are used to achieve a similar effect as tariff escalation, where the level of protection is higher for processed products than for the raw material (Mohan, Khorana, & Choudhury, 2013). Maplesden and Horgan (2016) studied the effect of NTBs on New

Zealand's forestry exports in different markets. Some of the NTBs that they found for solid wood exports in different markets were:

- China
    - Value added tax (VAT) differential between logs and sawn timber
    - Corruption, and officials charging incorrect tariffs
    - Inconsistent application of phytosanitary rules
    - Regional subsidies to local processors
    - State owned enterprises having monopolistic buying practices
    - Inability to find alternatives to methyl bromide fumigation, which means more expensive alternatives may have to be used
- India
    - Bureaucratic business practices and corruption at ports, where logs can be given preferential treatment to sawn timber
    - Requirement for methyl bromide application for logs, when it may not be necessary
    - Legislation protecting small sawn timber processors
- Other markets
    - Building and fire codes that favour the products of competing suppliers
    - Overly bureaucratic customs and entry paperwork in USA
    - High corruption in South East Asian nations

Some of these examples can highlight the difficulties in quantifying the effect of NTBs. The legislation protecting small sawn timber processors in India restricts the technology that is used. As a result, the New Zealand product used is often low quality sawn timber processed in India (Maplesden & Horgan, 2016). This has a negative reputational impact for New Zealand products, the effect of which would be nearly impossible to quantify.

Attempts have been made to try to quantify the effects of NTBs. Kee, Nicita, and Olarreaga (2009) used a gravity model to estimate the expected level of trade for different products to different markets. This was compared to the actual levels of trade, and using price elasticities of demand from other studies, they were able to estimate a price effect as an ad-valorem equivalent (AVE).

3.7 Competition

Global

Global competition for sawn timber could have a significant effect on New Zealand's sawn timber exports. As mentioned in *Global Markets, Section 3.3* New Zealand tends to export more logs than sawn timber to Northern Asian markets where Russia and Canada are large suppliers of sawn timber (FAO, 2017), although much of Russia's sawn timber supply is suspected to be 'squared logs' which other exporters might count as logs (Taylor, 2016). Numerous studies of New Zealand's forestry export industry in the past have cited global competition as being a barrier to New Zealand's sawn timber export industry. Edgar et al. (1992) mentioned that compared with Canada, the US South, Chile, and Sweden, New Zealand was at a significant disadvantage in terms of the total cost of manufacture and delivery. A Wood Processing Competitiveness Index used by Brown and Ortiz (2001) showed that New Zealand was less competitive than the US and Sweden (although more competitive that Russia). Revealed comparative advantage studies (Ballingall & Briggs, 2002; Gonuguntia, 2007) have highlighted that competition in wood products is strongest with Canada and Russia.

Maplesden and Horgan (2016) make specific mention of Canadian export policies being a type of non-tariff barrier for New Zealand sawn timber exports, by acting as an incentive for Canadian producers that effectively puts New Zealand producers at a disadvantage. The Provincial and Federal government policies that restrict log exports effectively lower the price paid by domestic log processors (Maplesden & Horgan, 2016). There are also a number of policies that support the domestic processing of logs through export promotion schemes, and research and development for processing (Maplesden & Horgan, 2016). These policies could be aiding the competitive advantage for New Zealand's sawn timber competitors.

Russia has also restricted log exports by implementing an export tax in 2007 (Gaston & Chang, 2016). This tariff limited the export of logs and pushed production towards sawn timber exports (Gaston & Chang, 2016). This could also provide a competitive advantage for Russian exporters of sawn timber.

When import markets, such as in China, cannot produce sawn timber for lower than the delivered cost of imports, they will produce less sawn timber and import more. Policies such as those in Canada and Russia will lead to a lower delivered cost for sawn timber imports than the in-market production cost for importers through lowering the log input cost for domestic mills in Canada and Russia, or raising it in the import market.

Domestic

In export markets, New Zealand sawn timber exporters face competition from other suppliers, and from the domestic processors in the importing markets. A common hypothesis put forward is that the major export markets for New Zealand sawn timber have lower incomes than New Zealand, and as such New Zealand processors need to overcome the disadvantage in labour costs (Brown & Ortiz, 2001).

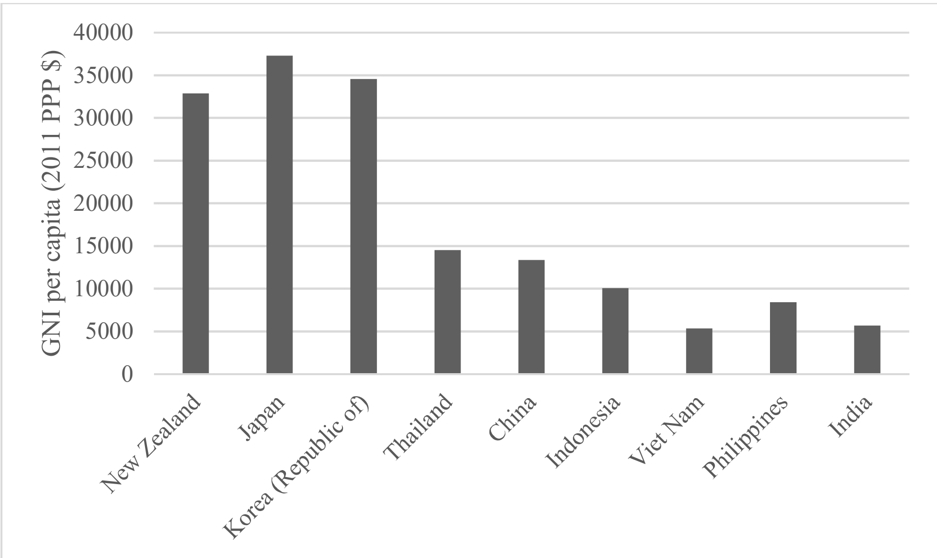


Figure 7 Major industrial timber export markets Gross National Income per capita 2015 (United Nations, 2016)

Labour costs are lowered in more automated mills, so New Zealand will need to automate out the difference (Brown & Ortiz, 2001). This hypothesis will be tested in this study by comparing labour costs across the different countries analysed with the Human Development Index. The scale of a mill is also important to overcome these differences, and New Zealand mills are weighted towards smaller scales (Jack, Hall, et al., 2013). Automation has increased significantly in New Zealand through newer and larger mills being established. As a result, there has been consolidation towards the larger and more automated mills. It has been shown that smaller mills are less competitive, suggesting the trend will continue (Hall, 2016).

3.8 Local Resources

The local resource could have an influence on the level and type of processing. This study will test whether areas with a softwood resource are more likely to import softwood logs for processing, than import softwood sawn timber.

Most of the areas to which New Zealand exports have a local harvest containing hardwoods (FAO, 2016). Some of the Northern Asian countries also have softwood resources, but the South East Asian countries are dominated by hardwoods (FAO, 2016). Of New Zealand's largest industrial sawn timber and log markets, only South Korea and Japan have a larger softwood harvest than hardwood (FAO, 2016).

4. Data & Methods

4.1 Data

The data used have been gathered from several different sources. The most important sources have been the Food and Agriculture Organisation of the United Nations (FAO), and the World Bank. There were data quality issues with some of the sources of data, and these are addressed further in this section.

4.1.1 Trade Data

All trade data used in the econometric analysis was from the FAO trade flows database. This data source has linked import-export data for all countries from 1997-2014. The limited availability of this data limited the analysis to these years. Statistics New Zealand data had a much greater granularity of export products. This allowed industrial sawn timber to be separated out from other sawn timber products, whereas the FAO trade flows database only separates out coniferous and non-coniferous (softwood and hardwood). As import data was needed for the demand model, Statistics New Zealand data could not be used, which meant a loss of granularity at the product level. To mitigate this, only countries that imported mostly industrial grade products were included in the analysis and it was assumed that the weighted average prices would still be representative of an industrial grade product, despite the small amounts of structural and appearance grades that were exported there. Countries that imported mostly structural or appearance grade products were excluded. This meant that USA and Australia were excluded. It was also found that while the Netherlands imported mostly an industrial grade product according the HS codes used, the price was more than double that of the same product being exported to other countries, which suggested there was a niche product being exported, and on this basis Netherlands was also excluded from the analysis.

The data from FAO did not cover the entire date range for all countries. For some countries, the data for 1997 was missing. Where this occurred New Zealand's export data from Statistics New Zealand was used in its place.

4.1.2 GDP

Gross Domestic Product (GDP) data was sourced from the World Bank. Real GDP in 2010 prices was used, so inflation rates did not affect the analysis. The local currency was used for each importing market, so changes between years weren't influenced by exchange rate fluctuations. International Monetary Fund (IMF) data was also sourced for the analysis, but it was too volatile to be useful for the analysis. The IMF data appeared to have changes in measurement methods, or something similar. This had been smoothed in the World Bank data. If IMF data was used then there would be big shifts in GDP measured that did not represent big shifts in income, so World Bank data was preferred. This is shown in Figure 8 where the data for Indian GDP is compared between the IMF and World Bank. Unfortunately, the World Bank did not have data for Viet Nam, while the IMF data could not be used in its place as it had a large step change between 2004 and 2005.

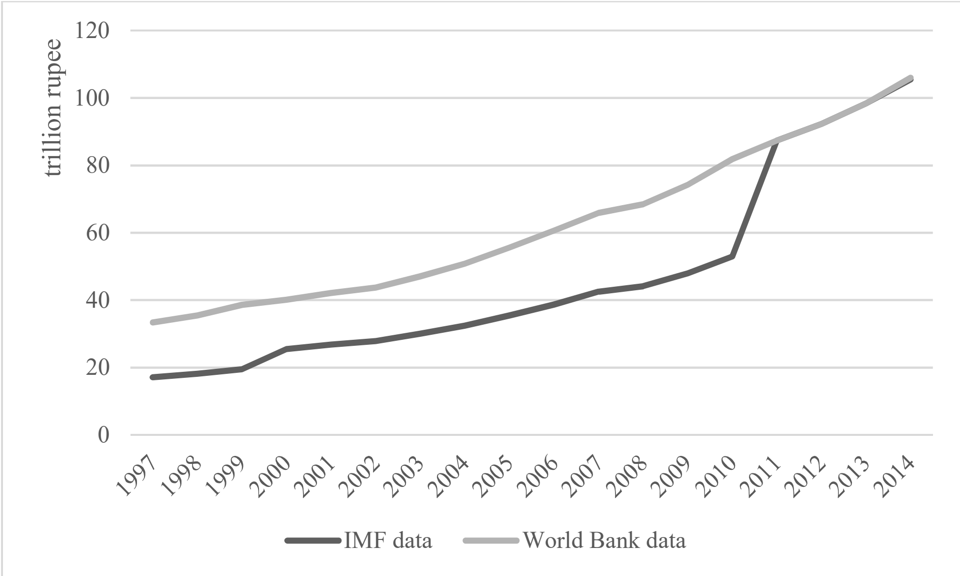


Figure 8 Comparison between IMF and World Bank data for Indian GDP (International Monetary Fund, 2017; World Bank, 2016)

4.1.3 Production

Industrial roundwood production data from FAO was used to indicate the presence of the local resource. The point of measuring the local resource was to identify whether a country will have experience processing that type of timber. The data is split into coniferous and non-coniferous (softwood and hardwood). Data was not particularly precise, and tended to stay level over many years. When New Zealand FAO harvest data was compared to MPI data for harvesting there was much less precision in the New Zealand data. This is acceptable, as the point is whether there is a 'large' or 'small' resource, and year to year fluctuations are of less interest.

4.1.4 Prices

Prices were found as the weighted average from FAO import volume and value data. Dividing the value by the volume gives a per unit value which is used as a proxy for import prices. Although this is the best available option for estimating import prices, it can lead to a lack of precision in measuring prices. As a weighted average of imports is used, changes in the quality or grade mix of products imported could cause a change in trade unit value, without any change in the underlying price.

Imports are measured at the cost insurance freight (CIF) price point, which is the most representative measure of the cost for importers to pay for products. Other measures such as Free on Board (FOB) do not consider the changes in freight costs. While FOB would be a better measure of the product value, it is important to capture the full costs of imports for the demand model being used, as this is the cost that will influence the demand for product in the importing market.

The prices found from FAO are nominal, and in US dollars. This means that in order to find real local currency units, transformations are required. IMF data was used for exchange rates and producer price indices (PPI). PPIs were used as most wood products are used as an input to some other production (such as construction).

Local currencies are preferred as local demand is most likely measured by local prices. Changes in the local currency rate can influence demand, but this would not be picked up if using a common currency, such as US dollars, in the model. Due to using only annual data, transforming by an average exchange rate over the year can cause a big loss in precision. If there was a big drop in exchange rate three quarters of the way through a year, and most imports were in the first part of the year, using an average currency rate will overestimate the actual cost faced by importers. This could be mitigated by analysing currency fluctuations on a much more granular level, perhaps monthly or even daily, and applying a dummy variable to the individual countries in years that have significant within year shifts in exchange rate. This step was not taken as that level of data could not be accessed across all the years available.

In countries where import data was missing from FAO, Statistics New Zealand export data was used in its place. To make it comparable, the data was converted into the local currency, and the average difference between the destination import price and the New Zealand export price was added, in the place of what would normally be freight and insurance costs.

4.1.5 Tariffs

Tariff data was sourced from the World Trade Organisation, Tariff Analysis Online database (WTO, 2017a). This allows for specific tariff rates for each product in the import markets. It also specifies different tariff rates for different countries, so this can take into account where New Zealand has signed a free trade agreement and has a tariff advantage over other countries. The HS codes used are different in each country. They do not necessarily cover all softwoods or hardwoods, where possible, the HS code for ‘pine’ products for logs or sawn timber was used, as the clear majority of New Zealand’s exports are *Pinus radiata.*

In some countries (Thailand, Indonesia) tariff data was not available for 1997, so it was assumed that the same tariff rate from 1998 was applied. In other cases, there was no data available for isolated years, but the preceding and following years had the same tariff rate, so it was assumed to have remained steady for the missing years.

4.1.6 Non-tariff barriers

The United Nations Trade Analysis Information System (TRAINS) database has information on non-tariff barriers (United Nations, 2017). Data is available for each country and product at a level 6 HS code. This shows if there is a core NTB present, and an estimated ad-valorem equivalent (AVE) for the NTBs present. The AVE is estimated in Kee et al. (2009) where a gravity model is used to estimate expected trade. The difference is converted to AVE using an assumed price elasticity rate. This is a general approach used for all products, so ignores where there could be other influences that affect the actual rate of trade not related to NTBs. This means that estimates could be biased.

Data is also gathered for NTBs from Maplesden and Horgan (2016). This describes particular NTBs in some countries that could be represented by a dummy variable in the model. It also identifies the value-added tax (VAT) difference between sawn timber and logs in China, that is effectively an NTB. As the Maplesden and Horgan (2016) study does not cover all of the countries that I am using in my demand model, it is inappropriate to use in panel models as the data would be inconsistent across countries.

Other NTB data includes data on corruption. The best uniform source of data across all countries for corruption is the Corruption Perception Index (CPI) produced by Transparency International. This is based on surveys in different countries, and applies a rating to each country in different years.

4.1.7 Labour Costs

Labour cost data was not generally available for the time periods covered in the model, the Human Development Index (HDI) from the United Nations was used as a proxy. The Gross National Income (GNI) per capita is part of the overall index and is also a good proxy for wage rates. However, including the full index which also takes into account life expectancy at birth, and years of schooling, could potentially give a better picture of labour costs. Less developed countries also tend to have lower worker protections and health and safety regulations, so these costs are also lower.

4.1.8 Summary Tables of Data

Table 1 Coverage of data used

Countries	Time Period
China, India, Indonesia, Japan, Philippines, South Korea, Thailand	1997-2014

Table 2 Summary of data used

Data	Notes/Units	Source
Gross Domestic Product	- Local Currency Unit - 2010 constant prices	World Bank
Import Volumes	- m^3	FAO
Import Value	- Cost, insurance, freight	FAO
Production	- Coniferous - Non-coniferous	FAO
Exchange Rates	- US dollar : Local currency	IMF
Producer Price Index	- 2010 base	IMF
Tariffs	- Import sawn timber and logs tariff lines	WTO
Non-tariff barriers	- AVEs - Presence (Y/N) - Corruption Perception Index	UN TRAINS Transparency International (Corruption Perception Index)
Labour Costs	- Human Development Index	UN

4.1.9 Software

All data collection storage and manipulation was done using Excel ® 2016, and Statistical Modelling was carried out using R 3.4.1 and RStudio 1.0.136.

R 3.4.1 is open source software, free to use, and maintained and improved through collaborative research. Although it is a powerful statistical programme, it has some limitations. As statistical software, rather than specialist econometric software, not all econometric tests are available on the R platform.

4.1.10 Pre-Test Diagnostics

Prior to conducting econometric analysis, time series properties of the data were tested. The Jarque Bera (JB) test (Bera & Jarque, 1981) was used to test for normal distribution of the data. The stationarity of the data is also tested. Stationary data is distributed about a mean, whereas non-stationary data trend over time, and therefore do not have a fixed stationary mean (Kennedy, 2008). This can cause the issue of spurious correlation, as a lot of economic data trends over time meaningful relationships may be found where they do not truly exist (Kennedy, 2008).

Stationarity testing requires different tests for panel data than for individual time series (Baltagi, 2013). The panel data estimator averages data across the countries in the panel. This means that the problem of spurious regression can be avoided as the number of countries in the panel *N,* and the time period covered *T,* tend toward infinity (Baltagi, 2013). The most common test for stationarity is the Augmented Dickey Fuller test (ADF) (Dickey & Fuller, 1979). The Maddala and Wu test (Maddala & Shaowen, 1999) tests the data for stationarity in panel form, using an amalgamation of the ADF tests for each. This tests the null hypothesis of non-stationarity. It also can be used to check the 'trend' stationarity, which tests if the data is stationary after accounting for a time trend in the mean. Other panel stationarity and unit root tests such as 'levenlin' and 'IPS' are not suitable for shorter time periods, with only 18 periods (Baltagi, 2013).

If data is non-stationary it can be estimated using cointegration analysis (Engle & Granger, 1987). If the residuals of the regression are stationary, despite non-stationary variables, then they are said to be cointegrated as the variation from the mean in one variable is explained by the variation in another (Engle & Granger, 1987). In cointegration analysis the regression is run in two steps. The regression is run normally first, then run again with an error correction term, which is the lagged regressions from the first equation. The first equation models the short run effect, and the second models the long run, the coefficient of the lagged error shows the number of periods that it takes to move from the long run to the short run (Engle & Granger, 1987).

4.2 Exploratory Data Analysis

Trade preferences were estimated using a modified revealed comparative advantage equation. Ballingall and Briggs (2002) measured revealed comparative advantage as when New Zealand's share of world exports for a product exceeds New Zealand's total exports as a percentage of world exports.

Using a similar approach, comparative advantage, or trade preference between logs and sawn timber, was measured as the proportion of New Zealand's total log exports sent to a certain market, compared with the proportion of total sawn timber exports sent to that market from all countries. If a greater proportion of logs than sawn timber was sent to a market, that market would be classified as a log market, and vice-versa. This is shown in equations 1 and 2 below.

Equation 1 Comparative advantage determinations of a sawn timber market

$$Sawn\ Timber\ Market = \frac{ST_{ec}}{ST_w} > \frac{L_{ec}}{L_w} \tag{1}$$

Equation 2 Comparative advantage determination of a log market

$$Log\ Market = \frac{ST_{ec}}{ST_w} < \frac{L_{ec}}{L_w} \tag{2}$$

Where ST is sawn timber, L is logs, ec is New Zealand's exports to a market, w is New Zealand's exports to the world. This is different in that it compares two products directly to measure the comparative advantage over the other product, rather than comparative advantage to supply of all products from New Zealand.

Import preferences were also measured for each country using a similar approach. Solid wood imports (logs and sawn timber) were measured on a roundwood equivalent basis. Roundwood equivalents are a measure of the equivalent volume of roundwood (logs) based on the outputs of wood products (UNECE, 2010). The proportion of imports of solid wood made up by logs and sawn timber was used to identify import preferences. If the proportion of imports made up from sawn timber was greater than that of logs it was deemed to have a sawn timber import preference.

Equation 3 Comparative advantage determination of sawn timber import preference

$$Sawn\ Timber\ Preference = \frac{ST_i}{ST_i + L_i} > \frac{L_i}{ST_i + L_i} \tag{3}$$

Equation 4 Comparative advantage determination of a log model

$$Log\ Preference = \frac{ST_i}{ST_i + L_i} < \frac{L_i}{ST_i + L_i} \tag{4}$$

4.3 Theoretical Framework

A model to estimate the export demand for sawn timber and logs was used, based on a study of China’s plywood market (Wan, Toppinen, & Hanninen, 2010). They used an export demand model to estimate elasticities of demand for plywood exports from China. Wan et al. (2010) used regression analysis to estimate the volume of product exported, explained by GDP in the importing country and the export price. It is expected that the importers income (measured by GDP) has a positive effect on demand, and the price would have a negative effect on demand, this would give a downward sloping demand curve (Wan et al., 2010).

All data was transformed using natural logs, this means the coefficients of the variables will be elasticities (Wooldridge, 2013). This common structure for modelling demand has been used in other studies of forest product demand including Buongiorno (1979), Turner and Buongiorno (2004), and Cheng, Mei, and Wan (2013). Cheng et al. (2013) use the basic structure of export volume expressed as a function of GDP and export price, but also add a variable to measure the impact of exchange rate volatility on trade. The model used by Wan et al. (2010) is shown below:

Equation 5 (Wan et al., 2010) econometric model of demand for China's export plywood from USA

$$Ln(EP)_t = a + bLn(US)_t + cLn(EPR)_t + u_t \tag{5}$$

EP is the export volume of plywood

a is a constant, and *b* and *c* are coefficients estimated econometrically

US is the real GDP of the USA in US dollars

EPR is the export price

t denotes time, which is measured across years

u is the error term

Ln(.) denotes that the natural log of the variable is used

As China's exports of plywood are predominantly exported to the USA, they use a single market to model the export demand, however, this is not the case for New Zealand's exports of sawn timber, so panel data was used with multiple markets for this study. Panel data also allow for the study to be consistent across many different markets, which will help to answer the research questions of why exports are sent to different markets. Other studies have used panel data to model elasticities of demand for wood products (Turner & Buongiorno, 2004), but are not specific to the exporting country, and do not take into account other variables such as tariffs.

Panel models, in particular macro panels, involve pooling of a cross section of countries across time (Baltagi, 2013). Panel models have many benefits, including increasing sample sizes, more coverage of data and control for heterogeneity of individuals (Baltagi, 2013). The panel model gives a single estimate of the elasticities of demand for New Zealand exports, rather than separate estimates for each country in the panel. Separate regressions could be used for each country, but that would result in far fewer degrees of freedom for each regression and the amalgamating effects of using a panel would be lost.

Import prices were used, rather than export prices, to control for the unknown changing effects of shipping and insurance costs. Tariffs were modelled by including the tariff rate in the price. Tariff rates are applied as percentage of the import price, so by multiplying the price by one plus the tariff rate, the true import cost is shown. Other variables were then added, as with the treatment of volatility in Cheng et al. (2013). The theoretical model used is shown below:

Equation 6 Theoretical model used to estimate demand for sawn timber or logs

$$Ln(IV)_{it} = a + bLn(GDP)_{it} + cLn(IPR)_{it} + xLn(y)_{it} + u_{it} \tag{6}$$

IV is the import volume of sawn timber, or logs

GDP is the GDP of the import country in real, domestic currency units

IPR is the import price paid by the import country in real, domestic units, with tariffs included in the price

y signifies other variables that will be used

Ln signifies that the natural log of the variable is used

a is a constant, and *b, c,* and *x* are coefficients

u is the error term

it signifies country and year

4.4 Demand Model

The demand model described in 4.3 was used to separately estimate the export demand for sawn timber and logs from New Zealand. This means the coefficients of different variables can be compared to understand their differing effects on the trade of sawn timber and logs. The significance and magnitude of effects for different variables shows which factors impact logs and sawn timber exports in different ways.

4.4.1 Fixed and Random Effects

The demand model was estimated using both a panel fixed effects model and a panel random effects model. The fixed effects model allows for different intercepts for the different countries in the panel, and models the changes over time within each country (Kennedy, 2008). The random effects model allows for use of time-invariant variables, and saves on degrees of freedom (Kennedy, 2008).

The general fixed effects model used for this study is shown by Equation 7. This is as per the model shown in Equation 6, but with *a* representing the unobserved time-invariant individual effect for each country.

Equation 7 General formula for demand model with fixed effects

$$Ln(IV)_{it} = bLn(GDP)_{it} + cLn(IPR)_{it} + xLn(y)_{it} + a_i + u_{it} \tag{7}$$

Equation 8 shows the general random effects model used in this study. In the model μ is the intercept. The error is made up of two terms U_i is the country specific error, and W_{it} is the individual error.

Equation 8 General formula for demand model with random effects

$$Ln(IV)_{it} = \mu + bLn(GDP)_{it} + cLn(IPR)_{it} + xLn(y)_{it} + U_i + W_{it} \tag{8}$$

As fixed effects and random effects allow for different intercepts, it means that variation between countries in the panel that aren't modelled can be accounted for by the intercept. The fixed effects model does this by specifying different intercepts, while the random effects model draws the intercept from a pool of possible intercepts (Kennedy, 2008). For a random effects model, there is an overall intercept, and a composite error term that consists of the traditional error, and an error that accounts for the individuals variation from the intercept. This means that for both random and fixed effects, different currencies can be used for different importers, and the variation in exchange rates between countries will be internalised into the fixed or random effects. For example, in the panel model GDP can be measured in both the Philippine Peso with an exchange rate with the US dollar of 0.020 and the Chinese Yuan with an exchange rate of 0.15 with the US dollar. The model will compare the trend between GDP and the import volumes, and the intercept will adjust for the difference in exchange rates. This feature of panel data allows the model to be estimated in the local currency for each importing nation. Without allowing for different intercepts between each country, a common currency, such as US dollars would need to be used, whereas using the local currency better represents the actual costs faced by importers.

The random effects model has the advantage of modelling a mix of the long and short-run effects in regression, while fixed effects only models the short-run effects (Kennedy, 2008). This is because the fixed effects approach can only model changes through time within each country, while the random effects approach can model effects from within each country, and between each country (Kennedy, 2008). The within country regression models the short-run effect as it models responses to changes over time, which may take time to adjust. The between regression models the long-run effect, by testing different levels of variables across different countries, which would be assumed to be at a long run equilibrium (Kennedy, 2008).

However, using random effects can cause bias by including the random intercept in the error term (Kennedy, 2008). When there is a variable that is correlated with some other unobserved effect, this will cause the random effects estimator to be biased (Kennedy, 2008). This is checked for using a Hausman test (J. A. Hausman, 1978), which compares the errors of the random effects, and fixed effects models. This can be corrected for though, using the Hausman-Taylor approach which allows a split between endogenous variables, correlated with the error term, and exogenous variables, which are not (J.A Hausman & Taylor, 1981). This approach still allows for the benefits of testing time invariant variables and the between country effects that random effects gives.

The models were also estimated in dynamic form using a robust two-step Arellano and Bond estimator (Arellano & Bond, 1991). The dynamic form of an equation includes a lagged dependent variable as an explanatory variable. Dynamic forms of models can control for autocorrelation effects and shows long-run effects of the variables (Arellano & Bond, 1991; Baltagi, 2013). They show the long run effects of changes by removing adjustment trends from the model. When a lagged dependent variable is included, it necessarily is correlated with the error term (Baltagi, 2013). Arellano and Bond (1991) propose a solution to this problem by using a generalised method of moments approach.

Autocorrelation could also be controlled by pooling regressions across time rather than across countries, or across both. However, for a panel with low N this causes a big drop in the degrees of freedom (Kennedy, 2008). Therefore, using a lagged dependent variable is preferred to pooling across time.

4.4.2 Other Variables

Other variables were added to the demand model described in 4.2. This model only shows the effect of income and prices, while to understand the difference between sawn timber and log trade, variables that showed the effect of other influences needed to be shown. These were tested using a number of different techniques and combinations. Other variables are described in Section 3:

- tariffs,
- non-tariff barriers,
- competition, and
- local resource

4.4.2.1 Tariffs

As tariffs and tariff wedges (the difference between the tariff for a processed good and the tariff for the raw material) were considered in the literature to have a significant impact on trade (Maplesden & Horgan, 2016; Solberg, Moiseyev, Kallio, & Toppinen, 2010; Sun et al., 2010; Zhu et al., 2000), most models tested included tariffs modelled as part of the price. Some studies, such as Parajuli, Chang, and Hill (2015) and Moncarz (2010) have used tariffs as separate variables in the econometric variables. Other studies such as those using the Global Forest Products Model, (Sun et al., 2010; Zhu et al., 2000) used tariffs as part of the import costs. This study used the approach of modelling tariffs as part of the import price. As tariffs are expressed as an ad-valorem rate on the price, the cost of the tariff is part of the overall cost faced by the importer, and correlated with the price, so it is appropriate to model the tariff as part of this cost. This was assumed to be the base model, to which other variables were added, either individually or in a combination.

The tariff wedge, the difference between the tariff for sawn timber and the tariff for logs, was modelled as a separate variable. This is a new approach for this study, where other studies have tended to model just the effect of tariffs on each product, or model the effect of the different tariff rates through a computable general equilibrium approach. As it is assumed that tariff wedges favour imports of the raw material, it was expected that the tariff wedge would have a negative result for sawn timber and a positive result for logs.

Tariffs are expressed as a percentage of price, so are almost always less than 1 (e.g. 14% for logs exported to China). This means that they cannot be modelled effectively in a double log formula, given that the natural log of 1 is 0, and anything less than one is negative. To overcome this, one plus the tariff wedge was used. This means that the result will be misleading as large change in the tariff wedge, that results in a large change in export volume, will be understated due to the one-plus transformation. This would mean a 100% change in tariff wedge from 5% to 10% would only be treated as a 4.8% change in the model, thus, if the tariff wedge elasticity was 1, then the coefficient for one plus the tariff wedge would show an elasticity of 21.3, a massive over-exaggeration.

4.4.2.2 Non-tariff barriers

NTBs were tested by applying dummy variables to countries where it was known that NTBs were present. This meant that if the dummy variable showed a significant negative effect, then the NTB was assumed to be affecting trade. If there was a negative variable for sawn timber, but not for logs, this meant that NTBs were being used to drive imports towards the raw material. Some more specific NTBs were tested in the model as other variables. China's differential value-added tax between logs and sawn timber was treated as a tariff wedge. Corruption was treated as another variable, where the natural log of the corruption perception index was used as an explanatory variable.

4.4.2.3 Competition

Competition was modelled in several different ways. The supply of timber in m^3 from other competitive sources, Canada, Russia, and USA were added as variables to the model. These were treated in the same way that New Zealand's supply was, as a natural log. As the supply from these countries was different to New Zealand's there were many countries where there was no supply in some years. In these instances, 1 has been added, so that the data can be used in a natural log formation. For Russia, there is also a test of a dummy variable to signify if Russia was a significant competitor (supplying more than 85% of the supply that came from New Zealand) after 2008, when export tariffs were imposed on logs. These sawn timber supply variables were also tested for the log model, rather than testing for log supply competition. The assumption is that higher sawn timber competition leads to more demand for logs from New Zealand, rather than sawn timber.

Competition with the domestic market was tested only with the Human Development Index (HDI). This is used as a proxy for wages. This is not a full test of whether competition with the domestic market influences trade, rather, specifically whether low wage or low income countries can compete more than higher income countries.

4.4.2.4 Local Resource

The local resource was tested by using the natural log of the annual harvest for each country. This is a useful proxy for the familiarity with certain products, as it shows what the normal level of harvest is. The annual harvest was tested for hardwood and softwood separately to show if there was a difference between the two.

4.4.3 Modelling Approach

The approach taken to modelling was to stage the tests of variables, before building up to a combined model. The base model, of real GDP and real prices had each variable added to test its effect. Each variable was tested in random and fixed effects, with the results tested in the Hausman test. If the Hausman test revealed that there was no correlation between variables and the error then the random effects model was used. If the Hausman test revealed that there was correlation between variables and the error, testing was then carried out controlling for endogenous variables with the Hausman-Taylor approach, and retested in the Hausman Test.

If the Hausman test passed then the Hausman-Taylor approach was used, and if it did not then the fixed effects approach was used.

If the tests resulted in statistically significant results of the expected magnitude and direction of effect, then post-test diagnostics were carried out. The model was then re-tested in a dynamic model using the Arellano and Bond approach. If the results were not significant or the coefficient had an unexpected sign then the variable was deemed to not be an improvement to the model and post-test diagnostics and dynamic model tested were not carried out.

In the final models, all variables that showed expected and statistically significant results were used in a combined model. The combined model was tested in fixed and random effects, and if necessary the Hausman-Taylor approach. The log demand model was tested in an optimum model, which used all of the significant variables, and a comparison model, which just used the same variables as the sawn timber demand model, for the purposes of direct comparisons of the effects of variables.

4.5 Application of the Model

The application of the model is shown through the testing of the effect that the different variables have on trade. The effects were measured by estimating the export volume of sawn timber and logs from the model, while varying the level of different inputs. This was compared to the estimations from the model with the inputs at the status quo. This shows the effect of different policy outcomes, or potential outcomes.

The status quo of trade of sawn timber and logs, is compared with the potential trade if all tariffs were removed, all other variables, such as GDP and price were held steady between the two. This shows the overall effect that tariffs are having on the difference in demand for sawn timber and logs. This approach was also taken for evaluation of Free Trade Agreements (FTA). The status quo scenario was compared with the counterfactual of tariff barriers remaining in place. This was extended into the trade to countries where FTAs were recently signed, to give an assessment of their likely effect on the trade of sawn timber and logs. Projections were made based on a steady three-year average price level, and a GDP growth rate at the three-year average. Other variables were kept steady.

4.6 Evaluation

Post testing diagnostics also must be run to test the time series properties of the residuals. The Breusch-Godfrey (BG) (Breusch, 1978) and (Godfrey, 1978) test was used to test for serial correlation of the errors, the Breusch-Pagan (BP) test was used to test for heteroscedasticity (Breusch & Pagan, 1980). When the errors in one period are correlated with the errors in another period, they are serially correlated (Kennedy, 2008). This issue can be a symptom of misspecification of variables, and can indicate a missing variable (Kennedy, 2008). Heteroscedasticity is where the variance trends with the magnitude of the variable (Kennedy, 2008). This can be a source of bias in the regression which can be overcome by using heteroscedastic robust estimators, or using generalised least squares (Kennedy, 2008). White heteroscedastic robust estimators were used to estimate whether the coefficients are still robust when heteroscedasticity is present, which means that the result is not biased (White, 1980). If the result is robust to heteroscedasticity it means that we can be confident that the coefficients are still significant despite the presence of heteroscedasticity. If the result is not robust to heteroscedasticity it means that there may still be a source of bias in the model (Kennedy, 2008). The software used, R, cannot perform the specified tests for serial correlation and robust estimators for the Hausman-Taylor tests. In cases where the Hausman-Taylor test was used and post-test diagnostics were required, serial correlation was checked using partial auto correlation function plots in Excel. Where necessary heteroscedasticity was analysed further by plotting the error and dependant variables in Excel. Robust errors were not able to be calculated.

The ability of the model to predict imports for each country was also analysed using a Mean Absolute Percentage Error (MAPE) approach. The percentage error is best used for comparing errors where the scale is different between the model outputs being compared (Hyndman & Athanasopoulos, 2013). The percentage error is the absolute error divided by the dependent variable, and the MAPE is the mean of the percentage errors across the whole period being analysed. The MAPE is usually tested on an independent set of data to analyse the forecasting accuracy for the model. In this case all of the available data has been used in the model, so there is no accessible independent data to test the ability of the model to forecast accurately (Hyndman & Athanasopoulos, 2013).

5. Results

5.1 Exploratory Data Analysis

The following results have been found using the adapted Ballingall and Briggs (2002) comparative advantage approach outlined in section 4.2. This shows the export preferences for logs or sawn timber based on the share of supply to each country.

Results showed that of New Zealand's top 12 markets there were 3 log markets and 9 sawn timber markets. The log markets were the highest value export markets. In total, just over $2 billion of logs were exported to the top three markets in 2015 (with over $1.5 billion in exports to China alone). Export revenue from the top 9 sawn timber exports amounted to $641 million in 2015.

Table 3 Log or sawn timber market determinations with export values

Export Market	*2015 export value*	*Preference*
China, People's Republic of	$1,522,535,927	Logs
Korea, Republic of	$359,885,350	Logs
India	$209,107,902	Logs
United States of America	$181,871,775	Sawn Timber
Australia	$152,957,402	Sawn Timber
Japan	$94,565,346	Sawn Timber
Taiwan	$55,506,954	Sawn Timber
Viet Nam	$52,572,761	Sawn Timber
Thailand	$32,562,863	Sawn Timber
Indonesia	$27,686,695	Sawn Timber
Philippines	$22,712,609	Sawn Timber
Netherlands	$20,470,145	Sawn Timber

The export preference scatter plot shows that most of the market preferences were either heavily skewed towards sawn timber or heavily skewed towards logs. Only Japan was evenly weighted between the two. In the scatter plot (Figure 9), countries that are below the line are designated as sawn timber markets, and countries above the line are designated as log markets.

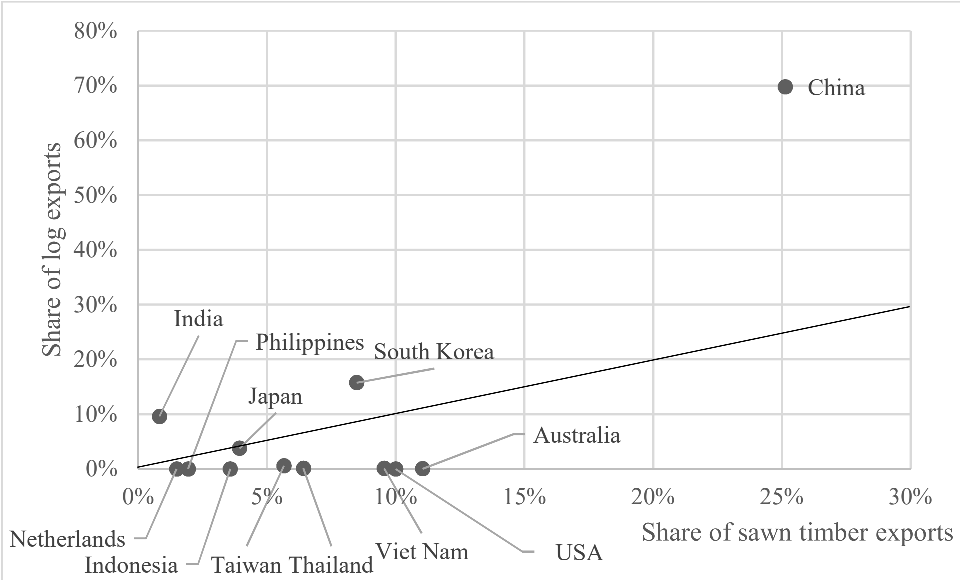


Figure 9 Share of New Zealand sawn timber and log exports by country of destinations

Plots show that in countries where New Zealand prefers to export logs, Canada and Russia are typically large sawn timber suppliers. This is shown in China, Japan, and South Korea, where imports of sawn timber are largely made up by Canada and Russia, while log imports are made up by New Zealand and USA.

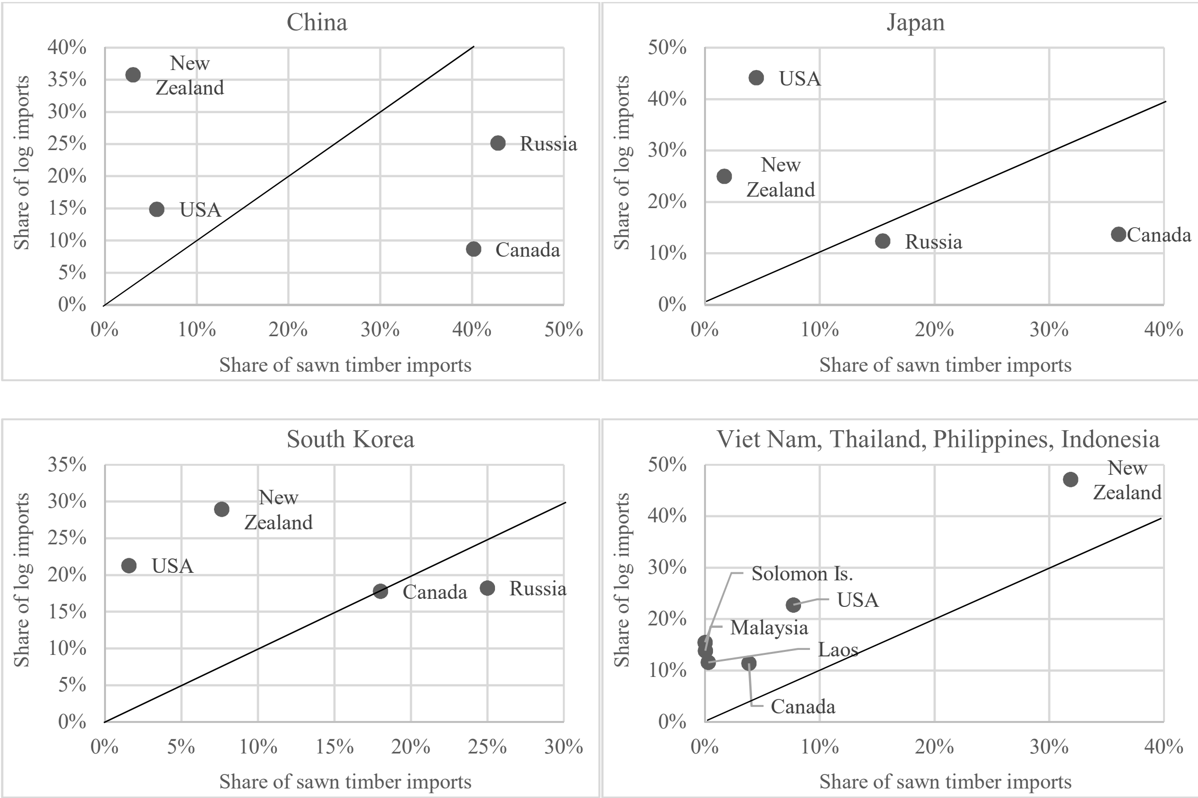


Figure 10 Import market preference from different suppliers

The Figure 10 charts show the import market preference from different suppliers for each market (South East Asian countries have been grouped). In the markets where Canada and Russia are present, importers prefer logs to sawn timber from New Zealand, whereas in South East Asia New Zealand is much further towards the sawn timber side of import preferences.

5.2 Econometric Analysis

5.2.1 Pre-test diagnostics

Pre-test diagnostics showed that most of the data was normally distributed. The Jarque-Bera test was used to test for the null hypothesis of normal data, and a result with a p-value of less than 0.05 signified that the data was non-normal. The JB test showed that all GDP, human development index, and corruption perception index data was normally distributed. Other data had a mix between normal and non-normal distributions according the JB tests. This depended on the country that the data belonged to. Indonesia, Japan and the Philippines had non-normally distributed sawn timber price data, while import volume data for sawn timber was non-normal for Indonesia and Thailand. See Appendix One.

Due to the small number of data sets that were not normally distributed, it was decided that no transformations should be used to create normal data. This would mean either imposing transformations on some datasets in the panel model but not others, or imposing transformations on all datasets in the panel despite most data being acceptable for use.

The Maddala-Wu tests showed that the data was stationary in panels for most of the variables tested. GDP, sawn timber price and import volume, softwood resource, and hardwood resource were all stationary in panels. Other data tested had errors for the tests due to missing observations. The most important concern was log import volume and price data, which could not be fully tested. However, it was decided to continue without cointegration analysis, as most data was recorded as stationary and there is lower chance of spurious correlations with panel data (Baltagi, 2013).

5.2.2 Basic Demand Model

The demand model in its most basic panel model form appeared to be a good fit, as shown in Table 4 and Table 5. For the sawn timber and log demand models, there were significant results ($p \leq 0.01$) for GDP and real price, with the expected signs, showing the classic downward sloping demand curve. These results had elasticities that were within the expected range to be similar to other studies. For all results in this section; summary results are shown in tables, full regression results are shown in Appendix Two.

Table 4 Basic sawn timber demand model results using fixed effects

Co-efficient	Estimate	Std. Error	t-value	P-value
Log(GDP)	1.42	0.32	4.46	0.00
Log(RPR)	-0.73	0.22	-3.38	0.00

Table 5 Basic log demand model results using fixed effects

Co-efficient	Estimate	Std. Error	t-value	P-value
Log(GDP)	1.15	0.46	2.51	0.01
Log(LOGPR)	-0.66	0.14	-4.83	0.00

5.2.3 Tariffs

Tariffs were added to the price to show the effective import price paid by the importer. The results were slightly different to the results of the prices modelled without tariffs but not significantly so, and the R-squared values (shown for all regressions in Appendix Two) were slightly higher. From this point on tariffs were modelled as part of the price to reflect the true cost faced by the importer.

Table 6 Basic sawn timber demand model using fixed effects

Co-efficient	Estimate	Std. Error	t-value	P-value
Log(GDP)	1.32	0.32	4.18	0.00
Log(RPRPT)	-0.73	0.21	-3.59	0.00

Table 7 Basic log demand model using fixed effects

Co-efficient	Estimate	Std. Error	t-value	P-value
Log(GDP)	1.12	0.46	2.44	0.02
Log(LOGPRPT)	-0.67	0.14	-4.85	0.00

The tariff wedge was added to see the effect that a difference in the sawn timber and log tariffs had on trade. This model was tested using both random and fixed effects, as the difference in tariff wedges between countries can show the effect of tariff wedges at different levels, and fixed effects can only show this where the tariff level changes over time within a country.

Table 8 Sawn timber model with tariff wedge using fixed effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	0.90	0.36	2.47	0.01
Log(RPRPT)	-0.77	0.21	-3.67	0.00
Log(TWPO)	-4.58	2.08	-2.20	0.03

Table 9 Sawn timber model with tariff wedge using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-5.85	6.24	-0.94	0.35
Log(GDP)	0.76	0.21	3.61	0.00
Log(RPRPT)	-0.77	0.17	-4.42	0.00
Log(TWPO)	-5.47	1.89	-2.88	0.00

Both models showed that there was a significant ($p \leq 0.01$) negative effect of the tariff wedge on demand for sawn timber. This is important as it shows that the effect of a tariff wedge is significant beyond just the effect that tariffs have on prices. Bringing in the tariff wedge caused a reduction in the measured demand elasticity of GDP, although other variables were not affected. The random effects model showed a more significant and greater magnitude of effect from the tariff wedge, which indicates it would be a better measure of the model. However, the Hausman Test suggests that the random effects model was biased as one or more of the variables were correlated with the error.

```
Hausman Test

data:  log(IV) ~ log(GDP) + log(RPRPT) + log(TWPO)
chisq = 164.47, df = 3, p-value < 2.2e-16
alternative hypothesis: one model is inconsistent
```

Using the Hausman-Taylor approach, assuming that GDP and real prices are exogenous, and the tariff wedge is endogenous, resulted in a model in which the errors were not correlated with variables. This means that the Hausman-Taylor approach has corrected for the problem of errors correlated with the variables that can occur in random effects.

Table 10 Sawn timber model with tariff wedge using Hausman Taylor approach

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-4.12	3.00	-1.37	0.17
Log(GDP)	0.68	0.12	5.75	0.00
Log(RPRPT)	-0.70	0.12	-5.79	0.00
Log(TWPO)	-5.25	2.46	-2.13	0.03

```
Hausman Test

data:  log(IV) ~ log(GDP) + log(RPRPT) + log(TWPO)
chisq = 0.77914, df = 3, p-value = 0.8544
alternative hypothesis: one model is inconsistent
```

```
studentized Breusch-Pagan test

data:  STtwpht
BP = 45.327, df = 3, p-value = 7.886e-10
```

The post-test diagnostics for the Hausman-Taylor test of sawn timber demand with the tariff wedge showed the residuals had signs of serial correlation and heteroscedasticity. Standard residual tests are not available in R for the Hausman-Taylor approach, but clear trends could be seen in the residual plots, suggesting that serial correlation was present for both models. There was also evidence of significant correlation in the lags on the partial autocorrelation plot. Heteroscedastic and serial correlation robust standard errors cannot be estimated in r for the Hausman-Taylor model.

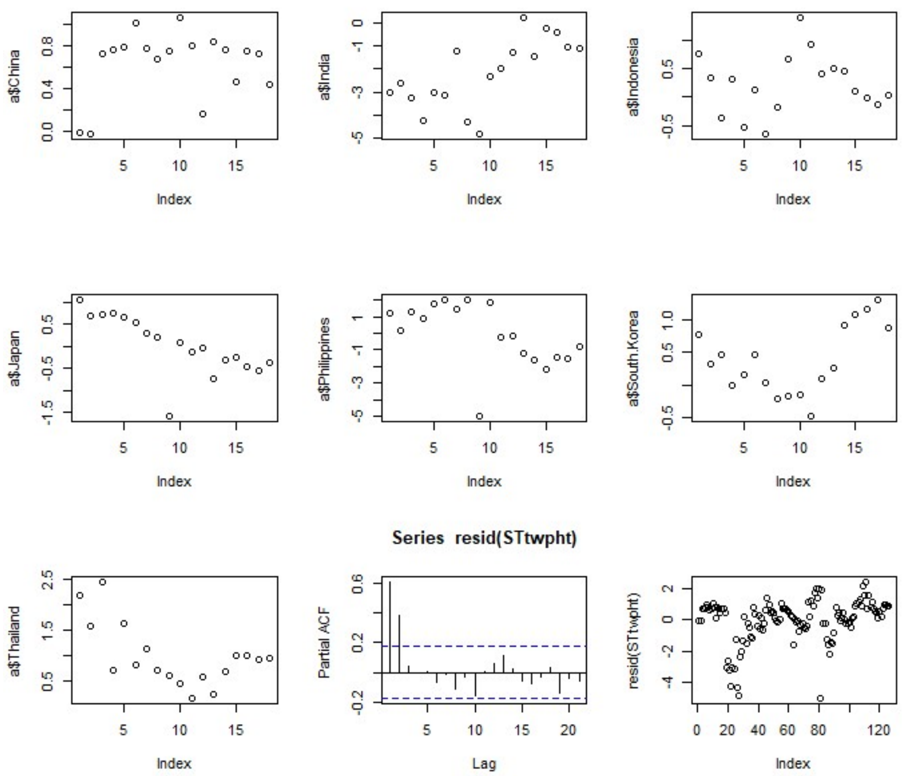


Figure 11 Residual plot of Sawn Timber model with tariff wedge using Hausman-Taylor approach

The tariff wedge is transformed to have one added to it. This means that the tariff wedge coefficient is misleading in this context. Large changes in the tariff wedge only result in a small change to the 'tariff wedge plus one'. This distortion gives an overestimate of the actual elasticity of the variable. The true elasticity can be found by dividing the actual change by the change in tariff rate. The actual elasticity of demand for the tariff wedge was -0.29 for this model.

When the tariff wedge was added to the log demand model there was a slight positive response for log demand, as expected, but the effect is not significant. This is not an unexpected result as the tariff wedge would be more likely to affect sawn timber demand. There was no real difference between the fixed and random effects model, and the Hausman Test showed no significant effect of correlation between the variables and the error term in the random effects model, so estimation using the Hausman-Taylor approach was unnecessary for the log model.

Table 11 Log demand model with tariff wedge using fixed effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	1.18	0.54	2.20	0.03
Log(LOGPRPT)	-0.67	0.14	-4.83	0.00
Log(TWPO)	0.60	3.00	0.20	0.84

Table 12 Log demand model with tariff wedge using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-8.41	9.25	-0.91	0.37
Log(GDP)	0.84	0.29	2.93	0.00
Log(LOGPRPT)	-0.74	0.13	-5.85	0.00
Log(TWPO)	0.03	2.74	0.01	0.99

```
Hausman Test
data:  log(LIV) ~ log(GDP) + log(LOGPRPT) + log(TWPO)
chisq = 4.3897, df = 3, p-value = 0.2223
alternative hypothesis: one model is inconsistent
```

The log demand model residual testing showed the presence of serial correlation and heteroscedasticity for the random effects model. The robust White test showed that the log demand model using random effects is robust to heteroscedasticity for GDP and price, but only the coefficient for price is robust to both heteroscedasticity and serial correlation.

```
Breusch-Godfrey/Wooldridge test for serial correlation in panel
models

data:  log(IV) ~ log(GDP) + log(RPRPT) + log(TWPO)
chisq = 33.896, df = 18, p-value = 0.01297
alternative hypothesis: serial correlation in idiosyncratic errors
```

```
studentized Breusch-Pagan test

data:  LOGtwr
BP = 28.41, df = 3, p-value = 2.979e-06
```

Table 13 Heteroscedastic robust standard errors for log model with tariff wedge using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-8.41	11.38	-0.74	0.46
Log(GDP)	0.84	0.34	2.47	0.02
Log(LOGPRPT)	-0.74	0.13	-5.91	0.00
Log(TWPO)	0.03	2.50	0.01	0.99

Table 14 Heteroscedastic and serial correlation robust standard errors for log model with tariff wedge using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-8.41	15.19	-0.55	0.58
Log(GDP)	0.84	0.50	1.67	0.10
Log(LOGPRPT)	-0.74	0.18	-4.07	0.00
Log(TWPO)	0.03	3.91	0.01	0.99

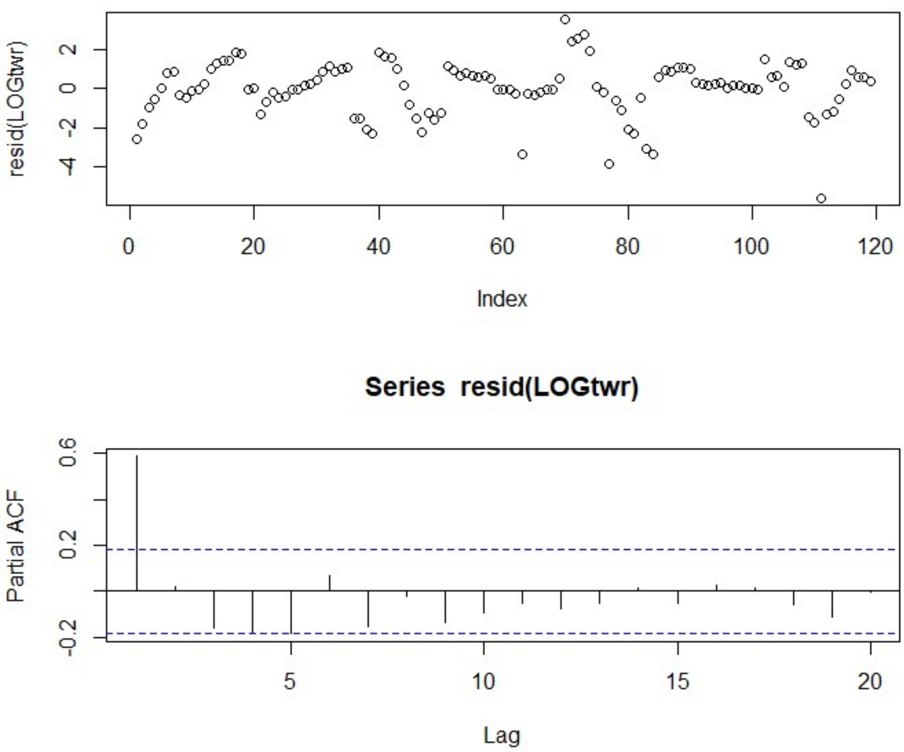


Figure 12 Residual plot for log demand model with tariff wedge using random effects and partial auto correlation function

The sawn timber model was also estimated using the Generalised Method of Moments, Arellano and Bond approach (Arellano & Bond, 1991). Using a lagged dependent variable can control for the autocorrelation errors, and show long run effects of the variables. Models that show effects of autocorrelation are often tested with a lagged dependent variable. The results of the model are shown below.

Table 15 Sawn timber GMM Arellano and Bond model including tariff wedge

Co-efficient	Estimate	Std. Error	t-value	P-value
Lag(Log(IV))	0.26	0.11	2.43	0.02
Log(GDP)	0.33	0.49	0.67	0.50
Log(RPRPT)	-0.85	0.30	-2.88	0.00
Log(TWPO)	-6.16	5.82	-1.06	0.29

Although the model had the expected signs for GDP, price and the tariff wedge, the coefficients for GDP and the tariff wedge are no longer significant. As this model is not an improvement on the random effects model post-test diagnostics were not carried out.

The log model was also tested using the Arellano and Bond method, however, the results showed unexpected signs for GDP and for the tariff wedge, and neither are significant. As this is not considered an improvement on the random effects model, post-test diagnostics were not carried out for the log model either.

Table 16 Log Arellano and Bond model including tariff wedge

Co-efficient	Estimate	Std. Error	t-value	P-value
Lag(Log(LIV))	0.38	0.09	4.40	0.00
Log(GDP)	-0.44	1.24	-0.36	0.72
Log(LOGPRPT)	-0.80	0.07	-11.46	0.00
Log(TWPO)	-3.01	4.12	-0.73	0.47

5.2.4 Non-tariff barriers

Testing for NTBs was undertaken with a number of methods. The UNTRAINS database records countries that have NTBs on different products. These were used in the model as dummy variables for the countries that have NTBs for sawn timber and logs respectively.

This effect cannot be tested using fixed effects as the dummy variables are time invariant. The first tests showed that there was no significant impact of NTBs on sawn timber trade or on the log trade, and the co-efficient had the incorrect sign.

Table 17 Sawn timber model with non-tariff barrier dummy variable using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-17.80	8.15	-2.18	0.03
Log(GDP)	1.12	0.25	4.54	0.00
Log(RPRPT)	-0.81	0.20	-4.12	0.00
NTB	1.18	1.89	0.62	0.53

Table 18 Log model with non-tariff barrier dummy variable using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-9.61	9.44	-1.02	0.31
Log(GDP)	0.86	0.28	3.07	0.00
Log(LOGPRPT)	-0.73	0.13	-5.74	0.00
NTB	0.61	1.81	0.34	0.71

The corruption perceptions index (CPI) was also tested by inclusion in the model as a log variable. This again showed the same result as the NTB dummy variable, of an incorrect sign, and non-significant results, both in fixed effects and random effects, for sawn timber and for logs.

Table 19 Sawn timber demand model with Corruption Perception Index using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-13.56	8.30	-1.63	0.11
Log(GDP)	0.98	0.28	3.53	0.00
Log(RPRPT)	-0.81	0.19	-4.23	0.00
CPI	0.68	0.76	0.89	0.37

Table 20 Log demand model with Corruption Perception Index using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-8.51	9.02	-0.94	0.35
Log(GDP)	0.84	0.29	2.87	0.00
Log(LOGPRPT)	-0.74	0.13	-5.84	0.00
CPI	-0.06	1.03	-0.06	0.96

The ad-valorem equivalent (AVE) estimates of NTBs from the UNTRAINS database were tested as separate variables, with 1 added to the ad-valorem rate, which allowed the natural log to be used in the model. They were tested using a random effects model as they are time invariant. These results also showed no significant effects for sawn timber or log demand models.

Table 21 Sawn timber demand model with AVE NTBs using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-17.30	7.90	-2.19	0.03
Log(GDP)	1.11	0.24	4.56	0.00
Log(RPRPT)	-0.80	0.20	-4.11	0.00
Log(AVESTPO)	16.27	24.96	0.65	0.52

Table 22 Log demand model with AVE NTBs using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-10.93	9.88	-1.11	0.27
Log(GDP)	0.90	0.29	3.06	0.00
Log(LOGPRPT)	-0.73	0.13	-5.63	0.00
Log(AVELOGPO)	2.89	5.23	0.55	0.58

As none of these NTB estimates improved the basic model in the first estimation, there was no attempt to run post-test diagnostics.

5.2.5 Competition

Competition effects for sawn timber were estimated for the three countries together, and then separately. When tested separately in random effects Canada and USA had significant positive effects, although of a very small magnitude. When tested together there were no significant effects. The Russian, post-2008 dummy variable also showed no significant effects. The variables for GDP, and price remained significant and showing correct signs, but are not shown in Table 23. The individual regressions are shown in Appendix 2.

Table 23 Sawn timber demand model with competitor effects shown when modelled separately and together using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*	*Model*
Log(CAN)	0.06	0.06	1.12	0.26	Combined
Log(RUS)	-0.00	0.05	-0.02	0.99	Combined
Log(USA)	0.07	0.04	1.77	0.08	Combined
Log(CAN)	0.11	0.05	2.19	0.03	Individual
Log(RUS)	0.04	0.04	0.93	0.35	Individual
Log(USA)	0.10	0.04	2.62	0.01	Individual
RUSP08D	0.02	0.32	0.08	0.94	Individual

As none of these effects appeared to improve the model, post-test diagnostics were not carried out for any of the models.

Competition effects were also tested together and separately for log demand. USA and Canada supply showed a significant positive effect on demand for logs, when tested together and separately ($p \leq 0.01$ for individual test, $p \leq 0.05$ for USA in combined test). This was tested in fixed effects and random effects. The Hausman test showed that there was no issue of variables correlated with the error term, so the random effects model was preferred.

Table 24 Log demand model with competitor effects shown when modelled separately and together using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*	*Model*
Intercept	-4.31	7.54	-0.57	0.57	Combined
Log(GDP)	0.61	0.24	2.54	0.01	Combined
Log(LOGPRPT)	-0.76	0.12	-6.51	0.00	Combined
Log(CAN)	0.23	0.07	3.17	0.00	Combined
Log(RUS)	-0.00	0.06	-0.04	0.97	Combined
Log(USA)	0.11	0.06	1.99	0.05	Combined
Log(CAN)	0.29	0.06	4.61	0.00	Individual
Log(RUS)	0.09	0.06	1.44	0.15	Individual
Log(USA)	0.19	0.05	-6.15	0.00	Individual
RUSP08D	0.33	0.39	0.85	0.40	Individual

For the combined model, post-test diagnostics showed issues with serial correlation, and heteroscedasticity.

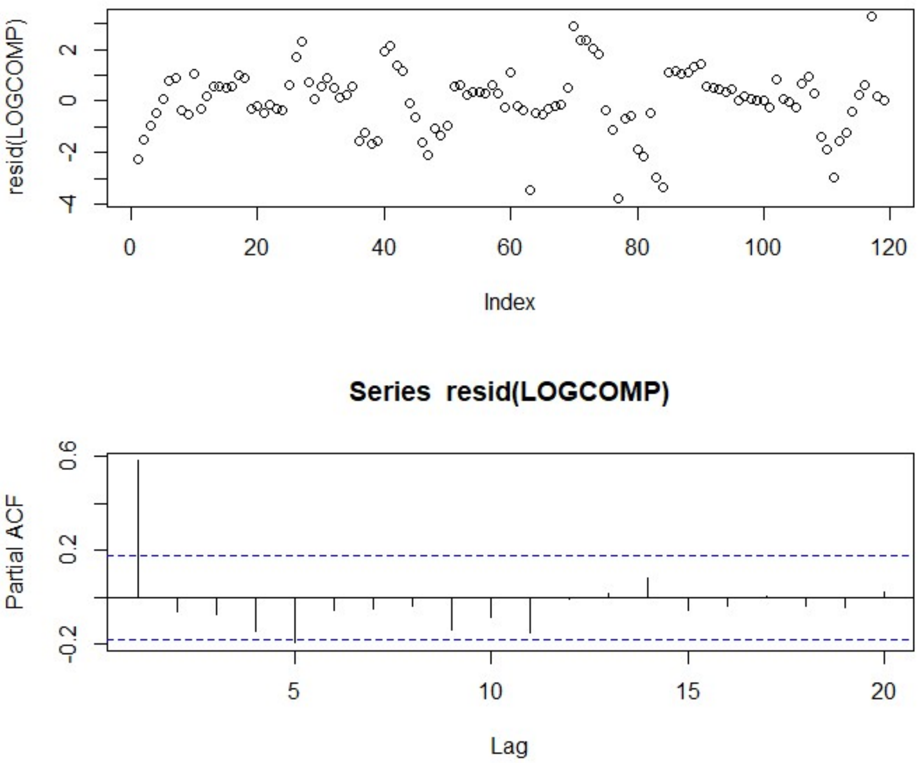


Figure 13 Residual plot and partial autocorrelation function for log demand model with competitor effects

```
Breusch-Godfrey/Wooldridge test for serial correlation in
panel models

data:  log(LIV) ~ log(GDP) + log(LOGPRPT) + log(CA
N) + log(RUS) + log(USA)
chisq = 51.285, df = 15, p-value = 7.41e-06
alternative hypothesis: serial correlation in idiosyncratic
errors
```

```
studentized Breusch-Pagan test

data:  LOGCOMP
BP = 19.008, df = 5, p-value = 0.001915
```

Heteroscedastic robust standard errors show that the results were less significant, but still significant at $p \leq 0.10$. The results were not robust to both heteroscedasticity and serial correlation.

Table 25 Log demand model with competitor effects using random effects and heteroscedastic robust standard errors

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-4.31	8.72	-0.49	0.62
Log(GDP)	0.61	0.26	2.34	0.02
Log(LOGPRPT)	-0.76	0.09	-8.60	0.00
Log(CAN)	0.23	0.14	1.66	0.10
Log(RUS)	-0.00	0.08	-0.03	0.98
Log(USA)	0.11	0.07	1.68	0.10

Testing the model using the Arellano and Bond method of generalised method of moments resulted in non-significant results for USA competition and GDP. As this did not improve the model post-test diagnostics were not carried out.

Labour costs in the importing countries were tested using the Human Development Index as a variable. The results showed that a higher HDI had a significant positive effect on demand for sawn timber.

Table 26 Sawn timber demand model with HDI using fixed effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	-2.70	1.37	-1.98	0.05
Log(RPRPT)	-0.80	0.21	-3.88	0.00
Log(HDI)	21.73	7.20	3.02	0.00

Table 27 Sawn timber demand model with HDI using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	7.62	10.94	0.70	0.49
Log(GDP)	0.37	0.34	1.09	0.28
Log(RPRPT)	-0.67	0.19	-3.48	0.00
Log(HDI)	6.15	2.35	2.62	0.01

Both the random effects model and the fixed effects model showed significant effects for the HDI, but also strong effects on the magnitude and significance of the GDP variable. The variance-covariance matrix reveals that this is due to a strong correlation between GDP and the HDI. This is likely due to the HDI having Gross National Income as a component of the index, which is highly correlated with GDP. This could also indicate that GDP can be an indicator of labour costs. As this made the GDP variable non-significant, it did not improve the model, so post-test diagnostics and further testing was not required, nor was testing with the log demand model.

Table 28 Variance-covariance matrix for sawn timber model with HDI using random effects

	(Intercept)	*log(GDP)*	*log(RPRPT)*	*log(HDI)*
(Intercept)	119.71	-3.65	0.58	19.91
log(GDP)	-3.65	0.12	-0.03	-0.60
log(RPRPT)	0.58	-0.03	0.04	0.15
log(HDI)	19.91	-0.60	0.15	5.51

5.2.6 Local Resource

The local resource was tested by using both hardwood and softwood harvests, tested separately. The random effects model for sawn timber showed a significant ($p \leq 0.01$) negative impact of a softwood harvest but not a hardwood harvest.

Table 29 Sawn timber demand model with softwood harvest using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-18.55	6.27	-2.96	0.00
Log(GDP)	1.22	0.21	5.85	0.00
Log(RPRPT)	-0.82	0.17	-4.81	0.00
Log(SFT)	-0.18	0.04	-4.00	0.00

Table 30 Sawn timber demand model with hardwood harvest using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-16.45	7.73	-2.13	0.04
Log(GDP)	1.07	0.24	4.41	0.00
Log(RPRPT)	-0.82	0.19	-4.32	0.00
Log(HWD)	0.05	0.04	1.27	0.21

The sawn timber softwood resource model had similar results for the fixed effects model, and a non-significant Hausman test, so the random effects model is preferred.

```
Hausman Test

data:  log(IV) ~ log(GDP) + log(RPRPT) + log(SFT)
chisq = 2.6266, df = 3, p-value = 0.4529
alternative hypothesis: one model is inconsistent
```

The post-test diagnostics showed that there were issues with heteroscedasticity and serial correlation. However, the robust standard error test showed that the results coefficients were robust to both heteroscedasticity and serial correlation.

```
Breusch-Godfrey/Wooldridge test for serial correlation i
n panel models

data:  log(IV) ~ log(GDP) + log(RPRPT) + log(SFT)
chisq = 30.165, df = 18, p-value = 0.03588
alternative hypothesis: serial correlation in idiosyncratic
errors
```

```
studentized Breusch-Pagan test

data:  STsftr
BP = 17.795, df = 3, p-value = 0.0004848
```

Table 31 Sawn timber demand model with softwood harvest using random effects and robust standard errors

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-18.55	12.57	-1.48	0.14
Log(GDP)	1.22	0.34	3.55	0.00
Log(RPRPT)	-0.82	0.18	-4.50	0.00
Log(SFT)	-0.18	0.04	-4.27	0.00

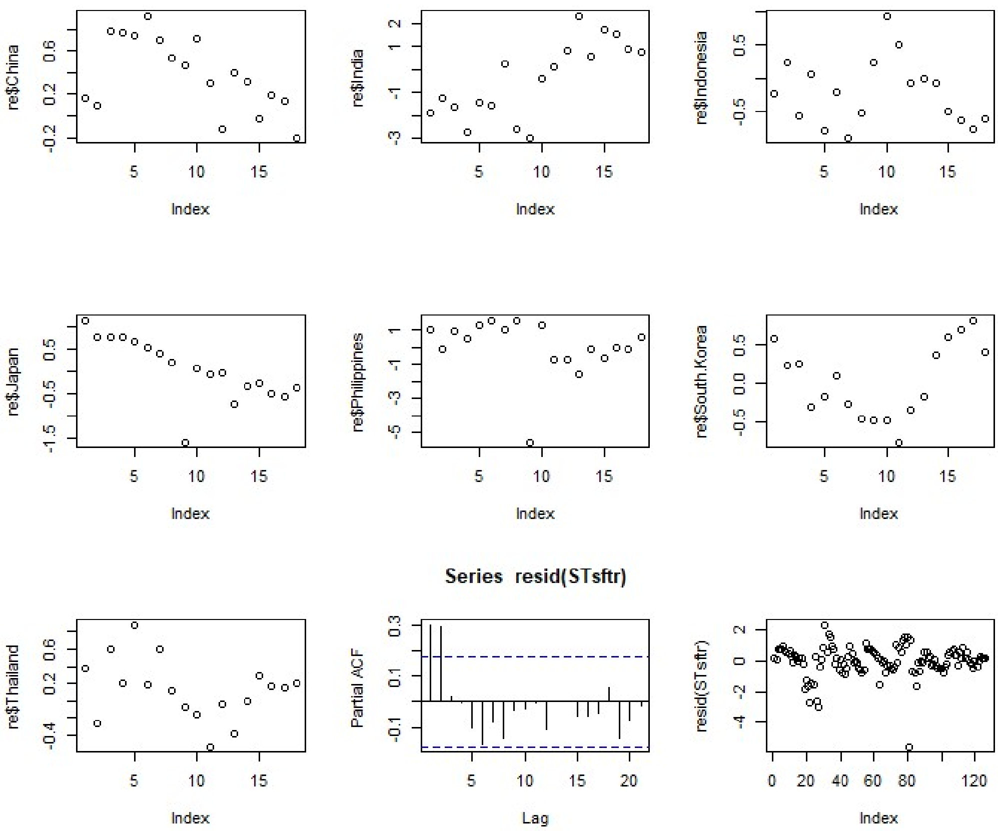


Figure 14 Residual plots for softwood timber model with softwood resource using random effects

The log demand model showed a significant ($p \leq 0.01$) negative effect for a softwood resource, for both fixed and random effects. The model did not pass the Hausman test, and did not pass when using the Hausman-Taylor approach, so fixed effects were preferred. The hardwood resource had no significant effect.

Table 32 Log demand model with softwood harvest using fixed effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	1.42	0.44	3.25	0.00
Log(LOGPRPT)	-0.70	0.13	-5.41	0.00
Log(SFT)	-0.29	0.07	-4.16	0.00

Table 33 Log demand model with hardwood harvest using fixed effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	1.06	0.46	2.30	0.02
Log(LOGPRPT)	-0.67	0.14	-4.88	0.00
Log(HWD)	0.06	0.06	-1.02	0.31

Post-test diagnostics showed that there was heteroscedasticity and serial correlation present, however the results were robust to heteroscedasticity, and mostly robust to both, with GDP losing significance.

```
Breusch-Godfrey/Wooldridge test for serial correlation i
n panel models

data:  log(LIV) ~ log(GDP) + log(LOGPRPT) + log(SF
T)
chisq = 53.857, df = 15, p-value = 2.776e-06
alternative hypothesis: serial correlation in idiosyncratic
errors
```

```
studentized Breusch-Pagan test

data:  LOGsft
BP = 11.162, df = 3, p-value = 0.01088
```

Table 34 Log demand model with softwood harvest using fixed effects and robust standard errors

Co-efficient	Estimate	Std. Error	t-value	P-value
Log(GDP)	1.42	0.78	1.81	0.07
Log(LOGPRPT)	-0.70	0.11	-6.27	0.00
Log(SFT)	-0.29	0.04	-6.90	0.00

Table 35 Log demand model with softwood harvest using fixed effects and heteroscedastic robust standard errors

Co-efficient	Estimate	Std. Error	t-value	P-value
Log(GDP)	1.42	0.44	3.25	0.00
Log(LOGPRPT)	-0.70	0.13	-5.41	0.00
Log(SFT)	-0.29	0.07	-4.16	0.00

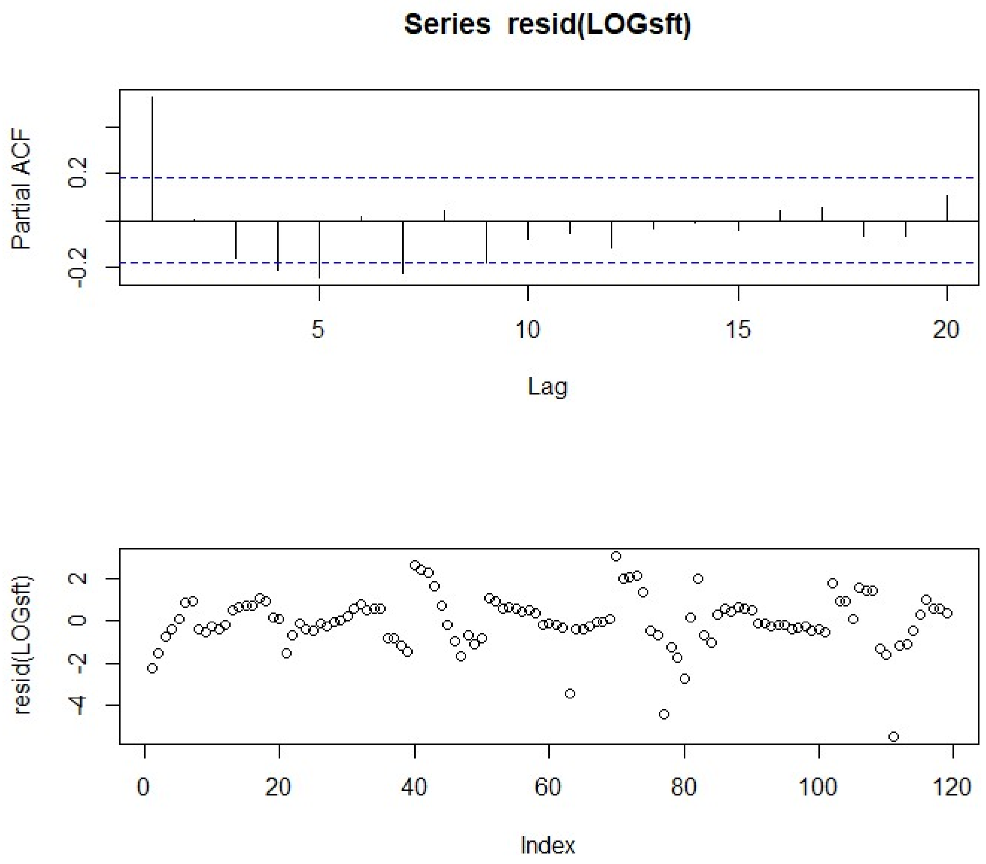


Figure 15 Residuals and partial auto correlation function for log demand model with softwood harvest

The sawn timber and log demand models were also tested using a dynamic model, which uses a lagged dependent variable, with the Arellano and Bond method. This showed similar results to the other models used, but with a lower magnitude effect for the softwood timber coefficient. Although the result showed that autocorrelation (and therefore serial correlation) is not present, the coefficients were less significant for both models. The log demand model was significantly affected by using a dynamic approach, and GDP became insignificant. Due to the smaller coefficient for the softwood harvest, and the loss of significance for some coefficients, it was decided that this approach did not improve the model and further post-test diagnostics were not run.

Table 36 Sawn timber demand model with softwood harvest using Arellano and Bond method

Co-efficient	Estimate	Std. Error	t-value	P-value
Lag(Log(IV),1)	0.18	0.16	1.12	0.26
Log(GDP)	1.13	0.58	1.95	0.05
Log(RPRPT)	-0.71	0.32	-2.2	0.03
Log(SFT)	-0.15	0.04	-3.51	0.00

Table 37 Log demand model with softwood harvest using Arellano and Bond method

Co-efficient	Estimate	Std. Error	t-value	P-value
Lag(Log(LIV),1)	0.34	0.08	4.52	0.00
Log(GDP)	0.10	1.00	0.10	0.92
Log(LOGPRPT)	-0.78	0.07	-10.83	0.00
Log(SFT)	-0.13	0.04	-3.02	0.00

5.2.7 Final Model

To estimate the final model, the results of the different variable tests were compared. Where a variable was tested, and showed significant results for the expected outcomes, and had minimal or no biases, then that variable would be carried forward into the final model. In the final model, the variables that were significant when tested individually were then together in the same model.

5.2.7.1 Sawn Timber Demand Model Regressions

Tables 38 to 40 below show the results from the best regressions from the tests for each variable. The best regression, was the regression that showed the most significant results, with random effects, or the Hausman-Taylor approach where those were applicable.

Table 38 Results of trade barrier regressions

	Trade Barriers				
Variable	**Basic**	**Tariff Wedge**	**NTB Dummy**	**CPI**	**AVE**
GDP	1.32***	0.68***	1.12***	0.98***	1.11***
Price	-0.73***	-0.70***	-0.81***	-0.81***	-0.80***
Tariff Wedge		-5.25***			
NTB Dummy			1.18		
CPI				0.68	
AVE					16.27

****p-value <0.01*
***p-value >0.01<0.05*
**p-value >0.05<0.10*

From the testing of these trade barrier variables, the tariff wedge was significant, whereas the NTB dummy variable, the CPI and AVE of NTBs were not found to be significant. The tariff wedge will be used in the final model, but the other variables will be discarded.

Table 39 Results of competition regressions

	Competition				
Variable	**CAN**	**USA**	**RUS**	**Combined Competitors**	**HDI**
GDP	0.91***	0.95***	0.89***	0.95***	0.37
Price	-0.76***	-0.86***	-0.82***	-0.81***	-0.67***
CAN	0.11**			0.06	
USA		0.10***		0.07*	
RUS			0.04	0.00	
HDI					6.15***

****p-value <0.01*
***p-value >0.01<0.05*
**p-value >0.05<0.10*

Competition variables that were tested showed significant results for Canada and USA supply, and the HDI. However, the variables for Canada and the USA showed the incorrect sign, and so they were discarded. The HDI was also significant, but it was correlated with GDP, and caused GDP to be non-significant, and so it was also discarded from the final model.

Table 40 Results of local resource regressions

	Local Resource	
Variable	**Softwood**	**Hardwood**
GDP	1.22***	1.07***
Price	-0.82***	-0.82***
Softwood	-0.18***	
Hardwood		0.05

****p-value <0.01*
***p-value >0.01<0.05*
**p-value >0.05<0.10*

Of the local resource variables, only the variable for the softwood harvest was significant, so it was used in the final model, but hardwood was not.

The results show that GDP and price are consistently significant and showing the correct sign. Not all other variables show significant results. The only models where the added variables improved the model were for the softwood harvest and the tariff wedge. Other variables were discarded.

5.2.7.2 Log Demand Model Regressions

Tables 41 to 43 show the results from the best regressions from the tests for each variable. The best regression, was the regression that showed the most significant results, with random effects, or the Hausman-Taylor approach where those were applicable.

Table 41 Results of trade barrier regressions

			Trade Barriers		
Variable	**Basic**	**Tariff Wedge**	**NTB Dummy**	**CPI**	**AVE**
GDP	1.15**	0.84***	0.86***	0.84***	0.90***
Price	-0.66***	-0.74***	-0.73***	-0.74***	-0.72***
Tariff Wedge		0.03			
NTB Dummy			0.61		
CPI				-0.06	
AVE					2.89

****p-value <0.01*
***p-value >0.01<0.05*
**p-value >0.05<0.10*

Of the trade barrier variables tested, none showed significant results. This means that no trade barrier variables were carried forward into the final model.

Table 42 Results of competition regressions

	Competition			
Variable	**CAN**	**USA**	**RUS**	**Combined Competitors**
GDP	0.63**	0.67**	0.65**	0.61**
Price	-0.76***	-0.73***	-0.72***	-0.76***
CAN	0.29***			0.22***
USA		0.19***		0.11**
RUS			0.09	0.00

****p-value <0.01*
***p-value >0.01<0.05*
**p-value >0.05<0.10*

There were significant results for Canada and the USA supply when tested together, and when tested separately. These variables were used in the final model, but the non-significant results for Russia were not used in the final model.

Table 43 Results of local resource regressions

	Local Resource	
Variable	**Softwood**	**Hardwood**
GDP	1.41***	1.06**
Price	-0.70***	-0.67***
Softwood	-0.29***	
Hardwood		0.06

****p-value <0.01*
***p-value >0.01<0.05*
**p-value >0.05<0.103*

As with the sawn timber model, the only significant variable for the local resources was for softwood, and hardwood was not significant.

The results that were carried forward into the final model were the Canada and USA competitor effects and the softwood harvest variable.

5.2.7.3 GDP and Price Elasticities

Across these regressions there were several different estimates of the income elasticity of demand and the price elasticity of demand. They were reasonably consistent across the different regressions. Summary statistics for the results from the preferred regressions are shown in Table 44.

Table 44 Summary statistics of elasticity estimates for GDP and Price

	GDP		*Price*	
	Sawn Timber	**Logs**	**Sawn Timber**	**Logs**
Minimum	0.68	0.61	-0.86	-0.76
Maximum	1.32	1.41	-0.67	-0.66
Mean	1.02	0.87	-0.78	-0.72
Median	0.98	0.84	-0.81	-0.73

This shows that the elasticity estimates for GDP were within a much tighter range for sawn timber, they were also less significant for many of the log demand model regressions. However, the estimates for price elasticity of demand were more precise than for sawn timber. GDP and price were both more elastic for sawn timber than for logs.

5.2.7.4 Sawn Timber Model

The combined sawn timber model was tested using the tariff wedge and softwood harvest as variables, as these were the results that were both significant and showing a correct sign. The model was tested first using fixed effects and random effects.

Table 45 Sawn timber demand model with tariff wedge and softwood harvest using fixed effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	1.26	0.35	3.57	0.00
Log(RPRPT)	-0.55	0.21	-2.67	0.01
Log(TW)	-4.03	1.96	-2.06	0.04
Log(SFT)	-0.21	0.05	-4.06	0.00

Table 46 Sawn timber demand model with tariff wedge and softwood harvest using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-11.63	6.33	-1.84	0.07
Log(GDP)	0.99	0.21	4.66	0.00
Log(RPRPT)	-0.77	0.17	-4.63	0.00
Log(TW)	-4.97	1.78	-2.77	0.01
Log(SFT)	-0.17	0.04	-3.95	0.00

```
Hausman Test

data:  log(IV) ~ log(GDP) + log(RPRPT) + log(TWPO
) + log(SFT)
chisq = 19.344, df = 4, p-value = 0.0006724
alternative hypothesis: one model is inconsistent
```

The Hausman test showed that there was a problem with the random effects model, in that there was correlation between the variables and the error term. As with the original tariff wedge model, this was controlled using the Hausman-Taylor approach, where GDP and price are assumed to be exogenous. The resulting regression passes the Hausman test, and so can be used for estimation. The resulting regression had the expected signs for the coefficients and significant results at $p \leq 0.05$.

Table 47 Sawn timber demand model with tariff wedge and softwood harvest using Hausman-Taylor approach

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-10.72	3.98	-2.70	0.01
Log(GDP)	1.01	0.17	5.95	0.00
Log(RPRPT)	-0.96	0.15	-6.25	0.00
Log(TW)	-4.45	2.05	-2.17	0.03
Log(SFT)	-0.11	0.04	-2.71	0.01

Hausman Test

data: log(IV) ~ log(GDP) + log(RPRPT) + log(TWPO
) + log(SFT)
chisq = 7.3457, df = 4, p-value = 0.1187
alternative hypothesis: one model is inconsistent

As the tariff wedge had one added the true elasticity for the tariff wedge is not as shown by this coefficient. For this model the true elasticity of demand for the tariff wedge was -0.25.

Post-test diagnostics cannot be run on the Hausman-Taylor approach using R. Plotting residuals in Excel showed that there was serial correlation for the first five lags, and heteroscedasticity. Lags 1 to 5 were shown to be significant at the 95% confidence interval for serial correlation, which suggests that there is strong serial correlation present. There is a trend towards errors at lower values of y, in the heteroscedasticity plot. This means that at low values there are much larger errors, and the results are biased for the lower values of y.

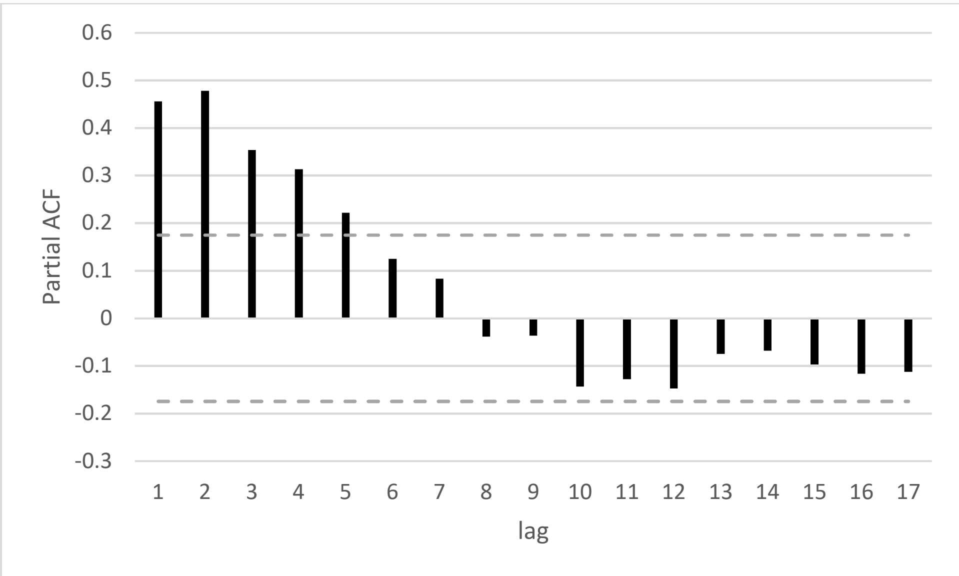


Figure 16 Partial auto correlation function for the sawn timber demand model using the Hausman-Taylor approach

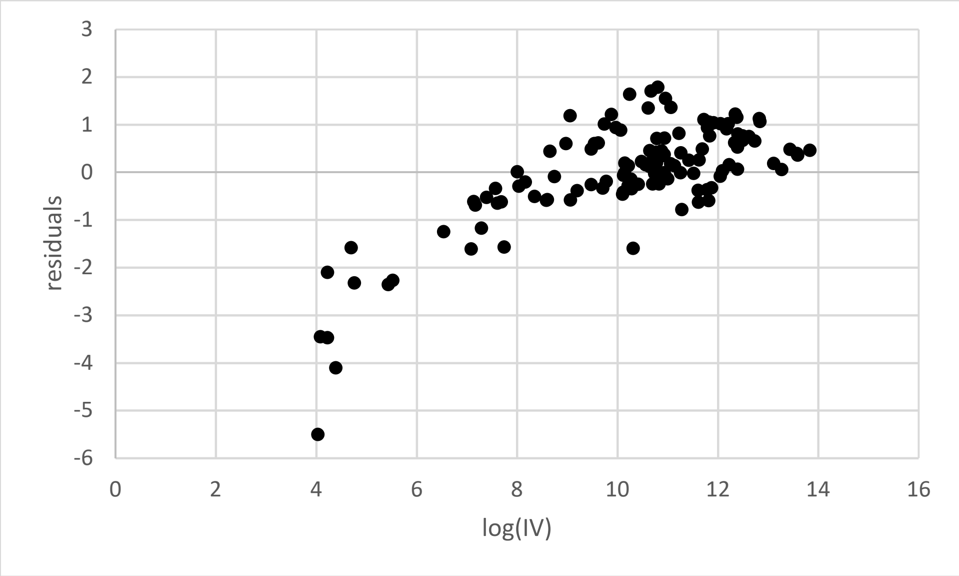
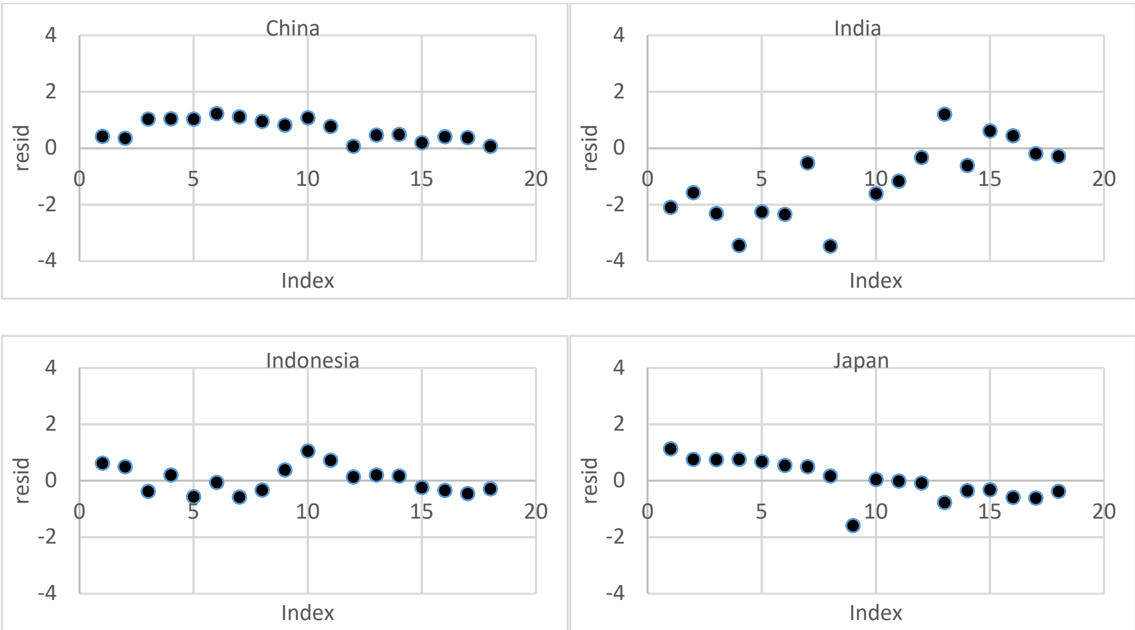


Figure 17 Scatter-plot of residuals vs. log(IV) to show heteroscedastic effects



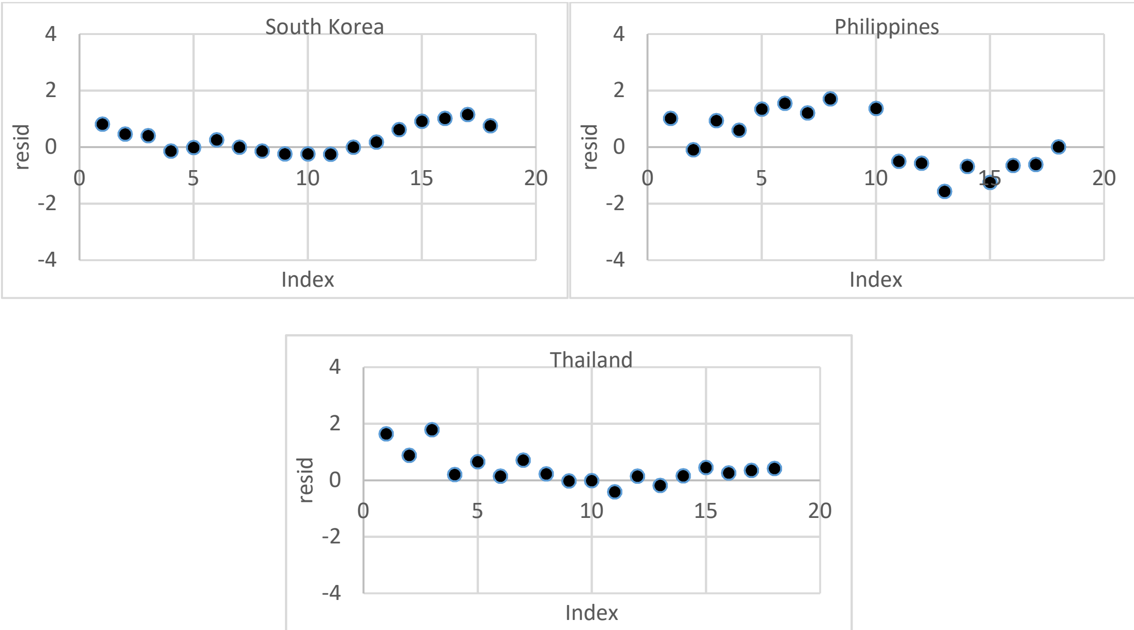


Figure 18 Residual plots for sawn timber model with tariff wedge and softwood harvest using Hausman-Taylor approach

The average random effects for each country of the Hausman-Taylor model are shown in Table 48 below. This shows the individual error for the countries in the panel. This is the difference between the intercept for the country and the general intercept. The random effects allow for differences between the countries not observed in the model to be incorporated into the error term. Most of the differences would be explained by the differences in currencies, although there are some effects not in the model that would come into this error term. By using panel data and allowing individual effects between countries to be internalised into the error term, it has allowed for different currencies to be used between the countries. The elasticities can be held constant between different countries, while the effect that currency has on the overall difference between measures of GDP and price between countries is incorporated into the error term.

Table 48 Random effects for final sawn timber model using Hausman-Taylor approach

Country	*Random Effect*
China	0.59
India	-1.69
Indonesia	-0.10
Japan	-0.13
Philippines	-0.22
South Korea	0.20
Thailand	0.36

Post-test diagnostics were also run for the fixed effects model. This showed that it did not have a serial correlation issue, though heteroscedasticity is present, and the heteroscedastic robust standard errors show not all coefficients were robust to heteroscedasticity, which means that it could be biased.

Table 49 Sawn timber demand model with tariff wedge and softwood harvest showing heteroscedastic and auto correlation robust standard errors using fixed effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	1.26	0.50	2.51	0.01
Log(RPRPT)	-0.55	0.36	-1.51	0.13
Log(TW)	-4.03	3.36	-1.20	0.23
Log(SFT)	-0.21	0.04	-5.39	0.00

```
Breusch-Godfrey/Wooldridge test for serial correlation in panel
models

data:  log(IV) ~ log(GDP) + log(RPRPT) + log(TWPO) + log(SF
T)
chisq = 24.602, df = 18, p-value = 0.1363
alternative hypothesis: serial correlation in idiosyncratic errors
```

```
studentized Breusch-Pagan test

data:  ST
BP = 21.739, df = 4, p-value = 0.0002258
```

5.2.7.5 Log Demand Model

5.2.7.5.1 Optimum Model

The log demand model was tested using both an optimum model, and a model that uses the same variables as the sawn timber model, as a direct comparison. The optimum model uses the variables that were tested as significant, and showing the correct signs in the initial models. These are the softwood harvest, and the competitor effects of Canada and USA. The model was tested using fixed and random effects.

Table 50 Log demand model with softwood harvest and competitor effects using fixed effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	0.76	0.42	1.79	0.08
Log(LOGPRPT)	-0.77	0.12	-6.46	0.00
Log(SFT)	-0.26	0.07	-3.94	0.00
Log(CAN)	0.20	0.07	2.95	0.01
Log(USA)	0.11	0.05	2.11	0.04

Table 51 Log demand model with softwood harvest and competitor effects using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-7.50	6.40	-1.17	0.24
Log(GDP)	0.75	0.21	3.57	0.00
Log(LOGPRPT)	-0.80	0.11	-7.02	0.00
Log(SFT)	-0.09	0.06	-1.67	0.10
Log(CAN)	0.24	0.07	3.47	0.00
Log(USA)	0.07	0.05	1.73	0.09

The model did not pass the Hausman test, so was assumed to have variables correlated with the error term. Testing with the Hausman-Taylor approach did not correct for this bias in the model, so in this case, the fixed effects model is preferred.

```
Hausman Test

data:  log(LIV) ~ log(GDP) + log(LOGPRPT) + log(S
FT) + log(CAN) + log(USA)
chisq = 18.68, df = 5, p-value = 0.002204
alternative hypothesis: one model is inconsistent
```

```
Breusch-Godfrey/Wooldridge test for serial correlation in panel
models

data:  log(LIV) ~ log(GDP) + log(LOGPRPT) + log(SFT) + log(
CAN) + log(USA)
chisq = 58.574, df = 15, p-value = 4.428e-07
alternative hypothesis: serial correlation in idiosyncratic errors
```

```
studentized Breusch-Pagan test

data:  LOG
BP = 11.268, df = 5, p-value = 0.04631
```

Post-test diagnostics show that there was an issue with serial correlation, and with heteroscedasticity, which is not overcome using heteroscedastic robust standard errors.

Table 52 Log demand model with softwood harvest and competitor effects using fixed effects – heteroscedastic robust standard errors

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	0.76	0.72	1.05	0.30
Log(LOGPRPT)	-0.77	0.07	-11.10	0.00
Log(SFT)	-0.26	0.04	-5.91	0.00
Log(CAN)	0.20	0.11	1.85	0.07
Log(USA)	0.11	0.07	1.57	0.12

The fixed effects for this model are shown in Table 53 below. These show the different intercepts for each country. The country specific fixed effects incorporate the differences in exchange rates between the countries.

Table 53 Fixed effects for optimum log demand model with softwood harvest and competitor effects

Country	*Fixed Effect*
China	-3.49
India	-2.43
Indonesia	-9.27
Japan	-4.81
Philippines	-9.13
South Korea	-2.03
Thailand	-8.93

5.2.7.5.2 Comparison Model

The model that mimics the sawn timber model, for the purposes of comparison, was tested in fixed effects and random effects models. The model did not pass the Hausman test, so was assumed to have variables correlated with the error term. Testing with the Hausman-Taylor approach did not correct for this bias in the model, so in this case also, the fixed effects model was preferred. The fixed effects model shows strong evidence of serial correlation, and heteroscedasticity, and the heteroscedastic robust standard errors show that GDP may not be robust to heteroscedasticity.

Table 54 Log demand model with softwood harvest and tariff wedge using fixed effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	1.50	0.51	2.97	0.00
Log(LOGPRPT)	-0.69	0.13	-5.39	0.00
Log(TW)	0.97	2.80	0.35	0.73
Log(SFT)	-0.30	0.07	-4.15	0.00

Table 55 Log demand model with softwood harvest and tariff wedge using random effects

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Intercept	-15.012	10.14	-1.48	0.14
Log(GDP)	1.12	0.32	3.52	0.00
Log(LOGPRPT)	-0.77	0.12	-6.20	0.00
Log(TW)	0.48	2.66	0.18	0.86
Log(SFT)	-0.21	0.7	-3.04	0.00

```
Hausman Test

data:  log(LIV) ~ log(GDP) + log(LOGPRPT) + log(T
WPO) + log(SFT)
chisq = 14.642, df = 4, p-value = 0.005505
alternative hypothesis: one model is inconsistent
```

Table 56 Log demand model with softwood harvest and tariff wedge using fixed effects – heteroscedastic robust standard errors

Co-efficient	*Estimate*	*Std. Error*	*t-value*	*P-value*
Log(GDP)	1.50	0.94	1.60	0.11
Log(LOGPRPT)	-0.69	0.13	-5.52	0.00
Log(TW)	0.97	4.17	0.23	0.82
Log(SFT)	-0.30	0.04	-6.65	0.00

The fixed effects for each country are shown below. The fixed effects shown are the different intercepts for each country. As with the other models the variance between the intercepts incorporates the differences in exchange rates.

Table 57 Fixed effects for log demand model with softwood harvest and tariff wedge

Country	*Fixed Effect*
China	-22.59
India	-24.37
Indonesia	-34.67
Japan	-25.87
Philippines	-28.67
South Korea	-25.02
Thailand	-29.35

5.2.7.5.3 Softwood Harvest Comparison

In order to compare the effect of the softwood harvest on demand for sawn timber and for logs, confidence intervals are found for the softwood harvest variables. This shows an overlap of the coefficient range at 95% confidence for softwood harvests in the log and sawn timber demand models.

Table 58 95% confidence intervals for swan timber demand model and log demand model

Model	***5%***	***95%***
Softwood demand model	-0.19	-0.03
Log demand model	-0.44	-0.16

5.3 Application of the Model

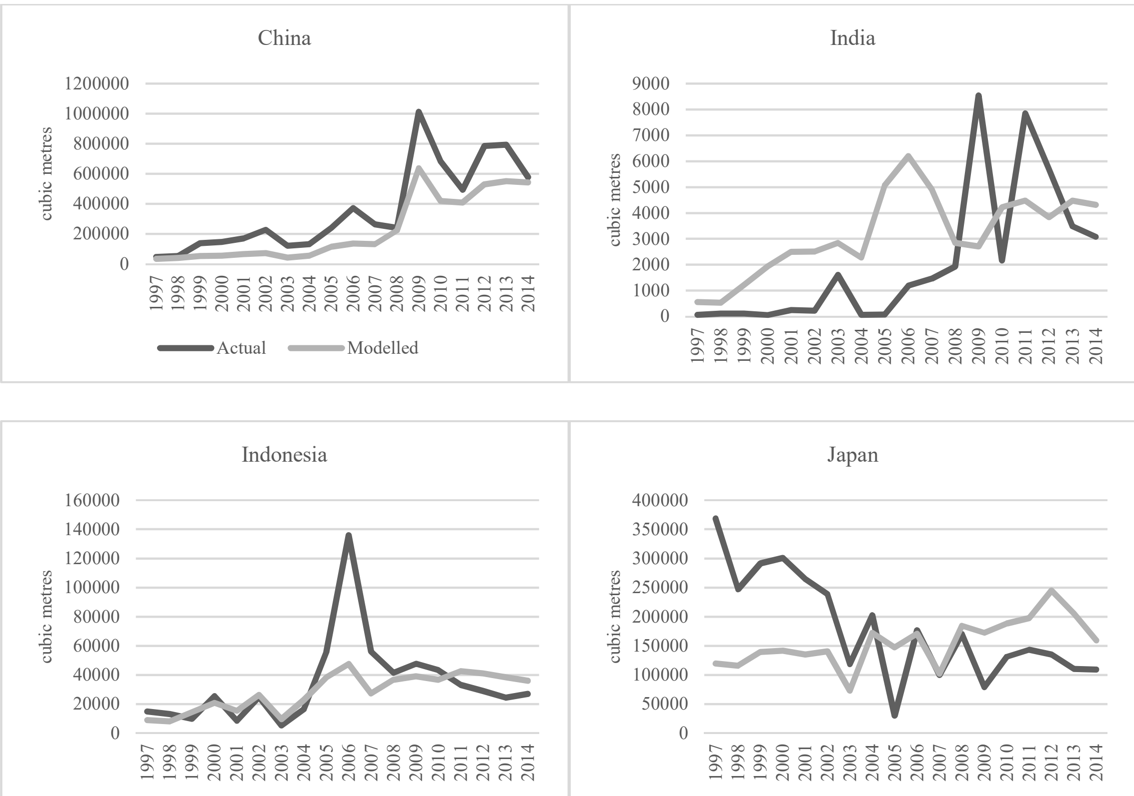
5.3.1 Country Estimates – Sawn Timber

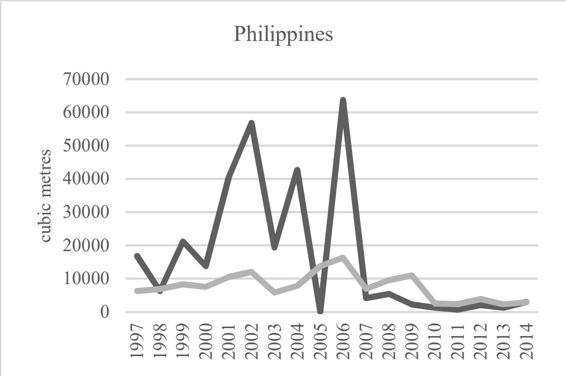
The modelled sawn timber imports compared to actual trade for each country revealed some inconsistencies in the models for sawn timber. Figure 19 below has the comparisons for each country. Mean Absolute Percentage Errors (MAPE) were calculated for the models predicting power in each country (Hyndman & Athanasopoulos, 2013). The limited availability of time series data has meant that this test is carried out on the same data that was used for the model, rather than an independent dataset. This means the results will be biased, although still useful for testing the relative accuracy of the model prediction between countries.

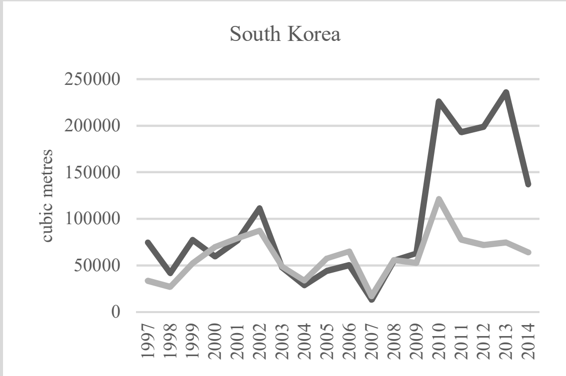
Table 59 Mean Absolute Percentage Errors for model predictions of each country's trade

Country	*MAPE*
China	5.3%
India	31.5%
Indonesia	4.0%
Japan	4.7%
Philippines	17.2%
South Korea	3.7%
Thailand	4.5%

The only countries for which the model was significantly worse than the others were India and the Philippines, where data was very volatile. China was relatively accurate, with movements consistent with actual movements. However, the model consistently underestimated trade in China. The model overestimated trade for the earlier years in India, and then failed to predict the volatility of trade between 2008 and 2014. This is a common issue for India, where data measurement errors lead to unexpected volatility. The model was accurate for Indonesia but didn't catch the large spike in 2006. Philippines data was not accurate for the earlier volatile years, but was for the years since 2009. In Japan, the movements from year to year appeared to match the actual trade, but there was a downward trend that wasn't captured by the model. This could be due to less population growth in Japan. In the other countries analysed, GDP growth is often associated with population growth, which leads to more building, but this is not the case in Japan. South Korea was very accurate until a large and permanent spike in imports in 2009 was missed by the model, this increase is similarly shown in New Zealand's export figures, so is unlikely to be a data error. This suggests that there may have been some shift in the export product exported to South Korea that has led to the higher demand. The model is accurate for Thailand.







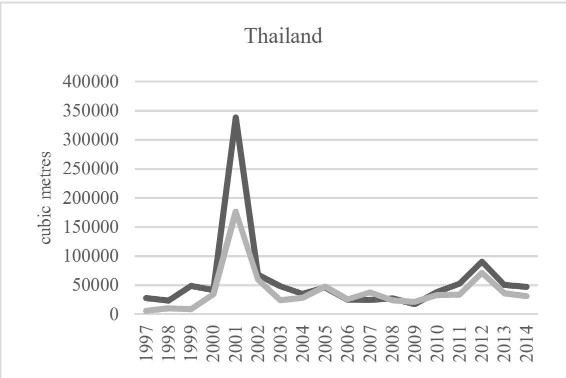


Figure 19 Actual import data and modelled imports for each country

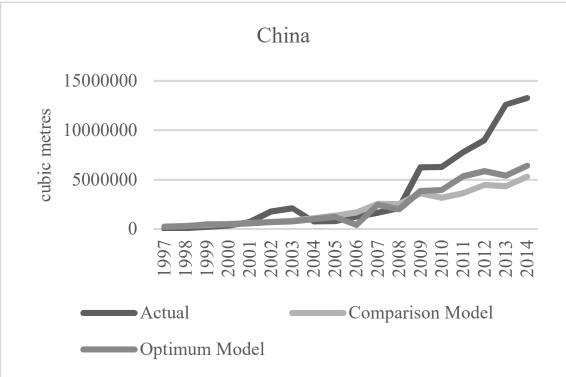
5.3.2 Country Estimates – Logs

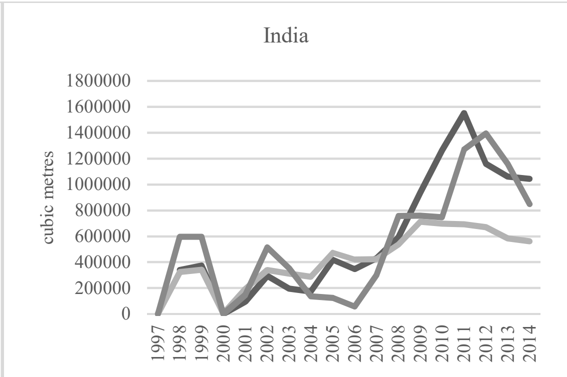
The MAPE results for each country show that the log models were inaccurate for the countries where the majority of exports were sawn timber, but much better for the log importing countries. As expected, the optimum log model models trade more accurately than the comparison model, with a smaller MAPE for every country modelled. The MAPE results for the log models are more accurate than the MAPE results for the sawn timber model. This is unsurprising, given that the overall r-squared results were also higher for the log models.

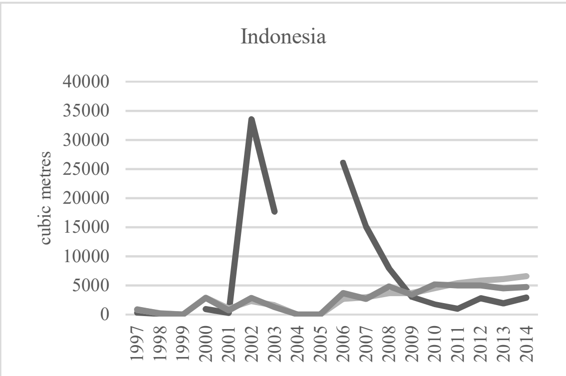
Both models underestimated the increase in imports from China, and only the optimum model captured the increase in trade to India. Both models had similar results for South Korea and Japan, which missed the downward trend in both countries. Results are shown in Figure 20 below.

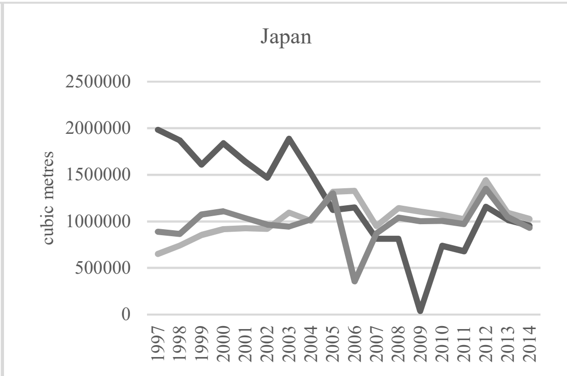
Table 60 Mean Absolute Percentage Error for each country in final log demand models

Country	*MAPE Comparison Model*	*MAPE Optimum Model*
China	5.5%	5.1%
India	4.0%	4.2%
Indonesia	16.5%	14.9%
Japan	4.7%	4.5%
Philippines	20.1%	18.7%
South Korea	2.6%	2.5%
Thailand	16.4%	12.5%









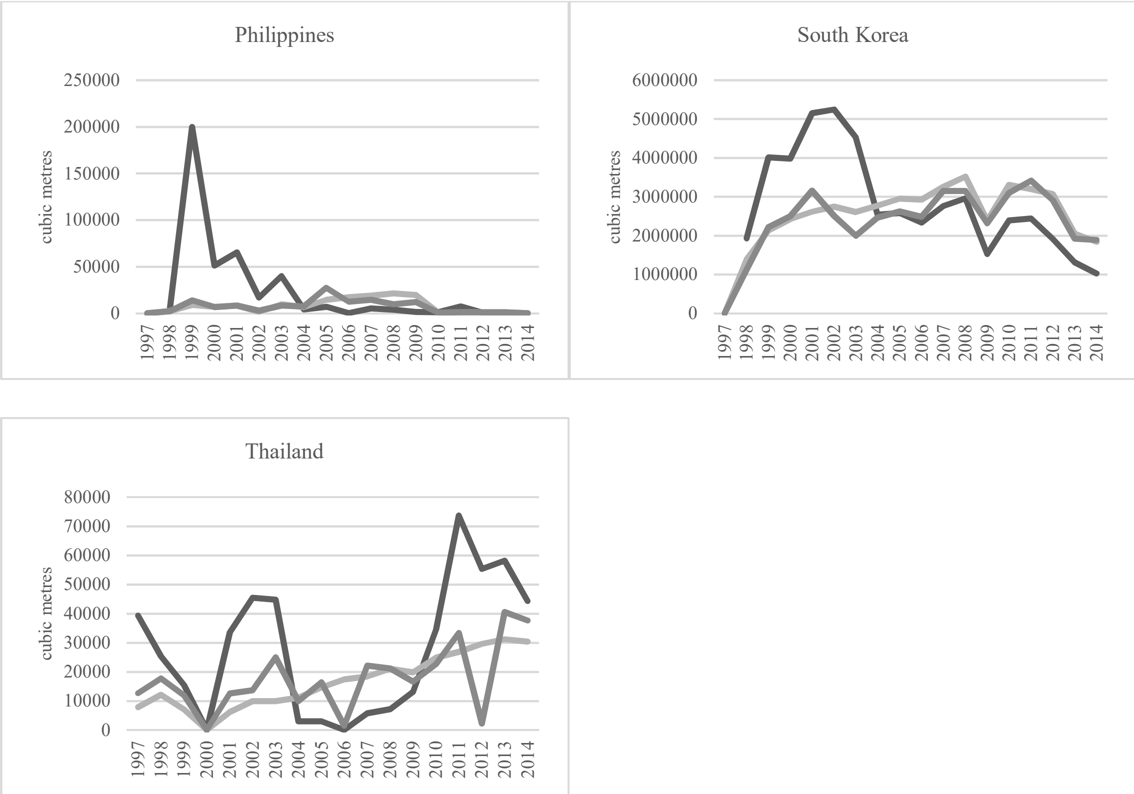


Figure 20 Log demand models country results compared to actual

5.3.3 Policy Applications

5.3.3.1 Tariff Removal

The models tested in the final model section of the results were used to evaluate the effects that the variables have on exports of sawn timber and logs. The first comparisons were on the effect of tariffs. Trade in 2014 was estimated using the models for sawn timber and logs, and then modelled again with all tariffs removed. Tariffs have two effects, on the import price, and in the tariff wedge, the effect of each is shown.

Tariffs are still present in three of the seven countries modelled; India, Thailand and South Korea. This means that tariffs can only be having a small effect on the difference between sawn timber and log exports overall. Figure 21 shows the effect of tariffs on sawn timber demand in each of these three countries. Figure 22 shows the split between the price effect and the tariff wedge effect.

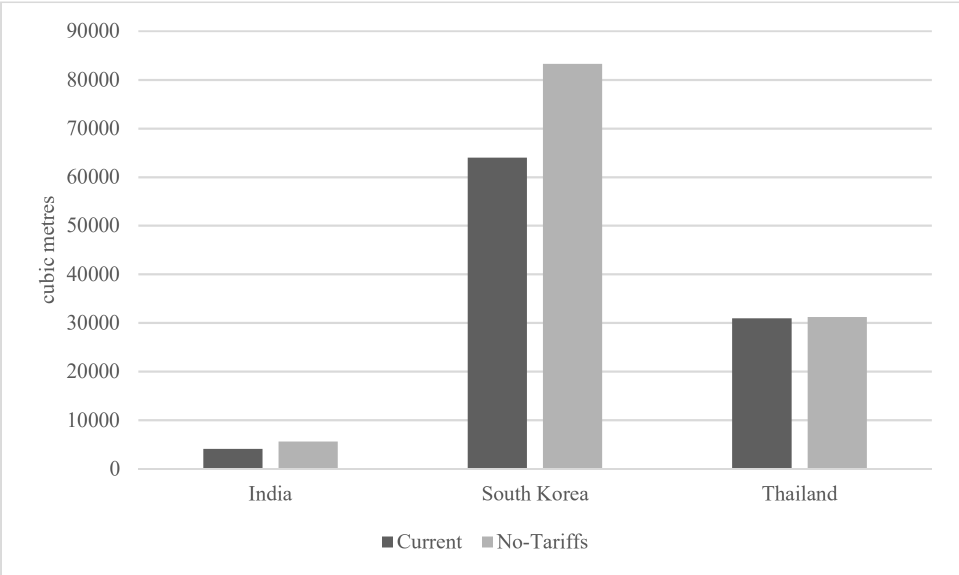


Figure 21 Modelled outputs of 2014 sawn timber trade, with and without tariffs

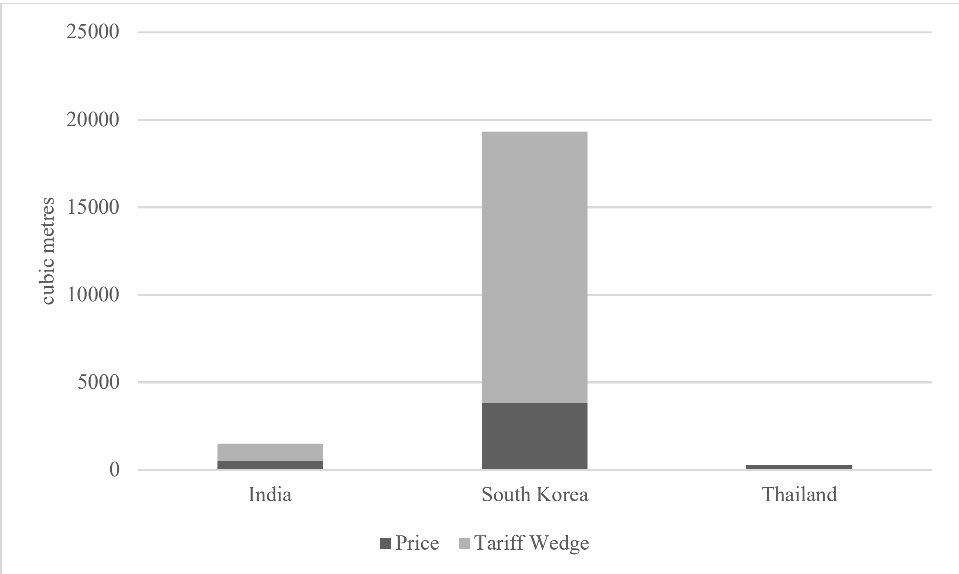


Figure 22 Tariff price and tariff wedge effects on sawn timber demand

Trade is very small in India, and in Thailand there is just a 1% tariff, that is matched in log tariffs so there is no tariff wedge. In South Korea, however, trade is significant, and the sawn timber tariff is 5%, while there are no tariffs on log imports. This shows that without tariffs

South Korea would demand significantly more sawn timber from New Zealand. Modelled trade in 2014 would increase from 63,949 m^3 to 83,267m^3, a difference of 30%.

Overall, if all tariffs were removed, modelled trade in 2014 would increase from 838,752 m^3 to 859,857 m^3, a change of just 2.5%. This is unsurprising as tariffs have been removed in most countries covered by this study.

5.3.3.2 Historical Tariff Effects

Historically tariffs had a very large effect. In countries where they have been removed the trade of sawn timber has increased, sometimes significantly. Of the countries studied, 4 have reduced tariffs as a result of Free Trade Agreements (FTAs); China, Indonesia, Philippines, and Thailand (a free trade agreement was signed with South Korea in 2015). Figure 23 shows the change in 2014 modelled sawn timber imports, if the tariff rate imposed directly before the FTA was signed remained in place. Figure 24 shows the split between the price effect and the tariff wedge effect.

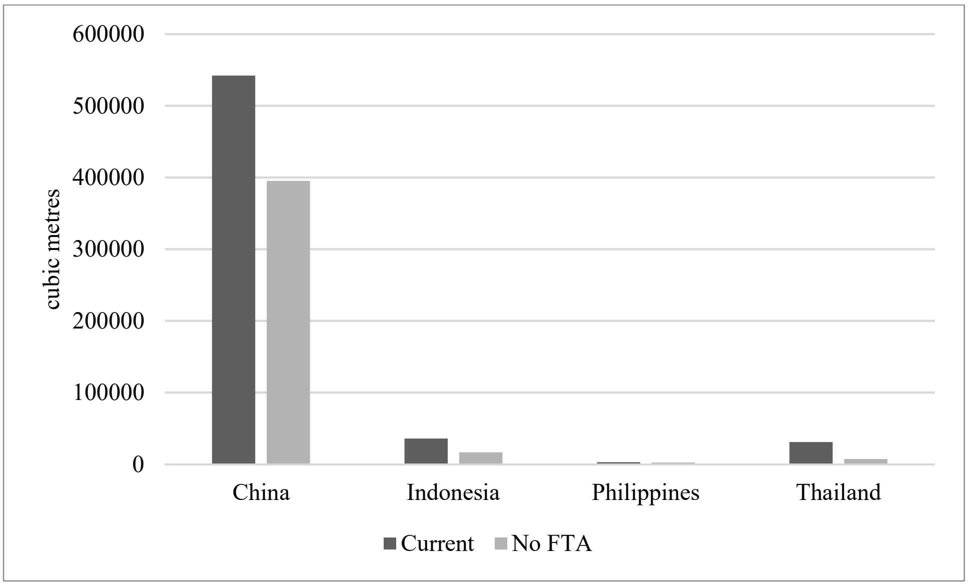


Figure 23 Difference in import demand for sawn timber due to the removal of historical tariffs

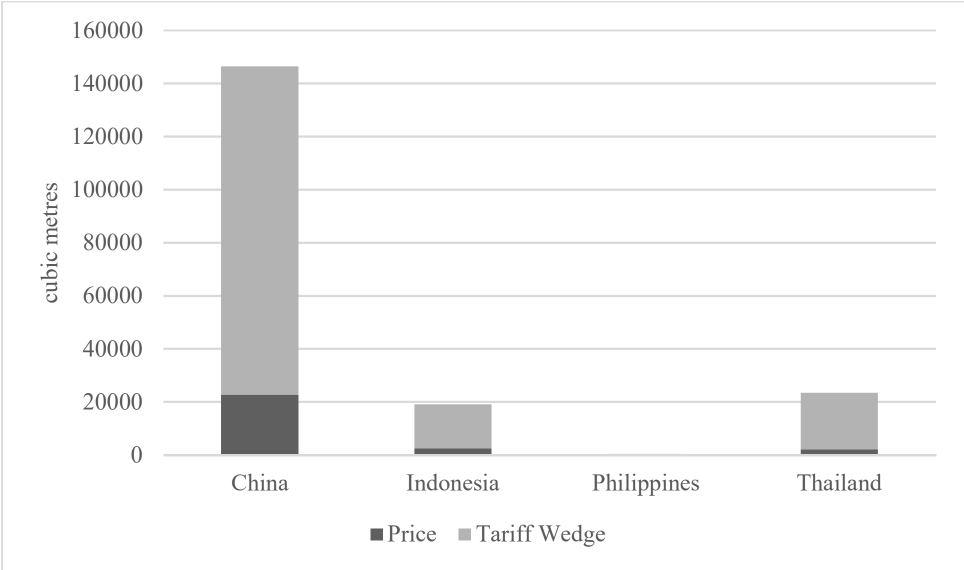


Figure 24 Tariff price and tariff wedge effects on annual demand for sawn timber

In China the removal of tariffs is estimated to have contributed to demand for 146,500m³ in added demand in 2014, and 895,791m³ since the implementation of the FTA. The effect of the China FTA is shown in more detail in Figure 25, where the counterfactual, tariffs and the tariff wedge remaining in place is also modelled. The figures used are shown in Table 61. For Indonesia annual demand in 2014 is increased by 19,115m³, in the Philippines it is just 434m³, and in Thailand it is 23,372m³.

Table 61 Comparison of model outputs for China imports with and without free trade with New Zealand

	Softwood Harvest	*GDP (Chinese Yuan 2010 Currency, no tariffs)*	*Real Price (Chinese Yuan 2010 Currency)*	*Status Quo Tariffs*	*Tariffs Remain*	*Status Quo Estimate*	*No FTA Estimate*
1997	68.7	2,616	2,773	6.0%	6.0%	34,133	34,133
1998	68.7	2,382	2,525	6.0%	6.0%	40,477	40,477
1999	64.1	1,919	2,035	6.0%	6.0%	54,034	54,034
2000	61.8	2,004	2,124	6.0%	6.0%	56,175	56,175
2001	60.0	1,866	1,978	6.0%	6.0%	65,580	65,580
2002	59.5	1,845	1,956	6.0%	6.0%	72,443	72,443
2003	60.8	3,467	3,675	6.0%	6.0%	43,502	43,502
2004	60.8	2,991	3,171	6.0%	6.0%	55,224	55,224
2005	60.8	1,552	1,645	6.0%	6.0%	115,541	115,541
2006	60.8	1,465	1,552	6.0%	6.0%	137,349	137,349
2007	34.6	1,868	1,980	6.0%	6.0%	132,622	132,622
2008	33.0	1,656	1,656	0.0%	6.0%	224,771	163,997
2009	34.5	610	610	0.0%	6.0%	637,619	465,218
2010	31.5	1,059	1,059	0.0%	6.0%	420,389	306,723
2011	29.4	1,209	1,209	0.0%	6.0%	408,559	298,092
2012	26.6	1,012	1,012	0.0%	6.0%	529,056	386,009
2013	29.5	1,037	1,037	0.0%	6.0%	550,832	401,896
2014	25.7	1,154	1,154	0.0%	6.0%	541,824	395,324

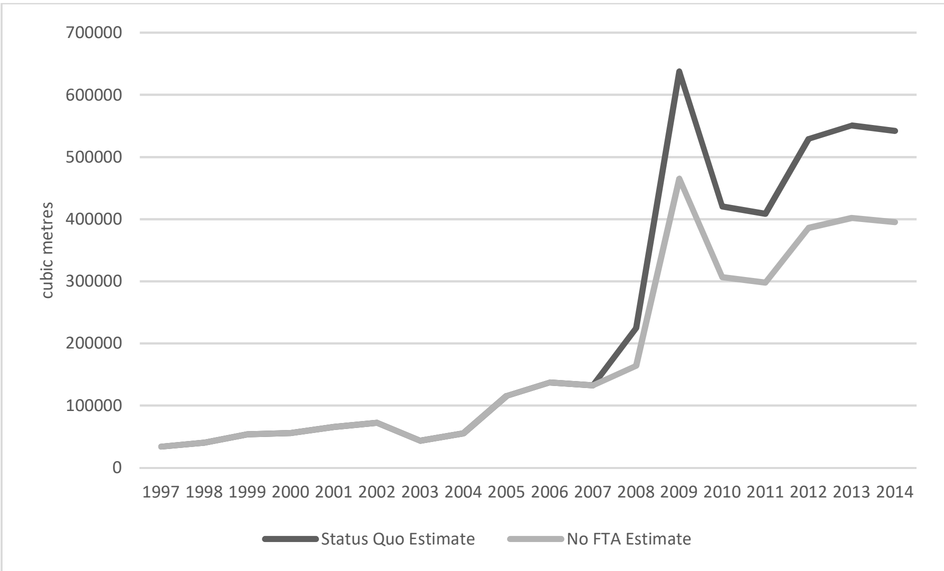


Figure 25 Effect of tariff removal on historical sawn timber demand in China

As Maplesden and Horgan (2016) state there is a non-tariff barrier in China in the form of a different value added tax being applied to logs and sawn timber. The sawn timber tax is higher (17% compared with 13%), and therefore it acts in the same way as a tariff wedge. The effect of removing this was modelled by using a negative tariff wedge value for China in 2014. The effect is an increase in sawn timber demand from 541,824 m³ to 675,727 m³, a change of 24.7%.

5.3.3.3 South Korea FTA Assessment

In 2015 an FTA between New Zealand and South Korea was signed. Under the agreement, South Korean import tariffs for New Zealand sawn timber would fall from 5% to 0%, phased out over 6 years. By assuming a constant real GDP growth rate at the 2014 six-year average, and constant prices, the effect of the sawn timber tariff phase out can be estimated. By the time tariffs are to be completely phased out in 2021, projected imports were 108,050 m³, which is 25,067 m³ higher than projected imports with a 5% tariff rate, an increase of 30.2%. Over the six years of tariffs being phased out, imports were projected to be 68,825 m³, or 15.7% higher, and in the five years following, imports were projected to be 135,203 m³, or 30.2% higher. The projections and assumptions are shown in Table 62 and Figure 26.

Table 62 Comparison of model output with tariffs eliminated in 2015 FTA and with no FTA

	Softwood Harvest (thousand m³)	*GDP (Korean Won 2010 Currency, no tariffs)*	*Real Price (Korean Won 2010 Currency)*	*Status Quo Tariffs*	*Tariff Phase Out*	*Status Quo Tariffs*	*Tariffs Phased Out*
2014	2,801	1,430	208	5.0%	5.0%	63,949	63,949
2015	2,801	1,484	208	5.0%	3.3%	66,380	72,509
2016	2,801	1,539	208	5.0%	3.5%	68,896	74,474
2017	2,801	1,597	208	5.0%	2.8%	71,508	80,188
2018	2,801	1,656	208	5.0%	2.1%	74,219	86,361
2019	2,801	1,718	208	5.0%	1.4%	77,032	93,034
2020	2,801	1,783	208	5.0%	0.7%	79,952	100,248
2021	2,801	1,849	208	5.0%	0.0%	82,983	108,050
2022	2,801	1,919	208	5.0%	0.0%	86,129	112,146
2023	2,801	1,990	208	5.0%	0.0%	89,394	116,397
2024	2,801	2,065	208	5.0%	0.0%	92,783	120,810
2025	2,801	2,142	208	5.0%	0.0%	96,300	125,389

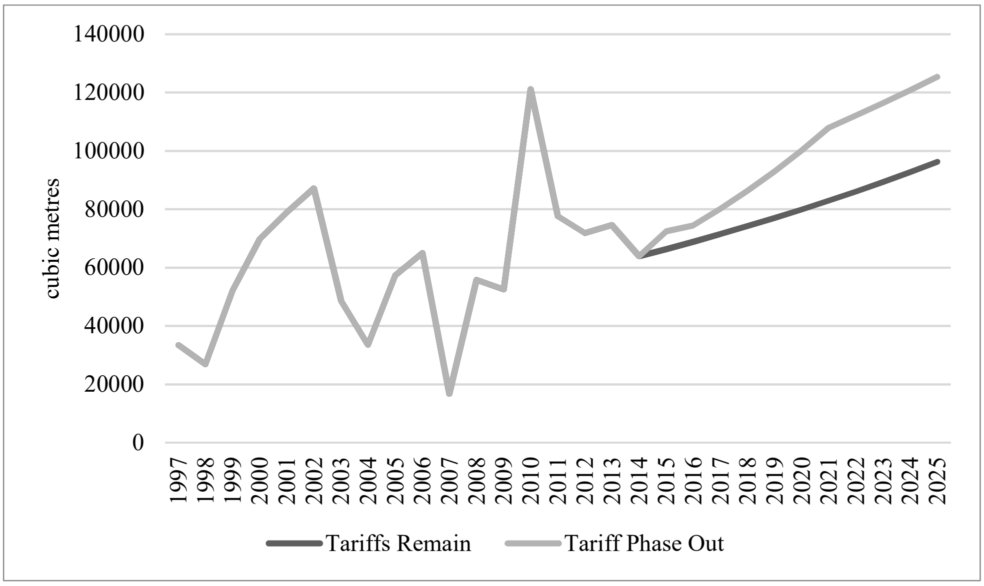


Figure 26 Comparison of model output with tariffs eliminated in 2015 FTA and with no FTA

5.3.3.4 Removal of Tariffs for Log Trade

The comparative log model was also tested to show the effect of removing tariffs on demand for logs. Overall for the three countries that still have tariffs, estimated imports of logs in 2014 would have dropped 92,200 m³, or 1.1% if tariffs were removed. The largest difference would be seen in South Korea, where imports would be expected to fall 4.6%, from 1,841,907 m³ to 1,756,937 m³ in 2014. Trade in India would be expected to drop slightly, 1.3%, as the negative change in the tariff wedge is offset by the increase in trade due to the price effect of removing tariffs. Thailand's imports would be expected to increase slightly, as there is no tariff wedge there, and removing the tariff would increase trade due to the price effect.

5.3.3.5 Effect on Import Preferences

Proportional changes that were modelled due to tariff reductions were added to New Zealand's export data to see whether it changed the log or sawn timber market status. This couldn't be applied to the modelled data, as the initial analysis used the share of exports as a proportion of total, and not all markets are modelled. This showed that although South Korea's shares of exports for sawn timber and logs would become much closer without tariffs, India and Thailand would be largely unaffected. If the value-added tax differential in China was treated as a tariff wedge and removed, the change in sawn timber demand would not fully explain the difference between the sawn timber and log trade.

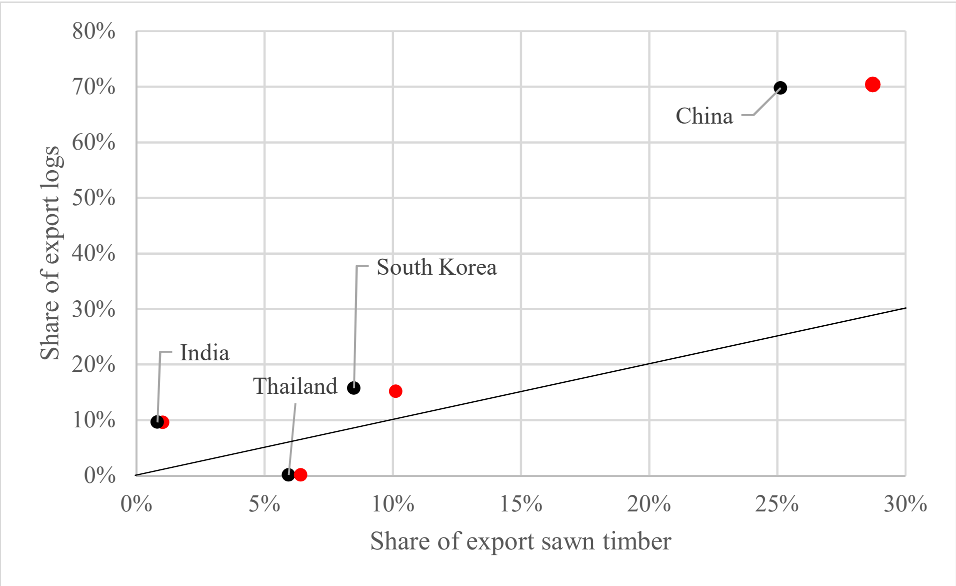


Figure 27 Comparison between import demand for logs and sawn timber with (black) and without (red) tariffs (China without VAT)

6. Discussion & Conclusions

6.1 Discussion of Results

6.1.1 Data Quality

Kennedy (2008) describes the difference between econometric theory and the realities of using econometric data, "Unfortunately, unpleasant realities of real-world data force applied econometricians to violate the prescriptions of econometric theory as taught by our textbooks". He discusses the importance of practical use of the 'rules' of econometrics and understanding the bounds and limits of data and econometric techniques. Not all data will be well behaved, and some regressions will be biased, but it is important to understand what risks are being taken and what the potential causes and results of these biases are.

The final models developed had reasonable coefficients, and significant results, but were not immune to bias. Serial correlation in the errors and the presence of heteroscedasticity mean that the results could be biased in some form. The final models also had relatively low adjusted R squared values.

Table 63 Adjusted r-squared and potential biases of final models

Model	***Adjusted R-squared***	***Heteroscedasticity Robust***	***Serial Correlation***
Sawn Timber	0.29	Unknown	Present
Log Comparison	0.31	No	Present
Log Optimum	0.42	No	Present

It is likely that the heteroscedasticity results for the sawn timber model are influenced heavily by some low readings, that may be data errors, or otherwise unexplained influences. This is shown for sawn timber in Figure 28, where the largest errors are at extremely low values of import volume. Most of these low readings are from India, where the model has not accurately predicted the low sawn timber imports, and the lowest is from the Philippines where there was a drop in imports from 2004 to 2005, which is not explained. This means the model cannot be used to accurately predict low values of import demand.

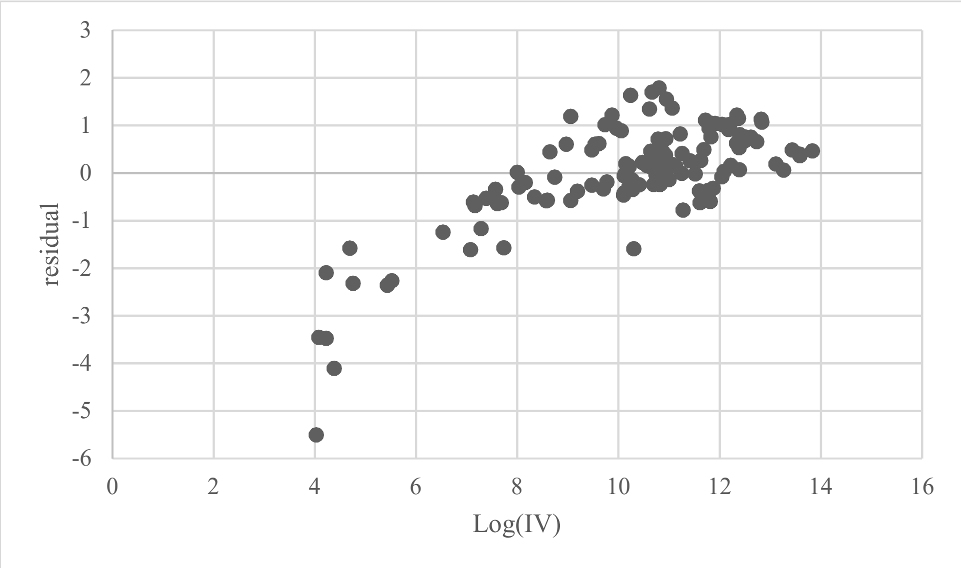


Figure 28 Heteroscedasticity plot for final sawn timber model

The log models did not suffer from these extremes, but still had a slight trend in the errors.

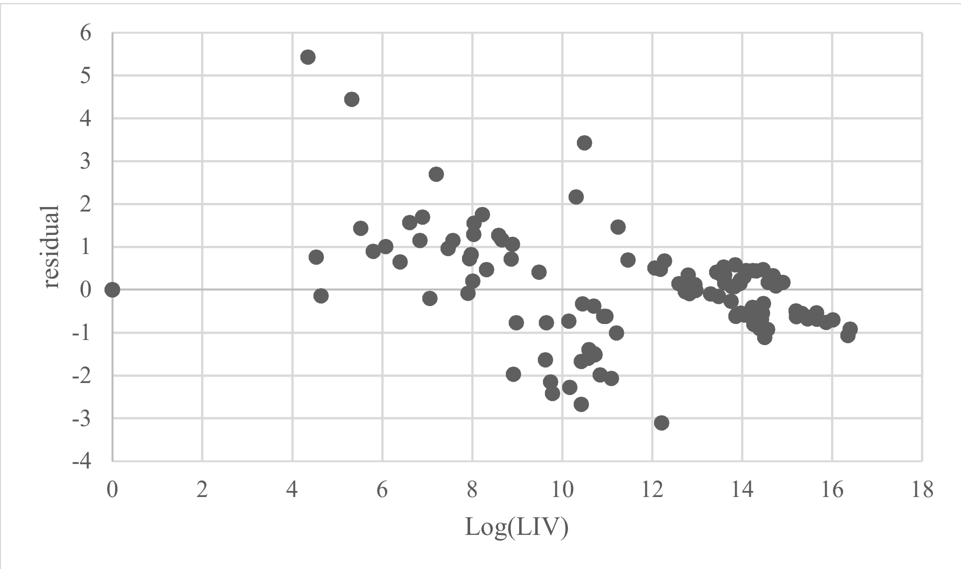


Figure 29 Heteroscedasticity plot for log comparison model

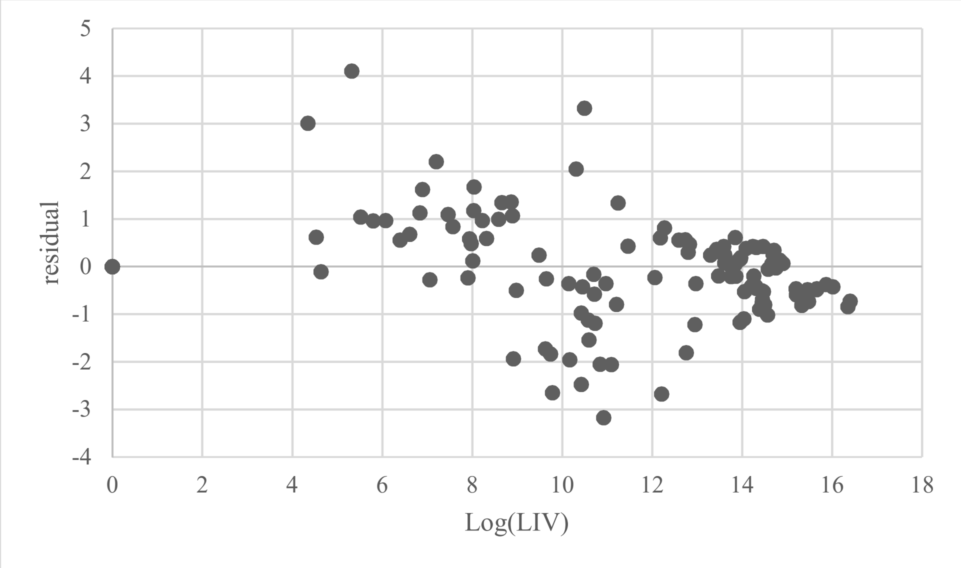


Figure 30 Heteroscedasticity plot for log optimum model

The serial correlation of errors could be caused by a number of different things. Serial correlation is a concern as it suggests that there is some missing variable that can explain the trend in errors. However, this does not necessarily make the estimates for the existing variables biased. The trends could be caused by a lack of precision of the variables used to estimate the models. For example, it could be that rather than demand being driven by GDP, imports are driven by some other macroeconomic factor that is correlated with GDP, such as industrial manufacturing or construction activity. This is quite a likely possibility, as a significant amount of sawn timber and logs are exported for use in construction in China, and industrial pallets in South Korea. There are likely to be similar drivers in other countries. There could also be a global driver that changes demand habits, such as the global financial crisis (to the extent this isn't picked up by GDP changes), or changes in the shipping industry.

It is also possible that supply changes could cause a trend in the errors. Supply preferences outside of those driven by price, such as long term contracts or business relationships, could have caused changing supply preferences over the time frames. This could be an area for future study, developing supply models for New Zealand timber supply.

These imprecisions could also explain the low adjusted r-squared values. Although the low r-squared suggests that there is still a significant amount of variation that is not explained by the model, the focus for this study is the coefficients of the variables rather than the overall predicting power of the model.

6.1.2 Dynamic Models

The dynamic models tested did not appear to make any improvements over the fixed and random effects models. By using a lagged dependent variable, a long-run effect is tested, and the r-squared is typically much higher. By allowing for a trend in the variation from one period to another the serial correlation issue is usually dealt with. However, this just internalises the error into the model, and doesn't actually increase its explanatory power. This can give a false confidence in the high r-squared.

6.1.3 Fixed and Random Effects

The fixed and random effects of the different models can be analysed for what they tell us about the different countries. As the models have shown significant results for a common elasticity of demand for price and GDP across different currencies, it can be concluded that the panel data approach using fixed and random effects is good approach for dealing with variations in currencies between countries. Although most of the difference is expected to be made up by the differences in currencies, this effect cannot be separated out from the other impacts in the error term. This means that there is little of significance that these effects can tell us.

However, in the sawn timber model India has a significantly lower random error than the other countries, despite having a higher exchange rate with the US dollar than other currencies in the model. This means that even when the exchange rates are taken into account, as well as the variables in the model, there is something supressing demand for sawn timber imports from New Zealand that is having a greater effect in India than other countries. This could be many things, such as NTBs, cultural differences, or other effects. Likewise, it can be seen that South Korean demand for sawn timber is higher than others, even after taking into account their low currency.

The effects are less clear for the log demand models, where variation appears to be more in line with the variations in currencies. There is a large difference in the magnitude of the fixed effects between the optimum model and the comparative model. This is not an important distinction, as the larger fixed effects are likely to be offsetting a higher elasticity for GDP, rather, the relative differences between the countries is the more important measure. There is little change in the differences between countries for each of these two models.

6.2 Conclusions

6.2.1 Concluding Statement

The research questions that this study has attempted to answer are:

1) Why does New Zealand export logs to some markets and sawn timber to others?
2) What are the characteristics of these markets that lead to this behaviour?
3) What effect does the removal of tariff barriers have on this behaviour?

In answer to these questions, this study has shown:

Question 1) The imposition of tariffs and non-tariff barriers have a material impact on demand for sawn timber in the markets that New Zealand exports to.

Question 2) Some measurable characteristics are shown to have a material effect. Tariff wedges were found to be suppressing the demand for sawn timber, while not impacting demand for logs, by 2.5% across all of the countries studied. In South Korea the effect was a 30% restriction in demand for sawn timber. Other characteristics, such as non-tariff barriers (NTB), competition effects and local resources, were not shown to have a statistically significant impact. However, it is expected that NTBs are having a material impact on demand for sawn timber, and this study has shown that the differently applied Value Added Tax in China could be suppressing demand for sawn timber from New Zealand by 24.7%.

Question 3) The effect of the removal of sawn timber through Free Trade Agreements (FTA) has increased demand for sawn timber. The study shows that sawn timber demand has increased in countries where tariffs have been removed. In the four countries studied, where FTAs have been signed, there was an estimated collective increase in demand of 189,421 m^3 for the 2014 year alone. An FTA was signed with South Korea in 2015, which will eliminate tariffs on sawn timber imports by 2020. This study estimates that this will result in an increase in demand for sawn timber from New Zealand of 30%.

The outcome from this thesis has clear policy implications for New Zealand government in an international trade context:

1) The pursuit of free trade agreements and tariff reduction is a good investment of government resources and should be continued.
2) Tariff reduction should target the elimination of tariff escalation. This practice causes an overweight drop in demand for higher value goods from New Zealand.

3) Non-tariff barriers can be at least as influential on the demand for imports from New Zealand as tariff barriers. Identification and removal of non-tariff barriers should remain a high priority for all trade negotiations.

These implications are also important from a strategic point of view for the forestry industry. As mentioned in the Rationale for Research 2.1, Evison (2016) states that in order to reach its full economic potential, the industry must obtain a shared view of the significant barriers to achieving the strategy and action to mitigate these barriers. This study has brought further understanding to this topic and provides rationale for government engagement with industry on NTBs.

Other hypotheses that have been modelled to answer the questions have been inconclusive. There is no clear evidence that competition from other sawn timber suppliers, or from the domestic market leads to log imports being preferred. While it seems also that the local resource determines to some extent how much demand there is for imported softwood, it probably doesn't lead to any preference between logs or sawn timber as the import supply.

6.2.2 Elasticities of GDP and Price

Results across all the regressions, shown in Table 44, suggest that for sawn timber, demand is approximately unit elastic for GDP and inelastic for price. Demand is less elastic for logs, for both GDP and price. This is consistent with economic theory, which says that demand for finished goods is more elastic than for raw materials (Layard & Walters, 1978). This is due to demand for raw materials typically entering into a manufacturing process which can't scale up and down as quickly as direct demand for the end use (Layard & Walters, 1978).

As the price elasticity of demand is higher for sawn timber, there is a correspondingly greater impact of applying a tariff to sawn timber imports. In the final models the price elasticity of demand for sawn timber is -0.96 which means applying a 10% tariff, thereby increase the price by 10% will reduce demand by 9.6%. For the final log demand model, the price elasticity of demand is -0.69, which means a 10% tariff would reduce demand by 6.9%.

6.2.3 Tariffs

The evidence shown in this model suggests that demand for both sawn timber and logs exported from New Zealand is negatively impacted by tariffs. Tariffs have a significant and measurable impact on the trade of sawn timber and logs when modelled in this study. Tariffs effectively raise the cost of importing timber, and lower returns for exporters, and as a result cause a reduction in the volume demanded. This is shown by the demand models where tariffs are modelled as part of the price, which has a significant and negative coefficient.

Further to this, a tariff wedge is shown to have a significant negative effect on sawn timber demand in addition to the price effect of the tariff. Tariff escalation causes a wedge between the cost of the raw material input and the finished good. The results of this study suggest that even when the negative price effect on demand from tariffs is taken into account, the tariff wedge has an additional negative impact on demand for sawn timber.

The increase in demand for logs due to the increase in the tariff wedge (effectively an increase in price relative to logs) was not shown to be statistically significant. It is likely that for total imports, an increase in the tariff wedge results in an increase in demand for logs, but the effect may not be specific to demand for New Zealand logs.

The effect that the tariff wedge has on sawn timber shows, as evidence has suggested, that sawn timber and logs are substitute goods. With a substitute good, an increase in price relative to its substitute will result in an increase in demand for its substitute, and if the goods have high substitutability the change in demand will be much greater. As the tariff wedge signifies a relative shift in the price between sawn timber and logs, which has an effect on the demand for sawn timber, then it can be concluded that these are substitute goods.

The magnitude of the difference between sawn timber and log markets, however, is not explained by the tariff wedge alone. There are only three countries of the seven studied where tariffs are still in place, and two where there is tariff escalation. These two countries (India and South Korea), are two of the three countries defined as 'log' markets in the scoping study, but would remain 'log' markets after trade is modelled without tariffs.

6.2.4 Non-Tariff Barriers

The demand models were unable to estimate any significant effect of non-tariff barriers. However, this by no means suggests that NTBs are not having a significant effect on trade in some countries. The models showed, by treating the differentially applied VAT in China as a tariff wedge, that sawn timber demand could be being suppressed by 24% due to this measure. Other NTBs could conceivably act in the same way. For example, a subsidy for log unloading from ships, that was not applied to sawn timber would make the delivered cost for logs comparatively cheaper than the delivered cost of sawn timber. Even a 1% cost on sawn timber that isn't imposed on logs could increase the effective tariff wedge, and drop demand for sawn timber by 5.5%, by substituting it for log demand.

The demand models developed here could be used as an effective tool for measuring the impact of NTBs in further studies. A value chain analysis could be used to analyse the costs that NTBs add to the value chain for logs and sawn timber. The total additional costs imposed on sawn timber over logs can then be expressed as an added value equivalent tariff wedge in the demand model.

6.2.5 Competitors

The attempt to model the impact of competitors by modelling their supply of sawn timber was not successful. Unexpected results were found when analysing the effect of competitors in the sawn timber model, and although the results for the log model showed that sawn timber supply from Canada and USA resulted in greater demand for New Zealand logs, this is far from conclusive. As there were significant positive results modelled for the influence of supply from USA and Canada on demand for sawn timber, as well as for logs, it is likely that there is a correlation but not a causation being modelled. Because these are suppliers of softwood around the Pacific Rim, the market is very similar for both Canada and USA supply, and New Zealand supply, so when there is an unexpected increase in demand for New Zealand's supply of softwood timber or logs, it is also seen in demand for Canada and USA logs. There is no good evidence to suggest that New Zealand sawn timber is getting crowded out by sawn timber supply from USA and Canada in these models.

This effect is not seen in demand for Russian products. This is likely due to Russia supplying a slightly different market, through overland border trade in the north of China, the largest market, than Pacific Rim countries. It may even be that changes in Pacific Rim timber demand are due to supply changes from Russia.

Although there has been no evidence to suggest that labour rates have a significant effect on demand for imported sawn timber or logs, this has not been adequately tested due to lack of data. The initial testing and evaluation does not suggest that there is any effect, but there may also be other efficiencies or inefficiencies in processing in certain countries that lead to demand between logs and sawn timber changing.

6.2.6 Softwood Timber Resource

The presence of a softwood timber resource in the importing country does not appear to be a deciding factor between sawn timber and log supply from New Zealand. Although there is a different elasticity of demand for sawn timber and logs due to changes in the local resource, they are not statistically significantly different from one another. As there is a relatively similar negative effect of increases in the local resource on demand for sawn timber and logs, this is likely to be a case of demand for imports, but not overall demand, changing based on supply. When internal supply increases, although there is no difference in total demand, sawn timber and logs will be supplied by the domestic harvest rather than the import market.

There is evidence to suggest that the hardwood and softwood markets operate with relative independence from one another. As hardwood harvest changes have no effect on the demand for imported sawn timber or logs, it is likely that in these markets, softwood and hardwood products are not substitutes.

6.2.7 Conclusion

This study has shed light on the question of why New Zealand exports sawn timber to some markets and logs to others. Using econometric demand models, it has quantified the effect that tariffs and tariff wedges have on the demand for New Zealand's sawn timber and log exports. Using tariff wedges as an individual variable has shown the effect that they have over and above the impact that tariffs have on prices. This effect is shown across different countries through the use of panel data, building on previous work in single country models. Other hypotheses have been tested and found to either warrant further research or have little impact.

This study will support the industry to gain a better understanding of the trade barriers faced for sawn timber exports. It also has policy implications for the New Zealand government, in that tariff and NTB reductions are an important goal for trade policy.

7. References

Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies, 58*(2), 277-297. doi:10.2307/2297968

Ballingall, J., & Briggs, P. (2002). *A look at New Zealand's comparative advantage*. Retrieved from Wellington: https://nzier.org.nz/static/media/filer_public/31/20/3120fa63-79ea-4438-a0a7-8a3fedd87b4e/wp2002-04_new_zealands_comparative_advantage.pdf

Baltagi, B. H. (2013). *Econometric Analysis of Panel Data* (5 ed.). United Kingdom: John Wiley & Sons Ltd.

Bera, A. K., & Jarque, C. M. (1981). Efficient tests for normality, homoscedasticity and serial independence of regression residuals. *Economics Letters, 7*(4), 313-318. doi:http://dx.doi.org/10.1016/0165-1765(81)90035-5

Breusch, T. S. (1978). Testing for autocorrelation in dynamic linear models. *Australian Economic Papers, 17*(31), 334.

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics. *The Review of Economic Studies, 47*(1), 239-253. doi:10.2307/2297111

Brown, C., & Ortiz, G. (2001). *The Forest Processing Investment Environment*. Retrieved from Wellington: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.15.3021&rep=rep1&type=pdf

Buongiorno, J. (1979). Income and price elasticities of demand for sawnwood and wood-based panels: A pooled cross-section and time-series analysis. *Canadian Journal of Forest Resources, 9*(2), 141-148.

Cheng, B., Mei, B., & Wan, Y. (2013). An Econometric Analysis of US Exports of Forest Products. *Forest Products Journal, 68*(7/8), 224-231. doi:10.13073/FPJ-D-13-00045

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series With a Unit Root. *Journal of the American Statistical Association, 74*(366), 427-431. doi:10.2307/2286348

Edgar, M. J., Lee, D., & Quinn, B. P. (1992). *New Zealand Forest Industries Strategy Study*. Wellington: New Zealand Forest Industries Council.

Engle, R. F., & Granger, C. W. F. (1987). Cointegration and error correctio: Representation, estimation and testing. *Econometricia, 55*, 251-276.

Evison, D. (2016). The case for new investment in wood processing in New Zealand. *New Zealand Journal of Forestry, 61*(1), 4-10.

FAO. (2016). *Forestry Production and Trade*. Retrieved from: http://www.fao.org/faostat/en/#data/FO

FAO. (2017). *Forestry Trade Flows* [Trade]. Retrieved from: http://www.fao.org/faostat/en/#data/FT

Forest Owners Association. (2016). *Facts and Figures 2015/16*. Retrieved from Wellington:

Gans, J., King, S., & Mankiw, N. G. (2012). *Principles of Microeconomics* (5th ed.): Cengage Learning Australia.

Gaston, C., & Chang, W.-Y. (2016). A trade flow analysis of the global softwood log market: implications of Russian log export tax reduction and New Zealand log production restriction. *Forestry, 89*(1), 20-35.

Godfrey, L. G. (1978). Testing Against General Autoregressive and Moving Average Error Models when the Regressors Include Lagged Dependent Variables. *Econometrica, 46*(6), 1293-1301. doi:10.2307/1913829

Gonuguntia, S. (2007). New Zealand forestry - an analysis of comparative advantage. *New Zealand Journal of Forestry*, 21-27.

Hall, P. (2016). The Impact of Operating Scale and Exchange Rate on the Profitability of Some Major Wood Processing Option - Analysis Using the Woodscape Model. *New Zealand Journal of Forestry, 61*(1).

Hausman, J. A. (1978). Specification Tests in Econometrics. *Econometrica, 46*(6), 1251-1271. doi:10.2307/1913827

Hausman, J. A., & Taylor, W. E. (1981). Panel data and unobservable individual effects. *Econometrica, 49*, 1377-1398.

Hyndman, R. J., & Athanasopoulos, G. (2013). *Forecasting: principles and practice*.

International Monetary Fund. (2017). *International Financial Statistics*. Retrieved from: http://www.imf.org/en/Data

Jack, M., Barry, L., Hall, P., & Goodison, A. (2013). *WoodScape Study - Technologies and Markets*. Retrieved from Rotorua: http://www.woodco.org.nz/strategic-plans/woodscape

Jack, M., Hall, P., Goodison, A., & Barry, L. (2013). *Woodscape Study - Summary Report*. Retrieved from http://www.woodco.org.nz/strategic-plans/woodscape

Kee, H. L., Nicita, A., & Olarreaga, M. (2009). Estimating Trade Restrictiveness Indicies. *Royal Economic Society, 119*(1), 172-199.

Kennedy, P. (2008). *A Guide to Econometrics* (6 ed.). United Kingdom: Blackwell Publishing.

Layard, P. R. G., & Walters, A. A. (1978). *Microeconomic Theory*. New York, Maidenhead: McGraw-Hill Education.

Maddala, G. S., & Shaowen, W. (1999). A Comparative Study of Unit Root Tests With Panel Data and a New Simple Test. *Oxford Bulletin of Economics & Statistics, 61*(4), 631.

Manley, B., & Evison, D. (2016) Material flow and end-use of harvested wood products produced from New Zealand log exports. Wellington: Ministry for Primary Industries.

Maplesden, F., & Horgan, G. (2016). *Non-tariff barriers to New Zealand forest products trade*. Retrieved from http://www.wpma.org.nz/UserFiles/WPMA/File/WOODCO%20TRADE%20BARRIERS%20Final%20Report%20March%202016.pdf

Ministry for Primary Industries. (2010). *New Zealand Wood Availability Forecasts 2010-2040*. Retrieved from Wellington: http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry

Ministry for Primary Industries. (2015). *December 2015 quarter trade* [Trade]. Retrieved from: http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry

Ministry for Primary Industries. (2017a). *Dec Years Exports By Product 1980-2016*. Retrieved from: http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry

Ministry for Primary Industries. (2017b). *December 2016 quarter production* [Production]. Retrieved from: http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry

Ministry for Primary Industries. (2017c). *Exports of Forestry Products from New Zealand by Main Countries of Destination for the Year Ended December 2016*. Retrieved from: http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry

Ministry for Primary Industries. (2017d). *Production of Rough Sawn Timber 1921-2016* [Annual]. Retrieved from: http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry

Ministry for Primary Industries. (2017e). *Production, trade, and consumption of roundwood, 1996 to most recent*. Retrieved from: https://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/wood-processing/

Ministry of Foreign Affairs and Trade. (2017). *Trade Policy*. Retrieved from Wellington: https://www.mfat.govt.nz/en/trade/nz-trade-policy/

Mohan, S., Khorana, S., & Choudhury, H. (2013). Why Developing Countries Have Failed to Increase Their Exports of Agricultural Processed Products. *Economic Affairs, 33*(1), 48-64. doi:10.1111/ecaf.12000

Moncarz, P. E. (2010). Argentina's import patterns: trade preferences and the extensive margin of trade. *Journal of Economic Policy Reform, 13*(1), 61-85.

New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview 2016*. Retrieved from Wellington: http://www.treasury.govt.nz/economy/overview/2016/nzefo-16.pdf

OECD. (2005). *Looking Beyond Tariffs*: OECD Publishing.

Parajuli, R., Chang, S. J., & Hill, R. C. (2015). How effective is the United States-Canada softwood lumber agreement 2006? An econometric study. *Forest Science, 61*(6), 1041-1049. doi:doi:http://dx.doi.org.ezproxy.canterbury.ac.nz/10.5849/forsci.15-014

Reinert, K. A., Rajan, R. S., Glass, A. J., & Davis, L. S. (2009). *The Princeton Encyclopedia of the World Economy*. New Jersey: Princeton University Press.

Solberg, B., Moiseyev, A., Kallio, A. M. I., & Toppinen, A. (2010). Forest Sector Market Impacts of Changed Roundwood Export Tariffs and Investment Climate in Russia. *Forest Policy and Economics, 12*, 17-23.

Statistics New Zealand. (2016). *New Zealand Merchandise Trade* [Trade Data]. Retrieved from: http://www.stats.govt.nz/infoshare

Statistics New Zealand. (2017). *Overseas Trade Indexes - Price - OTP*. Retrieved from: http://www.stats.govt.nz/infoshare/ViewTable.aspx?pxID=a083c0ca-3f13-4af8-8d8a-2c42fc4fc577

Sun, L., Bogdanski, B. E. C., Stennes, B., & van Kooten, G., C. (2010). Impacts of tariff and non-tariff trade barriers on the global forest products trade: an application of the Global Forest Product Model. *International Forestry Review, 12*(1), 49-65.

Taylor, R. (2016). Supply and Demand: Analyzing Europe and Russia. *Wood Business*. Retrieved from www.woodbusiness.ca website: https://www.woodbusiness.ca/industry-news/markets/supply-and-demand-3775

Transparency International. (2017). *Corruption Perceptions Index 2016*. Retrieved from

Turner, J. A., & Buongiorno, J. (2004). Estimating Price and Income Elasticities of Demand for Imports of Forest Products from Panel Data. *Scandinavian Journal of Forest Research, 19*, 358-373.

United Nations. (2016). *Human Development Index*. Retrieved from: http://hdr.undp.org/en/composite/HDI

United Nations. (2017). Trade Analysis Information System. Retrieved from http://unctad.org/en/Pages/DITC/Trade-Analysis/Non-Tariff-Measures/NTMs-trains.aspx

Wan, M., Toppinen, A., & Hanninen, R. (2010). Econometric Analysis of China's Plywood Market. *Forest Products Journal, 60*(7/8), 679-687.

White, H. (1980). A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedacticity. *Econometricia, 48*(4), 817-838.

Woodco. (2012). *New Zealand Forest and Wood Products Industry Strategic Action Plan*. Retrieved from Wellington: http://woodco.org.nz/images/stories/pdfs/ForestWood_Strategic_Action_Plan.pdf

Wooldridge, J. M. (2013). *Introductory Econometrics* (6 ed.). Boston: Cengage Learning.

World Bank. (2016). *World Bank DataBank*. Retrieved from: http://data.worldbank.org/

World Bank. (2017). *Doing Business 2017*. Retrieved from Washington: http://www.doingbusiness.org/reports/global-reports/doing-business-2017

General Agreement on Tariffs and Trade 1994, (1994).

WTO. (2017a). Tariff Analysis Online. Retrieved from https://tao.wto.org/welcome.aspx?ReturnUrl=%2fdefault.aspx

WTO. (2017b). Understanding the World Trade Organisation. Retrieved from https://www.wto.org/english/thewto_e/whatis_e/tif_e/agrm2_e.htm

Zhu, S., Buongiorno, J., & Brooks, D. J. (2000). Effects of accelerated tariff liberalization on the forest products sector: a global modeling approach. *Forest Policy and Economics, 2*, 57-78.

Appendix One

Jarque-Bera tests for Normal Distribution

	Sawn Timber		Logs	
	Price	**Import Volume**	**Price**	**Import Volume**
China	0.57	0.29	0.11	0.16
India	0.44	0.05	NA	NA
Indonesia	0.01	0.00	NA	NA
Japan	0.00	0.63	0.53	0.75
Philippines	0.63	0.12	NA	NA
'South Korea'	0.00	0.25	NA	NA
Thailand	0.75	0.00	0.00	0.56

	GDP	*HDI*	*CPI*
China	0.44	0.51	0.83
India	0.47	0.53	0.43
Indonesia	0.45	0.58	0.50
Japan	0.48	0.69	0.36
Philippines	0.51	0.52	0.36
'South Korea'	0.57	0.49	0.41
Thailand	0.52	0.57	0.69

	Canada	*Russia*	*USA*
China	0.15	0.22	NA
India	NA	NA	NA
Indonesia	0.22	NA	0.96
Japan	0.37	0.67	NA
Philippines	0.00	NA	0.01
'South Korea'	0.24	0.26	0.00
Thailand	NA	NA	NA

	SFT	*HWD*
China	0.29	0.31
India	0.29	0.00
Indonesia	NA	0.18
Japan	0.54	0.01
Philippines	0.16	0.24

'South Korea'	0.50	0.09
Thailand	NA	0.02

Appendix Two

Sawn Timber Basic Model

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPR), data = exportmodel2,
    model = "within", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-5.0000 -0.4510  0.0188  0.4940  2.6800

Coefficients :
         Estimate Std. Error t-value  Pr(>|t|)
log(GDP)  1.41497    0.31742  4.4577 1.911e-05 ***
log(RPR) -0.72974    0.21563 -3.3842 0.0009719 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    160.51
Residual Sum of Squares: 127.06
R-Squared:      0.20837
Adj. R-Squared: 0.15424
F-statistic: 15.3983 on 2 and 117 DF, p-value: 1.1574e-06
```

Log Basic Model

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPR), data = exportmodel2,
    model = "within", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -5.420  -0.509  -0.109   0.721   3.810

Coefficients :
           Estimate Std. Error t-value  Pr(>|t|)
log(GDP)    1.15376    0.45915  2.5128   0.01343 *
log(LOGPR) -0.66388    0.13749 -4.8284 4.474e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    287.74
Residual Sum of Squares: 212.66
R-Squared:      0.26092
Adj. R-Squared: 0.20717
F-statistic: 19.4167 on 2 and 110 DF, p-value: 5.9991e-08
```

Sawn Timber Basic Model Including Tariffs

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT), data = exportmodel2,
    model = "within", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -5.020  -0.444   0.022   0.485   2.670

Coefficients :
           Estimate Std. Error t-value  Pr(>|t|)
log(GDP)    1.32139    0.31633  4.1773  5.71e-05 ***
log(RPRPT) -0.76706    0.21388 -3.5863 0.0004906 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    160.51
Residual Sum of Squares: 125.69
R-Squared:      0.21696
Adj. R-Squared: 0.16342
```

Log Basic Model Including Tariffs

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT), data = exportmodel2,
    model = "within", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -5.430  -0.506  -0.108   0.718   3.800

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
log(GDP)      1.12283    0.46030  2.4393   0.01631 *
log(LOGPRPT) -0.66754    0.13751 -4.8545 4.015e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    287.74
Residual Sum of Squares: 212.26
R-Squared:      0.26232
Adj. R-Squared: 0.20867
F-statistic: 19.5579 on 2 and 110 DF, p-value: 5.4052e-08
```

Sawn Timber Model Including Tariff Wedge – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(TWPO), data = exportmodel2,
    model = "within", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-4.9800 -0.4460 -0.0416  0.5050  2.4400

Coefficients :
           Estimate Std. Error t-value  Pr(>|t|)
log(GDP)    0.90205    0.36477  2.4729 0.0148507 *
log(RPRPT) -0.77141    0.21045 -3.6655 0.0003738 ***
log(TWPO)  -4.58114    2.07823 -2.2043 0.0294740 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    160.51
Residual Sum of Squares: 120.63
R-Squared:      0.24844
Adj. R-Squared: 0.19013
F-statistic: 12.7819 on 3 and 116 DF, p-value: 2.826e-07
```

Sawn Timber Model Including Tariff Wedge – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(TWPO), data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 1.040   1.020 0.351
individual    1.925   1.387 0.649
theta:  0.8293

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -4.970  -0.410   0.129   0.512   2.120

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -5.85056    6.23291 -0.9387 0.3497619
log(GDP)     0.75621    0.20975  3.6053 0.0004527 ***
log(RPRPT)  -0.76787    0.17375 -4.4194 2.159e-05 ***
log(TWPO)   -5.46526    1.89475 -2.8844 0.0046374 **
```

```
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    173.81
Residual Sum of Squares: 128.78
R-Squared:      0.25909
Adj. R-Squared: 0.24087
F-statistic: 14.2209 on 3 and 122 DF, p-value: 5.2461e-08
```

Sawn Timber Model Including Tariff Wedge – Random Effects, Hausman Taylor Approach

```
Oneway (individual) effect Hausman-Taylor Model
Call:
pht(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(TWPO) | log(GDP) +
    log(RPRPT), data = exportmodel2, model = "ht", index = c("CTY",
    "YR"))

T.V. exo  : log(GDP), log(RPRPT)
T.V. endo : log(TWPO)
T.I. exo  :
T.I. endo :

Balanced Panel: n=7, T=18, N=126

Effects:
                  var std.dev share
idiosyncratic 1.01373 1.00684 0.929
individual    0.07711 0.27769 0.071
theta:  0.3503

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -5.030  -0.344   0.316   0.776   2.440

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -4.11602    3.00339 -1.3705   0.17054
log(GDP)     0.67989    0.11823  5.7508 8.884e-09 ***
log(RPRPT)  -0.69969    0.12075 -5.7943 6.861e-09 ***
log(TWPO)   -5.25515    2.46176 -2.1347   0.03278 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    616.83
Residual Sum of Squares: 235.41
F-statistic: 65.8884 on 3 and 122 DF, p-value: < 2.22e-16
```

Log Model Including Tariff Wedge – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(TWPO),
```

```
    data = exportmodel2, model = "within", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -5.410  -0.530  -0.111   0.728   3.810

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
log(GDP)      1.17673    0.53575  2.1964   0.03018 *
log(LOGPRPT) -0.66721    0.13812 -4.8306 4.477e-06 ***
log(TWPO)     0.59657    2.99616  0.1991   0.84255
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    287.74
Residual Sum of Squares: 212.18
R-Squared:      0.26259
Adj. R-Squared: 0.2017
F-statistic: 12.938 on 3 and 109 DF, p-value: 2.7172e-07
```

Log Model Including Tariff Wedge – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(TWPO),
    data = exportmodel2, model = "random", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.947   1.395 0.292
individual    4.715   2.171 0.708
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8363  0.8414  0.8460  0.8461  0.8503  0.8503

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-5.5700 -0.4920  0.1480  0.0067  0.9020  3.5100

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -8.40544    9.25427 -0.9083  0.365632
log(GDP)      0.83770    0.28606  2.9283  0.004109 **
log(LOGPRPT) -0.74371    0.12709 -5.8519 4.672e-08 ***
log(TWPO)     0.03214    2.74073  0.0117  0.990664
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    305.12
Residual Sum of Squares: 225.1
R-Squared:      0.26233
```

```
Adj. R-Squared: 0.24309
F-statistic: 13.6254 on 3 and 115 DF, p-value: 1.1477e-07
```

Sawn Timber Model with Tariff Wedge – Arellano and Bond Method

```
Oneway (individual) effect One step model

Call:
pgmm(formula = log(EV) ~ lag(log(EV), 1) + log(GDP) + log(RPRPT) +
   log(TWPO) | lag(log(EV), 2:99), data = exportmodel2, effect = "individual",
   model = "onestep")

Balanced Panel: n=7, T=18, N=126

Number of Observations Used:  112

Residuals
     Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
-7.326000 -0.339400 -0.042290 -0.005002  0.431500  8.661000

Coefficients
                Estimate Std. Error z-value Pr(>|z|)
lag(log(EV), 1)  0.26308    0.10838  2.4275 0.015204 *
log(GDP)         0.32720    0.48961  0.6683 0.503950
log(RPRPT)      -0.85187    0.29537 -2.8841 0.003925 **
log(TWPO)       -6.15832    5.82325 -1.0575 0.290265
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Sargan Test: chisq(135) = 7 (p.value=1)
Autocorrelation test (1): normal = -1.436625 (p.value=0.15082)
Autocorrelation test (2): normal = 1.369179 (p.value=0.17094)
Wald test for coefficients: chisq(4) = 132.5138 (p.value=< 2.22e-16)
```

Log Model with Tariff Wedge – Arellano and Bond Method

```
Oneway (individual) effect One step model

Call:
pgmm(formula = log(LEV) ~ lag(log(LEV), 1) + log(GDP) + log(LOGPRPT) +
   log(TWPO) | lag(log(LEV), 2:99), data = exportmodel2, effect = "individual",
   model = "onestep")

Balanced Panel: n=7, T=18, N=126

Number of Observations Used:  101

Residuals
     Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
-3.849000 -0.291400  0.004573  0.000680  0.318200  5.762000

Coefficients
                 Estimate Std. Error  z-value  Pr(>|z|)
```

```
lag(log(LEV), 1)  0.376871   0.085638   4.4008 1.079e-05 ***
log(GDP)        -0.440832   1.239455  -0.3557    0.7221
log(LOGPRPT)     -0.799354   0.069723 -11.4647 < 2.2e-16 ***
log(TWPO)       -3.005136   4.117296  -0.7299    0.4655
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Sargan Test: chisq(135) = 7 (p.value=1)
Autocorrelation test (1): normal = -1.840043 (p.value=0.065762)
Autocorrelation test (2): normal = 1.393307 (p.value=0.16353)
Wald test for coefficients: chisq(4) = 2455.916 (p.value=< 2.22e-16)
```

Sawn Timber Model with NTB Dummy – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + NTB, data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 1.084   1.041 0.165
individual    5.486   2.342 0.835
theta:  0.8958

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -4.990  -0.378   0.126   0.477   2.420

Coefficients :
            Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -17.79581    8.15126 -2.1832   0.03094 *
log(GDP)      1.11673    0.24588  4.5418 1.320e-05 ***
log(RPRPT)   -0.80613    0.19585 -4.1160 7.042e-05 ***
NTB           1.17929    1.88839  0.6245   0.53347
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    165.46
Residual Sum of Squares: 130.29
R-Squared:      0.21255
Adj. R-Squared: 0.19319
F-statistic: 10.9769 on 3 and 122 DF, p-value: 1.9657e-06
```

Log Model with NTB Dummy – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)
```

```
Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + NTB, data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.947   1.395 0.286
individual    4.862   2.205 0.714
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8387  0.8437  0.8483  0.8484  0.8525  0.8525

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-5.5200 -0.4910  0.1730  0.0065  0.9090  3.4900

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -9.60897    9.44438 -1.0174  0.311086
log(GDP)      0.86419    0.28110  3.0743  0.002636 **
log(LOGPRPT) -0.73428    0.12790 -5.7409 7.794e-08 ***
NTB           0.60640    1.80588  0.3358  0.737641
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    304.61
Residual Sum of Squares: 224.54
R-Squared:      0.26294
Adj. R-Squared: 0.24372
F-statistic: 13.6691 on 3 and 115 DF, p-value: 1.0948e-07
```

Sawn Timber Model with CPI – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(CPI), data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 1.081   1.040 0.159
individual    5.706   2.389 0.841
theta:  0.8979

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -4.860  -0.449   0.116   0.474   2.350

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -13.55942    8.30414 -1.6329 0.1050788
```

```
log(GDP)      0.97589    0.27666  3.5274 0.0005922 ***
log(RPRPT)   -0.81265    0.19189 -4.2349 4.459e-05 ***
log(CPI)      0.68379    0.76448  0.8944 0.3728427
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    165.27
Residual Sum of Squares: 129.68
R-Squared:      0.21529
Adj. R-Squared: 0.196
F-statistic: 11.1574 on 3 and 122 DF, p-value: 1.5984e-06
```

Log Model with CPI – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(CPI),
    data = exportmodel2, model = "random", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.923   1.387 0.291
individual    4.679   2.163 0.709
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8367  0.8417  0.8464  0.8464  0.8506  0.8506

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-5.5700 -0.4880  0.1440  0.0068  0.8990  3.5300

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -8.508479   9.018537 -0.9434   0.34743
log(GDP)      0.843493   0.293642  2.8725   0.00485 **
log(LOGPRPT) -0.744513   0.127546 -5.8372 5.001e-08 ***
log(CPI)     -0.058068   1.031323 -0.0563   0.95520
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    305.04
Residual Sum of Squares: 225.05
R-Squared:      0.26234
Adj. R-Squared: 0.2431
F-statistic: 13.6257 on 3 and 115 DF, p-value: 1.1473e-07
```

Sawn Timber Model with AVE NTBs – Random Effects

```
Oneway (individual) effect Random Effect Model
```

```
  (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(AVESTPO),
    data = exportmodel2, model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 1.084   1.041 0.171
individual    5.240   2.289 0.829
theta:  0.8934

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -4.910  -0.404   0.104   0.472   2.390

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -17.29512    7.89955 -2.1894   0.03047 *
log(GDP)       1.10758    0.24288  4.5603 1.224e-05 ***
log(RPRPT)    -0.80431    0.19592 -4.1053 7.335e-05 ***
log(AVESTPO)  16.27131   24.95943  0.6519   0.51569
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    165.69
Residual Sum of Squares: 130.46
R-Squared:      0.21265
Adj. R-Squared: 0.19329
F-statistic: 10.9837 on 3 and 122 DF, p-value: 1.9505e-06
```

Log Model with AVE NTBs – Random Effects

```
Oneway (individual) effect Random Effect Model
  (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(AVELOGPO),
    data = exportmodel2, model = "random", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.947   1.395 0.267
individual    5.359   2.315 0.733
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8462  0.8510  0.8553  0.8554  0.8593  0.8593

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-5.4800 -0.5330  0.1150  0.0061  0.8880  3.5300

Coefficients :
```

```
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)   -10.92972    9.88033 -1.1062  0.270944
log(GDP)        0.89932    0.29392  3.0598  0.002757 **
log(LOGPRPT)   -0.72366    0.12852 -5.6307 1.289e-07 ***
log(AVELOGPO)   2.89440    5.23106  0.5533  0.581126
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    303.07
Residual Sum of Squares: 223.12
R-Squared:      0.26387
Adj. R-Squared: 0.24467
F-statistic: 13.7355 on 3 and 115 DF, p-value: 1.019e-07
```

Sawn Timber Model with Competitor Effects – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(CAN) + log(RUS) +
    log(USA), data = exportmodel2, model = "within", index = c("CTY",
    "YR"))

Balanced Panel: n=7, T=18, N=126

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-5.3600 -0.4170 -0.0332  0.5620  2.6000

Coefficients :
            Estimate Std. Error t-value  Pr(>|t|)
log(GDP)    1.201307   0.403859  2.9746 0.0035820 **
log(RPRPT) -0.770643   0.219386 -3.5127 0.0006368 ***
log(CAN)    0.058013   0.056912  1.0193 0.3101972
log(RUS)   -0.019796   0.055598 -0.3561 0.7224532
log(USA)    0.073742   0.042560  1.7327 0.0858590 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    160.51
Residual Sum of Squares: 118.8
R-Squared:      0.25985
Adj. R-Squared: 0.18843
F-statistic: 8.00466 on 5 and 114 DF, p-value: 1.6948e-06
```

Sawn Timber Model with Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(CAN) + log(RUS) +
    log(USA), data = exportmodel2, model = "random", index = c("CTY",
```

```
   "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
              var std.dev share
idiosyncratic 1.042   1.021  0.16
individual    5.457   2.336  0.84
theta:  0.8975

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -5.300  -0.387   0.111   0.474   2.310

Coefficients :
             Estimate  Std. Error t-value  Pr(>|t|)
(Intercept) -1.3253e+01  8.5245e+00 -1.5547 0.1226425
log(GDP)     9.5250e-01  2.7451e-01  3.4698 0.0007242 ***
log(RPRPT)  -8.1091e-01  1.9135e-01 -4.2378 4.456e-05 ***
log(CAN)     6.2919e-02  5.6061e-02  1.1223 0.2639638
log(RUS)    -8.4176e-04  4.7959e-02 -0.0176 0.9860257
log(USA)     7.4676e-02  4.2077e-02  1.7747 0.0784780 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    165.3
Residual Sum of Squares: 122.6
R-Squared:      0.25831
Adj. R-Squared: 0.2274
F-statistic: 8.35837 on 5 and 120 DF, p-value: 8.2979e-07
```

Sawn Timber Model with Canada Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(CAN), data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
              var std.dev share
idiosyncratic 1.051   1.025 0.251
individual    3.132   1.770 0.749
theta:  0.8647

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -5.210  -0.322   0.117   0.464   2.380

Coefficients :
            Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -12.309915   6.726232 -1.8301   0.06967 .
log(GDP)      0.912227   0.223280  4.0856 7.904e-05 ***
log(RPRPT)   -0.759804   0.184605 -4.1158 7.046e-05 ***
```

```
log(CAN)      0.110931   0.050684  2.1887   0.03052 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    168.86
Residual Sum of Squares: 128.54
R-Squared:      0.23876
Adj. R-Squared: 0.22004
F-statistic: 12.755 on 3 and 122 DF, p-value: 2.6322e-07
```

Sawn Timber Model with Russia Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(RUS), data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 1.083   1.041 0.311
individual    2.400   1.549 0.689
theta:  0.8436

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -4.890  -0.348   0.121   0.474   2.240

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -10.265947   6.863709 -1.4957 0.1373181
log(GDP)      0.894379   0.233094  3.8370 0.0001987 ***
log(RPRPT)   -0.818986   0.181638 -4.5089 1.508e-05 ***
log(RUS)      0.042026   0.044996  0.9340 0.3521476
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    171.67
Residual Sum of Squares: 134.9
R-Squared:      0.21419
Adj. R-Squared: 0.19487
F-statistic: 11.0847 on 3 and 122 DF, p-value: 1.7371e-06
```

Sawn Timber Model with USA Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(USA), data = exportmodel2,
```

```
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 1.034   1.017 0.248
individual    3.129   1.769 0.752
theta:  0.8657

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -5.200  -0.382   0.115   0.488   2.140

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -12.188821   6.691557 -1.8215  0.070978 .
log(GDP)      0.947927   0.218150  4.3453 2.896e-05 ***
log(RPRPT)   -0.856950   0.179319 -4.7789 4.966e-06 ***
log(USA)      0.097262   0.037147  2.6183  0.009957 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    168.74
Residual Sum of Squares: 126.39
R-Squared:      0.25098
Adj. R-Squared: 0.23256
F-statistic: 13.6267 on 3 and 122 DF, p-value: 1.0039e-07
```

Sawn Timber Model with Russia post-2008 Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + RUSP08D, data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 1.083   1.041 0.176
individual    5.060   2.249 0.824
theta:  0.8916

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -4.940  -0.388   0.123   0.467   2.380

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -15.504718   8.306812 -1.8665 0.0643714 .
log(GDP)      1.069445   0.274258  3.8994 0.0001582 ***
log(RPRPT)   -0.831089   0.205510 -4.0440 9.245e-05 ***
RUSP08D       0.024272   0.320627  0.0757 0.9397802
---
```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    165.87
Residual Sum of Squares: 131.06
R-Squared:      0.20986
Adj. R-Squared: 0.19043
F-statistic: 10.8009 on 3 and 122 DF, p-value: 2.4064e-06
```

Log Model with Competitor Effects – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(CAN) +
    log(RUS) + log(USA), data = exportmodel2, model = "within",
    index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-3.4500 -0.5450 -0.0398  0.5830  3.5600

Coefficients :
              Estimate Std. Error t-value Pr(>|t|)
log(GDP)      0.605527   0.543924  1.1133 0.268093
log(LOGPRPT) -0.749374   0.127810 -5.8632 5.11e-08 ***
log(CAN)      0.213999   0.073410  2.9151 0.004331 **
log(RUS)     -0.036769   0.070788 -0.5194 0.604534
log(USA)      0.130641   0.055444  2.3563 0.020280 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    287.74
Residual Sum of Squares: 172.24
R-Squared:      0.40141
Adj. R-Squared: 0.33988
F-statistic: 14.3508 on 5 and 107 DF, p-value: 9.6238e-11
```

Log Model with Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(CAN) +
    log(RUS) + log(USA), data = exportmodel2, model = "random",
    index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
```

```
idiosyncratic 1.610   1.269 0.378
individual    2.651   1.628 0.622
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8027  0.8088  0.8143  0.8144  0.8193  0.8193

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-3.7900 -0.4610  0.0872  0.0043  0.6320  3.2500

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -4.3140713  7.5358010 -0.5725   0.56814
log(GDP)      0.6135620  0.2418100  2.5374   0.01253 *
log(LOGPRPT) -0.7585988  0.1164577 -6.5139 2.108e-09 ***
log(CAN)      0.2253604  0.0710473  3.1720   0.00195 **
log(RUS)     -0.0023094  0.0589755 -0.0392   0.96883
log(USA)      0.1102977  0.0554045  1.9908   0.04892 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    313.06
Residual Sum of Squares: 186.56
R-Squared:      0.40413
Adj. R-Squared: 0.37776
F-statistic: 15.325 on 5 and 113 DF, p-value: 1.7491e-11
```

Log Model with Canada Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(CAN),
    data = exportmodel2, model = "random", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.662   1.289 0.229
individual    5.611   2.369 0.771
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8608  0.8652  0.8691  0.8692  0.8728  0.8728

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-3.8700 -0.5450  0.0856  0.0028  0.7240  3.2500

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -4.47726    8.87451 -0.5045   0.61487
log(GDP)      0.62979    0.27413  2.2974   0.02341 *
log(LOGPRPT) -0.76050    0.11641 -6.5329 1.832e-09 ***
log(CAN)      0.28880    0.06270  4.6060 1.067e-05 ***
---
```

```
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    300.28
Residual Sum of Squares: 187.25
R-Squared:      0.37642
Adj. R-Squared: 0.36015
F-statistic: 23.1384 on 3 and 115 DF, p-value: 8.6252e-12
```

Log Model with Russia Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(RUS),
    data = exportmodel2, model = "random", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.945   1.395 0.341
individual    3.757   1.938 0.659
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8173  0.8230  0.8281  0.8282  0.8328  0.8328

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-5.3500 -0.5400  0.1760  0.0052  0.8250  3.5200

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -3.211591   8.669736 -0.3704   0.71174
log(GDP)      0.650638   0.276786  2.3507   0.02044 *
log(LOGPRPT) -0.718294   0.126596 -5.6739 1.059e-07 ***
log(RUS)      0.088364   0.061184  1.4442   0.15139
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    309.42
Residual Sum of Squares: 223.93
R-Squared:      0.27638
Adj. R-Squared: 0.2575
F-statistic: 14.6361 on 3 and 115 DF, p-value: 3.8854e-08
```

Log Model with USA Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(USA),
```

```
   data = exportmodel2, model = "random", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
               var std.dev share
idiosyncratic 1.710   1.308 0.257
individual    4.944   2.224 0.743
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8499  0.8545  0.8588  0.8589  0.8627  0.8627

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-4.2600 -0.5640  0.1780  0.0055  0.6930  2.9700

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -4.868642   8.672802 -0.5614  0.575638
log(GDP)      0.668672   0.268192  2.4933  0.014081 *
log(LOGPRPT) -0.728118   0.118333 -6.1532 1.138e-08 ***
log(USA)      0.194465   0.049176  3.9545  0.000133 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    302.35
Residual Sum of Squares: 196.5
R-Squared:      0.35013
Adj. R-Squared: 0.33317
F-statistic: 20.6483 on 3 and 115 DF, p-value: 8.9814e-11
```

Log Model with Russia post-2008 Competitor Effects – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(RUS) +
    RUSP08D, data = exportmodel2, model = "random", index = c("CTY",
    "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.9630  1.4011 0.723
individual    0.7514  0.8669 0.277
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.6149  0.6254  0.6350  0.6353  0.6440  0.6440

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-5.3100 -0.5860  0.3630  0.0064  0.8610  3.4000

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
```

```
(Intercept)  -1.349100   5.165896 -0.2612  0.794444
log(GDP)      0.583740   0.180637  3.2316  0.001610 **
log(LOGPRPT) -0.738788   0.130487 -5.6618 1.136e-07 ***
log(RUS)      0.157286   0.056544  2.7816  0.006331 **
RUSP08D       0.118955   0.418731  0.2841  0.776860
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    387.01
Residual Sum of Squares: 254.95
R-Squared:      0.34143
Adj. R-Squared: 0.31832
F-statistic: 14.7618 on 4 and 114 DF, p-value: 9.5253e-10
```

Log Model with Competitor Effects – Arellano and Bond Method

```
Oneway (individual) effect One step model

Call:
pgmm(formula = log(LEV) ~ lag(log(LEV), 1) + log(GDP) + log(LOGPRPT) +
    log(CAN) + log(RUS) + log(USA) | lag(log(LEV), 2:99), data = exportmodel2,
    effect = "individual", model = "onestep", index = c("CTY",
        "YR"))

Balanced Panel: n=7, T=18, N=126

Number of Observations Used:  101

Residuals
     Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
-3.131000 -0.359000  0.000000  0.007738  0.375000  4.524000

Coefficients
                  Estimate Std. Error  z-value  Pr(>|z|)
lag(log(LEV), 1)  0.357684   0.067623   5.2894 1.227e-07 ***
log(GDP)         -0.503585   1.263146  -0.3987   0.69013
log(LOGPRPT)     -0.898756   0.025803 -34.8317 < 2.2e-16 ***
log(CAN)          0.208667   0.090306   2.3107   0.02085 *
log(RUS)         -0.021012   0.135228  -0.1554   0.87652
log(USA)          0.068400   0.058170   1.1759   0.23965
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Sargan Test: chisq(135) = 7 (p.value=1)
Autocorrelation test (1): normal = -1.737003 (p.value=0.082387)
Autocorrelation test (2): normal = 0.9643896 (p.value=0.33485)
Wald test for coefficients: chisq(6) = 189805.4 (p.value=< 2.22e-16)
```

Sawn Timber Model with HDI – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
```

```
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(HDI), data = exportmodel2,
    model = "within", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-5.1900 -0.4620  0.0215  0.6120  2.5100

Coefficients :
           Estimate Std. Error t-value  Pr(>|t|)
log(GDP)   -2.70252    1.36792 -1.9756 0.0505703 .
log(RPRPT) -0.80346    0.20719 -3.8779 0.0001752 ***
log(HDI)   21.73443    7.20147  3.0181 0.0031280 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    160.51
Residual Sum of Squares: 116.54
R-Squared:      0.27397
Adj. R-Squared: 0.21764
F-statistic: 14.5909 on 3 and 116 DF, p-value: 3.9871e-08
```

Sawn Timber Model with HDI – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(HDI), data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 1.005   1.002  0.22
individual    3.553   1.885  0.78
theta:  0.8756

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-5.0700 -0.3910  0.0377  0.5360  2.2100

Coefficients :
            Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  7.61559   10.94143  0.6960 0.4877326
log(GDP)     0.37162    0.33983  1.0935 0.2763106
log(RPRPT)  -0.66993    0.19274 -3.4758 0.0007061 ***
log(HDI)     6.15243    2.34647  2.6220 0.0098551 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    167.57
Residual Sum of Squares: 125.45
R-Squared:      0.25136
Adj. R-Squared: 0.23295
```

F-statistic: 13.6541 on 3 and 122 DF, p-value: 9.7414e-08

Sawn Timber Model with Softwood Harvest – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(SFT), data = exportmodel2,
    model = "within", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Residuals :
    Min.  1st Qu.   Median  3rd Qu.     Max.
-5.51000 -0.43500  0.00958  0.54500  2.47000

Coefficients :
           Estimate Std. Error t-value  Pr(>|t|)
log(GDP)    1.64209    0.30623  5.3622 4.246e-07 ***
log(RPRPT) -0.53660    0.20791 -2.5810    0.0111 *
log(SFT)   -0.21234    0.05106 -4.1587 6.161e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    160.51
Residual Sum of Squares: 109.38
R-Squared:      0.31856
Adj. R-Squared: 0.26569
F-statistic: 18.0757 on 3 and 116 DF, p-value: 1.0842e-09
```

Sawn Timber Model with Softwood Harvest – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(SFT), data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                 var std.dev share
idiosyncratic 0.9429  0.9710 0.286
individual    2.3505  1.5331 0.714
theta:  0.8524

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-5.5600 -0.3710  0.0966  0.5720  2.3300

Coefficients :
            Estimate Std. Error t-value  Pr(>|t|)
```

```
(Intercept) -18.546997   6.268918 -2.9586  0.003713 **
log(GDP)      1.221170   0.208669  5.8522 4.178e-08 ***
log(RPRPT)   -0.822445   0.170881 -4.8130 4.305e-06 ***
log(SFT)     -0.179935   0.044982 -4.0001  0.000109 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    170.46
Residual Sum of Squares: 119.25
R-Squared:      0.30041
Adj. R-Squared: 0.2832
F-statistic: 17.4624 on 3 and 122 DF, p-value: 1.6987e-09
```

Sawn Timber Model with Hardwood Harvest – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(HWD), data = exportmodel2,
    model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 1.073   1.036 0.157
individual    5.749   2.398 0.843
theta:  0.8987

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -4.950  -0.374   0.120   0.412   2.380

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -16.452025   7.734354 -2.1271   0.03542 *
log(GDP)      1.074260   0.243421  4.4132 2.213e-05 ***
log(RPRPT)   -0.821297   0.190162 -4.3189 3.213e-05 ***
log(HWD)      0.053773   0.042335  1.2702   0.20644
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    165.19
Residual Sum of Squares: 128.77
R-Squared:      0.2205
Adj. R-Squared: 0.20133
F-statistic: 11.5034 on 3 and 122 DF, p-value: 1.0771e-06
```

Log Model with Softwood Harvest – Fixed Effects

```
Oneway (individual) effect Within Model
```

```
Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(SFT),
    data = exportmodel2, model = "within", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-5.4600 -0.4790 -0.0688  0.6390  3.1000

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
log(GDP)      1.415924   0.435258  3.2531   0.00152 **
log(LOGPRPT) -0.695228   0.128487 -5.4109 3.755e-07 ***
log(SFT)     -0.297326   0.071427 -4.1627 6.306e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    287.74
Residual Sum of Squares: 183.14
R-Squared:      0.3635
Adj. R-Squared: 0.31095
F-statistic: 20.7499 on 3 and 109 DF, p-value: 1.0411e-10
```

Log Model with Softwood Harvest – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(SFT),
    data = exportmodel2, model = "random", index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.680   1.296 0.302
individual    3.879   1.970 0.698
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8325  0.8376  0.8424  0.8425  0.8467  0.8467

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-5.8100 -0.4410  0.2090  0.0091  0.9460  2.9700

Coefficients :
               Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -12.545381   8.515852 -1.4732 0.1434344
log(GDP)       1.034381   0.269086  3.8441 0.0001989 ***
log(LOGPRPT)  -0.783121   0.122964 -6.3687  4.06e-09 ***
log(SFT)      -0.170707   0.065936 -2.5890 0.0108687 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    305.96
```

```
Residual Sum of Squares: 213.24
R-Squared:      0.3032
Adj. R-Squared: 0.28502
F-statistic: 16.6668 on 3 and 115 DF, p-value: 4.6654e-09
```

Log Model with Softwood Harvest – Hausman Taylor Approach

```
Oneway (individual) effect Hausman-Taylor Model
Call:
pht(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(SFT) |
    log(GDP) + log(LOGPRPT), data = exportmodel2, model = "ht",
    index = c("CTY", "YR"))

T.V. exo  : log(GDP), log(LOGPRPT)
T.V. endo : log(SFT)
T.I. exo  :
T.I. endo :

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                 var std.dev share
idiosyncratic 1.6352  1.2788 0.697
individual    0.7108  0.8431 0.303
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.6353  0.6454  0.6548  0.6550  0.6634  0.6634

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 -5.950  -0.503   0.271   0.008   0.986   3.060

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -8.193336   5.559976 -1.4736    0.1406
log(GDP)      0.885443   0.196026  4.5170 6.273e-06 ***
log(LOGPRPT) -0.886085   0.132389 -6.6931 2.185e-11 ***
log(SFT)     -0.035833   0.060155 -0.5957    0.5514
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    1134.8
Residual Sum of Squares: 271.28
F-statistic: 122.02 on 3 and 115 DF, p-value: < 2.22e-16
```

Log Model with Hardwood Harvest – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(HWD),
    data = exportmodel2, model = "within", index = c("CTY", "YR"))
```

```
Unbalanced Panel: n=7, T=15-18, N=119

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-5.4400 -0.5940 -0.0095  0.7290  3.7900

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
log(GDP)      1.062911   0.464002  2.2907    0.0239 *
log(LOGPRPT) -0.670898   0.137528 -4.8782 3.674e-06 ***
log(HWD)      0.059799   0.058882  1.0156    0.3121
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    287.74
Residual Sum of Squares: 210.27
R-Squared:      0.26923
Adj. R-Squared: 0.20889
F-statistic: 13.3861 on 3 and 109 DF, p-value: 1.6785e-07
```

Sawn Timber Model with Softwood Harvest – Arellano and Bond Method

```
Oneway (individual) effect One step model

Call:
pgmm(formula = log(EV) ~ lag(log(EV), 1) + log(GDP) + log(RPRPT) +
    log(SFT) | lag(log(EV), 2:99), data = exportmodel2, effect = "individual",
    model = "onestep")

Balanced Panel: n=7, T=18, N=126

Number of Observations Used:  112

Residuals
      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
-7.220000 -0.385400 -0.061010  0.003421  0.490000  8.101000

Coefficients
                 Estimate Std. Error z-value  Pr(>|z|)
lag(log(EV), 1)  0.182245   0.162323  1.1227 0.2615546
log(GDP)         1.133867   0.581292  1.9506 0.0511050 .
log(RPRPT)      -0.708070   0.317492 -2.2302 0.0257344 *
log(SFT)        -0.145266   0.041404 -3.5085 0.0004506 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Sargan Test: chisq(135) = 7 (p.value=1)
Autocorrelation test (1): normal = -1.504541 (p.value=0.13244)
Autocorrelation test (2): normal = 1.470105 (p.value=0.14153)
Wald test for coefficients: chisq(4) = 540.1814 (p.value=< 2.22e-16)
```

Log Model with Softwood Harvest – Arellano and Bond Method

```
Oneway (individual) effect One step model

Call:
pgmm(formula = log(LEV) ~ lag(log(LEV), 1) + log(GDP) + log(LOGPRPT) +
    log(SFT) | lag(log(LEV), 2:99), data = exportmodel2, effect = "individual",
    model = "onestep")

Balanced Panel: n=7, T=18, N=126

Number of Observations Used:  101

Residuals
     Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
-3.855000 -0.247900  0.000000  0.003379  0.316300  5.598000

Coefficients
                  Estimate Std. Error  z-value  Pr(>|z|)
lag(log(LEV), 1)  0.340540   0.075295   4.5227 6.105e-06 ***
log(GDP)          0.100425   1.003441   0.1001   0.92028
log(LOGPRPT)     -0.783047   0.071669 -10.9258 < 2.2e-16 ***
log(SFT)         -0.126958   0.041976  -3.0245   0.00249 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Sargan Test: chisq(135) = 7 (p.value=1)
Autocorrelation test (1): normal = -1.888497 (p.value=0.058959)
Autocorrelation test (2): normal = 1.273616 (p.value=0.2028)
Wald test for coefficients: chisq(4) = 378.3393 (p.value=< 2.22e-16)
```

Sawn Timber Demand Model with Tariff Wedge and Softwood Resource – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(TWPO) + log(SFT),
    data = exportmodel2, model = "within", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-5.4600 -0.4220 -0.0196  0.5550  2.2700

Coefficients :
            Estimate Std. Error t-value  Pr(>|t|)
log(GDP)    1.261987   0.353828  3.5667 0.0005281 ***
log(RPRPT) -0.548204   0.205129 -2.6725 0.0086231 **
log(TWPO)  -4.034374   1.956372 -2.0622 0.0414445 *
log(SFT)   -0.205186   0.050478 -4.0648 8.827e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    160.51
Residual Sum of Squares: 105.48
R-Squared:      0.34286
Adj. R-Squared: 0.28572
F-statistic: 15.0001 on 4 and 115 DF, p-value: 6.787e-10
```

Sawn Timber Demand Model with Tariff Wedge and Softwood Resource – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(TWPO) + log(SFT),
    data = exportmodel2, model = "random", index = c("CTY", "YR"))

Balanced Panel: n=7, T=18, N=126

Effects:
                 var std.dev share
idiosyncratic 0.9172  0.9577 0.316
individual    1.9883  1.4101 0.684
theta:  0.8419

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-5.5700 -0.4270  0.0139  0.5700  2.0100

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -11.628394   6.325492 -1.8383 0.0684651 .
log(GDP)      0.992731   0.213249  4.6553 8.358e-06 ***
log(RPRPT)   -0.770139   0.166356 -4.6295 9.292e-06 ***
log(TWPO)    -4.967003   1.795027 -2.7671 0.0065448 **
log(SFT)     -0.171552   0.043417 -3.9512 0.0001312 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    171.91
Residual Sum of Squares: 113.06
R-Squared:      0.34235
Adj. R-Squared: 0.32061
F-statistic: 15.747 on 4 and 121 DF, p-value: 2.1156e-10
```

Sawn Timber Demand Model with Tariff Wedge and Softwood Resource – Hausman-Taylor approach

```
Oneway (individual) effect Hausman-Taylor Model
Call:
pht(formula = log(EV) ~ log(GDP) + log(RPRPT) + log(TWPO) + log(SFT) |
    log(GDP) + log(RPRPT), data = exportmodel2, model = "ht",
    index = c("CTY", "YR"))

T.V. exo  : log(GDP), log(RPRPT)
T.V. endo : log(TWPO), log(SFT)
T.I. exo  :
T.I. endo :
```

```
Balanced Panel: n=7, T=18, N=126

Effects:
                var std.dev share
idiosyncratic 0.8864  0.9415 0.834
individual    0.1770  0.4208 0.166
theta:  0.5335

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
 -5.500  -0.345   0.163   0.703   1.780

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
(Intercept) -10.719495   3.980645 -2.6929  0.007083 **
log(GDP)      1.005483   0.169068  5.9472 2.728e-09 ***
log(RPRPT)   -0.957825   0.153278 -6.2489 4.132e-10 ***
log(TWPO)    -4.445042   2.046882 -2.1716  0.029885 *
log(SFT)     -0.111913   0.041344 -2.7069  0.006792 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    616.83
Residual Sum of Squares: 156.01
F-statistic: 89.3481 on 4 and 121 DF, p-value: < 2.22e-16
```

Log Demand Model with Competitor Effects and Softwood Resource – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(SFT) +
    log(CAN) + log(USA), data = exportmodel2, model = "within",
    index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Residuals :
   Min. 1st Qu.  Median 3rd Qu.    Max.
-4.1600 -0.5750 -0.0282  0.4990  3.1200

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
log(GDP)      0.755283   0.422372  1.7882 0.0765750 .
log(LOGPRPT) -0.771903   0.119418 -6.4639 3.112e-09 ***
log(SFT)     -0.259771   0.065928 -3.9403 0.0001454 ***
log(CAN)      0.202559   0.068749  2.9463 0.0039469 **
log(USA)      0.107300   0.050864  2.1095 0.0372302 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    287.74
Residual Sum of Squares: 150.79
R-Squared:      0.47594
Adj. R-Squared: 0.42207
F-statistic: 19.4353 on 5 and 107 DF, p-value: 1.0002e-13
```

Log Demand Model with Competitor Effects and Softwood Resource – Random Effects

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(SFT) +
    log(CAN) + log(USA), data = exportmodel2, model = "random",
    index = c("CTY", "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.409   1.187  0.47
individual    1.591   1.261  0.53
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.7638  0.7709  0.7774  0.7776  0.7834  0.7834

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-4.2300 -0.4170  0.1810  0.0066  0.7080  3.0200

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -7.498002   6.397034 -1.1721 0.2436197
log(GDP)      0.754925   0.211479  3.5697 0.0005259 ***
log(LOGPRPT) -0.799330   0.113878 -7.0192 1.761e-10 ***
log(SFT)     -0.094968   0.056951 -1.6675 0.0981787 .
log(CAN)      0.240305   0.069206  3.4723 0.0007321 ***
log(USA)      0.094890   0.054860  1.7297 0.0864158 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    324.19
Residual Sum of Squares: 187.78
R-Squared:      0.42089
Adj. R-Squared: 0.39526
F-statistic: 16.4179 on 5 and 113 DF, p-value: 3.7237e-12
```

Log Demand Model with Competitor Effects and Softwood Resource – Hausman-Taylor Approach

```
Oneway (individual) effect Hausman-Taylor Model
Call:
pht(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(SFT) +
    log(CAN) + log(USA) | log(GDP) + log(LOGPRPT), data = exportmodel2,
    model = "ht", index = c("CTY", "YR"))

T.V. exo  : log(GDP), log(LOGPRPT)
```

```
T.V. endo : log(SFT), log(CAN), log(USA)
T.I. exo  :
T.I. endo :

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
               var std.dev share
idiosyncratic 1.3463  1.1603 0.742
individual    0.4677  0.6839 0.258
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.5987  0.6095  0.6195  0.6197  0.6287  0.6287

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-4.3800 -0.6240  0.2170  0.0044  0.8870  3.2800

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -8.834422   4.958238 -1.7818 0.0747873 .
log(GDP)      0.786906   0.178477  4.4090 1.039e-05 ***
log(LOGPRPT) -0.847588   0.124156 -6.8268 8.682e-12 ***
log(SFT)     -0.067230   0.055782 -1.2052 0.2281164
log(CAN)      0.272267   0.077261  3.5240 0.0004251 ***
log(USA)      0.111506   0.061690  1.8075 0.0706838 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    1134.8
Residual Sum of Squares: 234.67
F-statistic: 86.6899 on 5 and 113 DF, p-value: < 2.22e-16
```

Hausman Test – Log Demand Model Hausman-Taylor Approach, Fixed Effects

```
Hausman Test

data:  log(LEV) ~ log(GDP) + log(LOGPRPT) + log(SFT) + log(CAN) + log(USA)
chisq = 22.342, df = 5, p-value = 0.0004507
alternative hypothesis: one model is inconsistent
```

Log Demand Model with Tariff Wedge and Softwood Resource – Fixed Effects

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(TWPO) +
    log(SFT), data = exportmodel2, model = "within", index = c("CTY",
    "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Residuals :
```

```
  Min. 1st Qu.  Median 3rd Qu.    Max.
-5.4200 -0.4900 -0.0739  0.6600  3.1100

Coefficients :
             Estimate Std. Error t-value  Pr(>|t|)
log(GDP)      1.504173   0.505944  2.9730  0.003637 **
log(LOGPRPT) -0.694766   0.129016 -5.3851 4.264e-07 ***
log(TWPO)     0.968023   2.796340  0.3462  0.729885
log(SFT)     -0.298120   0.071753 -4.1548 6.535e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    287.74
Residual Sum of Squares: 182.94
R-Squared:      0.36421
Adj. R-Squared: 0.30534
F-statistic: 15.4668 on 4 and 108 DF, p-value: 4.9463e-10
```

Log Demand Model with Tariff Wedge and Softwood Resource – Random Effects

```
Oneway (individual) effect Random Effect Model
  (Swamy-Arora's transformation)

Call:
plm(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(TWPO) +
    log(SFT), data = exportmodel2, model = "random", index = c("CTY",
    "YR"))

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                var std.dev share
idiosyncratic 1.694   1.301 0.225
individual    5.841   2.417 0.775
theta  :
  Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.8623  0.8666  0.8705  0.8706  0.8741  0.8741

Residuals :
  Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-5.7500 -0.4820  0.1370  0.0083  0.9150  2.9600

Coefficients :
               Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -15.012049  10.143705 -1.4799 0.1416482
log(GDP)       1.117513   0.317094  3.5242 0.0006124 ***
log(LOGPRPT)  -0.768802   0.123970 -6.2015 9.226e-09 ***
log(TWPO)      0.484407   2.660088  0.1821 0.8558262
log(SFT)      -0.205271   0.067547 -3.0390 0.0029444 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    300.02
Residual Sum of Squares: 205.01
R-Squared:      0.31679
Adj. R-Squared: 0.29281
F-statistic: 13.2084 on 4 and 114 DF, p-value: 7.1341e-09
```

Log Demand Model with Tariff Wedge and Softwood Resource – Hausman-Taylor Approach

```
Oneway (individual) effect Hausman-Taylor Model
Call:
pht(formula = log(LEV) ~ log(GDP) + log(LOGPRPT) + log(TWPO) +
    log(SFT) | log(GDP) + log(LOGPRPT), data = exportmodel2,
    model = "ht", index = c("CTY", "YR"))

T.V. exo  : log(GDP), log(LOGPRPT)
T.V. endo : log(TWPO), log(SFT)
T.I. exo  :
T.I. endo :

Unbalanced Panel: n=7, T=15-18, N=119

Effects:
                 var std.dev share
idiosyncratic 1.6334  1.2780  0.69
individual    0.7342  0.8569  0.31
theta  :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.6406  0.6506  0.6598  0.6600  0.6683  0.6683

Residuals :
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-5.9400 -0.5000  0.2810  0.0081  0.9980  3.0500

Coefficients :
              Estimate Std. Error t-value  Pr(>|t|)
(Intercept)  -8.429575   5.887492 -1.4318    0.1522
log(GDP)      0.893897   0.206752  4.3235 1.536e-05 ***
log(LOGPRPT) -0.886634   0.135513 -6.5428 6.038e-11 ***
log(TWPO)     0.263472   2.959336  0.0890    0.9291
log(SFT)     -0.039695   0.060857 -0.6523    0.5142
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    1134.8
Residual Sum of Squares: 269.62
F-statistic: 91.4531 on 4 and 114 DF, p-value: < 2.22e-16
```

Hausman Test – Log Demand Model Hausman-Taylor Approach and Fixed Effects

```
Hausman Test

data:  log(LEV) ~ log(GDP) + log(LOGPRPT) + log(TWPO) + log(SFT) | log(GDP) +  ...
chisq = 39.996, df = 4, p-value = 4.336e-08
alternative hypothesis: one model is inconsistent
```