ANALYSIS OF NEW ZEALAND'S MAJOR FORESTRY MARKETS

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Harvested Wood Products in Greenhouse Gas Accounting and Emissions Trading

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1. Introduction

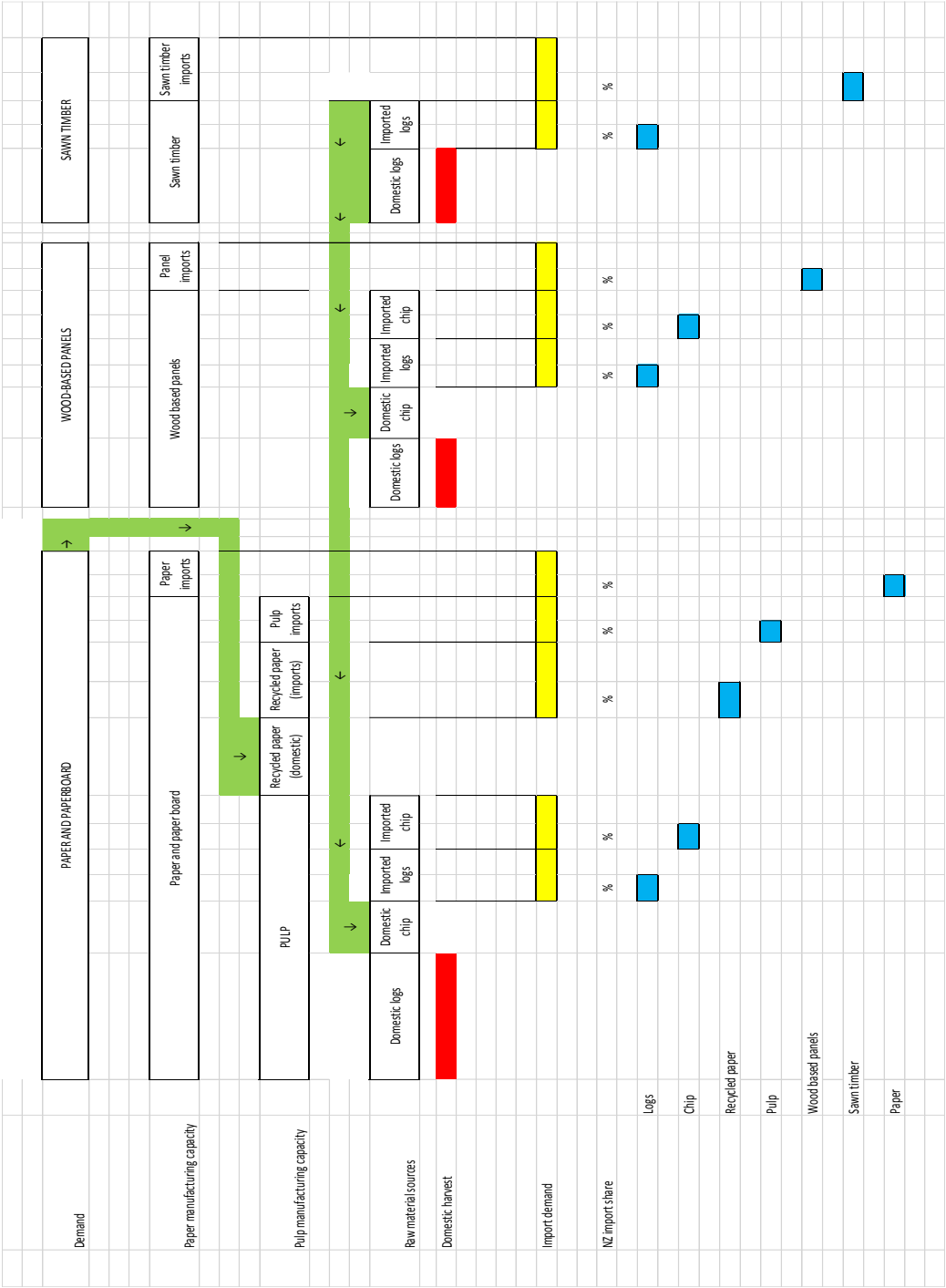
Available date have been identified and analysed using exploratory data analysis. This research has attempted to combine information collected in market with publicly available data. This is an innovative approach – most market studies used either of these methods but not both. The strength of this method is that is combines all available information. In a situation where there are significant data gaps, and the analytical methods tend to often yield results that do not always make sense from an economics or a practical viewpoint, this is a sensible approach.

Econometric estimation has been attempted for demand functions for broad product categories in each major country of interest except India where data quality (and time series length) did not allow this. Criteria for model selection included statistical results, compliance with economic theory, and simplicity (to facilitate use for forecasting).

2. Modelling approach

Import demand for products in key markets can be estimated from the demand for each major product group, less the amount produced locally. The amount produced locally can be produced either from domestically sourced logs or imported logs, and so the log import demand can be determined by subtraction. This model is summarised below:

Figure 2.1 Modeling approach



There are a number of key assumptions implicit in this model structure:

1. If domestic harvest is available, it will be preferred to imports
2. Domestic processing capacity is used in preference to product imports
3. Hardwood and softwood-based products are perfect substitutes.
4. The exports of forestry products are assumed to be insignificant

2.1 Scope

What are the important export markets for the purposes of this study? Important markets are those where the most of New Zealand's harvest is consumed, since the fate of the wood (end use and life in use) is the focus of the HWP study. Table 2.1 shows that over half of the wood harvested for export went to China in 2015 (year ending December).

Table 2.1: Exports by product and country in roundwood equivalent, y.e. June 2016 (m3)

	Logs and poles	**Sawn timber and sleepers**	**Wood pulp**	**Paper and paperboard**	**Panels**	**Total**	**% of total**
Total	15,735,316	3,343,872	3,047,174	1,140,799	1,172,498	24,439,659	
China	10,359,972	895,766	1,233,426	134,093	79,853	12,703,111	52.0%
Korea	2,799,567	234,794	253,270	81,523	9,334	3,378,488	13.8%
India	1,859,228	65,532	153,148	34,303	25,845	2,138,055	8.7%
Japan	442,698	79,485	300,939	0	493,129	1,316,252	5.4%
Australia	3,856	322,657	319,714	475,767	117,279	1,239,274	5.1%
Indonesia	83	143,461	272,729	11,501	71,927	499,701	2.0%
USA	0	367,744	0	19,352	84,504	471,600	1.9%

Source MPI Exports by product and country

The table above shows that the top 5 markets (China, Korea, India, Japan and Australia) take 85% of the volume harvested for export. These data are incomplete (they don't include other products) nevertheless it is likely to be strongly indicative of the total wood-flow. This is the same as the top 5 ranked in terms of value (which includes other products) – see Fig 5.1. On a product basis, Table 2.1 shows that 64% of exports was logs, 14% sawn timber, 12% wood pulp, 5% paper and paperboard and 5% wood-based panels. Looking at individual country and product markets, logs into China (42%), logs into Korea (11%) logs into India (8%), wood pulp into China (5%) and sawn timber into China (4%) are the major flows

This paper will therefore focus on the top 4 markets because Australia has usage very similar to New Zealand and could be modelled using defaults.

2.2 Data availability and quality

The availability of good quality data is always an issue in economics. The FAO data has a number of issues which are highlighted below.

2.2.1 Materials balance

One example of this is the materials flow balance shown in Table 2.3. In this analysis balance was achieved by varying the proportion of sawlog and pulp logs in the domestic harvest. This does not tie in with current harvest data from FAO.

The first requirement is to be able to reconcile the data for 2014 from FAO. This is important for any modelling exercise. The assumptions are that solid wood production (sawn timber and plywood) drives log imports to these countries. This is an important simplifying assumption – it makes it much simpler to explain the log trade if it is dependent in the first instance on providing material for these industries. If we needed to explain it from the fibre based industries we would have to account for non-wood fibre, recovered fibre and more informal (and possible unrecorded) sources of very low grade wood. Two other points are also relevant here:

1. Although low grade logs are sold in New Zealand's markets, they are sawn or peeled in labour intensive small scale industries rather than being chipped and pulped
2. Although the trade with Korea, for example, is driven by need for feedstock for MDF, this is achieved through sawing logs (and some scanning and sorting for the low grade logs that would not be appropriate for sawn timber)

For both these reasons this assumption seems appropriate

In Table 2.3 the "balancing item" is the % of total harvest that is solid wood (and, to a lesser extent, the conversion factors). However conversion factors are aligned with the in-market surveys as far as possible.

It can be seen that the proportion of harvest that is solid wood varies greatly, and would need some confirmation from other sources (for New Zealand radiata pine the proportion is 80% to 90% sawlogs and veneer logs). We know that South Korea's resource is poor quality (small and malformed), however recent resource projections for Korea indicate harvest should be about 80% sawlogs. Little is known about the other resources, and further confirmation is required, especially the Indian and Chinese resources.

Table 2.3: Reconciliation of materials flows for New Zealand's major developing markets, 2014

	Korea	Japan	India	China	TOTAL
Sawn timber production	2,343,000	10,616,000	6,889,000	68,410,000	88,258,000
Plywood production	482,000	2,902,000	2,521,000	104,146,000	110,051,000
MDF and Particleboard production	2,840,000	1,480,000	223,500	77,435,000	81,978,500
Industrial roundwood production	4,195,000	21,057,000	49,517,000	168,681,300	
Actual log imports	3,775,094	4,199,476	6,530,917	53,691,691	
Conversion factors					
Conversion factor sawn timber	0.5	0.56	0.65	0.65	
Conversion factor plywood	0.65	0.65		0.95	
Conversion factor residue from sawn timber	0.3	0.3		0.3	
Conversion factor residue from plywood	0.3	0.3		0	
Conversion factor "plywood" India			0.25		
Log requirements to meet production needs					
Saw-logs	4,686,000	18,957,143	10,598,462	105,246,154	
Veneer logs	741,538	4,464,615		109,627,368	
Residue from sawn timber	1,405,800	5,687,143		31,573,846	
Residue from plywood	222,462	1,339,385		0	
Block-board output India			2,649,615		
Total residue	1,628,262	7,026,527	0	31,573,846	
Total solid-wood logs required	5,427,538	23,421,758	10,598,462	214,873,522	
Total harvest	4,195,000	21,057,000	49,517,000	168,681,300	
% of total harvest solid-wood	0.45	0.91	0.08	0.95	
Estimated harvest of saw-logs and veneer logs	1,887,750	19,161,870	3,961,360	160,247,235	
Imports required for solid-wood	3,539,788	4,259,888	6,637,102	54,626,287	

Source: FAO FAOSTAT database

2.2.2 Price data

There is a shortage of price data and unit values show some very surprising trends, which call into question the accuracy of the data

2.2.3 End use activity data

The quality of construction data in China are questionable – there are a number of difference series which appear to represent very different quantities

2.2.4 Resource data

Lack of clarity on purpose and quality of forest plantings. There is a lack of reliable forecasts of resource availability in the future

2.3 Other issues

2.3.1 Mobility of wood processing capacity

The Asian countries studied are connected in terms of investment in wood processing capacity, For example, wood processing capacity tends to be quite mobile and follows market opportunity. For example Taiwanese investment moved to China (as did Japanese investment). Investment is now moving to Vietnam as labour costs increase in China. This is demonstrated partly by the data which show the changing components of forestry imports into countries as they develop

2.3.2 The importance of forestry product exports (not just domestic consumption)

Log imports are driven partially by the exports of primary processed products, and also secondary manufactures such as furniture. This was the same for Korea as for China now. The modelling exercise is made more complex by the

2.3.3 Statistical and econometric issues

Recent work on econometrics has considered data problems using more sophisticated techniques such as as co-integration, have not been applied in this paper.

2.4 Suggested approach

The key demand models shown below appear to be reasonably robust (reasonable statistical results, explanatory variables are logical and comply with economic theory). It is suggested that these are used to produce forecasts, based on forecasts of explanatory variables. The demand for logs should be projected using scenarios of processing capacity and resource availability

3. Literature Review

3.1 Review of literature

This literature review includes a summary of key points on analytical methods and data sources, and an annotated review of key sources. This review is intended to highlight relevance to the current project, both in terms of findings and methods.

3.1.1 Modelling and model estimation

Buongiorno, J., et al. (2003) **o**utlines the development of the GFPM, a multi-region, multi-product spatial equilibrium model. The book outlines the development of individual supply and demand equations within the model, and also describes a number of applications of the model – a base scenario, and alternatives including the effects of the Asian economic crisis, effects of tariff liberalisation, US paper recycling policies, effects of regional trade agreements on New Zealand, and impacts of US harvest restrictions. There are a number of other applications of the model that have also been published.

Buongiorno, J., et al. (2012) outlines the results of the US RPA (Resources Planning Act) assessment for 2010. The objective was to assess the implications of the IPCC projections on world forestry. The analysis tool was the GFPM which is a spatial dynamic economic model of the forest products sector. Three of the four scenarios assumed a high usage of wood for biofuel, the fourth assumes a lower demand for energy wood. For each country the model examines a range of primary, intermediate and end products and also provides estimates of area of new forest. Of particular significance to the current project are the scenarios of net industrial round-wood trade by region, and trade in other products to 2060. These forecasts could form a comparison point for the results of the current study.

Buongiorno, J. and S. Zhu (2015a) provides a methodology to improve the quality of the FAO forestry database (FAOSTAT). This is the primary database for this type of work. In addition this paper calculates technical (I/O) coefficients and manufacturing costs empirically from these data, and from prior knowledge. It uses a goal programming approach to estimate these coefficents and cost values for each year, and provides useful trends in technical change particularly in the pulp and paper industry, where waste paper is becoming a much more significant input

Buongiorno, J. and S. Zhu (2015b) conclude that the utilisation of wood from planted forests allows for the production of more wood at a lower price. The consumption and production of wood products is also increased (ranging from a 14% increase in industrial roundwood consumption and a 1% increase in paper and paperboard consumption. Consumers benefit from planted forests, however producers are worse off. Utilisation of planted forests will also decrease the harvest of natural forests

Jianbang Gan (2004) uses the CGE model GTAP, the authors conclude that China's imports of forestry products will increase significantly. The expectation is that increased imports will reduce prices of sawn timber other wood products and pulp and paper in China. It is expected that a large proportion would be further processed into final products and re-exported. This would also result in an increase in exports

Gregory, G.R. (1966) estimates relationship between consumption of wood (dependent variable) and measure of income and wood availability. Does this for 53 countries, across high and low income countries. Suggests that there is not a constant elasticity of wood consumption with respect to income.

Haim, D., Adams, D.M., White, E.M. (2014) provides excellent quantitative data on the construction end use of wood products in USA. They note that 67% of all wood products are used in three segments of construction - new home construction, repair and remodelling and non-residential building (Comprising 66% of lumber and 83% of structural panels and 52% of non-structural panels).

InN addition to the three segments that the authors recognise in their study their literature review demonstrates that previous work has studied 5 enduses (residential new construction, residential upkeep and improvements, non-residential, and two manufacturing end uses (Adams et. al 1992). They summarise past work on lumber and wood panel price elasticities, and generalise these findings.

He, D., and C. Barr (2004) **d**escribes the increase in paper and paperboard capacity from 13.7 million tonnes in 1990 to 43 million tonnes in 2003. Projected increases in capacity raise concerns about raw material supply:

- How much fibre will be needed
- What types of fibre
- Where will it come from

Authors describe the use of a proprietary econometric model to project paperboard demand supply and trade. Having forecast domestic consumption, they use knowledge of installed capacity to determine domestic production, and then by subtraction, infer the trade quantity. They produce projections for demand production and net imports for paper and paperboard by grade to 2010 (from a base year of 2003). They then project the demand for non-wood pulp, recovered paper and different grades of wood pulp. Suggests that softwood fibre from Russia and New Zealand will be important, and hardwood from Brazil and Indonesia. Concern this demand is leading to illegal logging in some countries. Authors suggest it will also have implications for rural development in China as companies look to secure more wood from domestic plantations. Also noted policy of downsizing the small scale non-wood pulp producers (to reduce pollution of watersheds). Large kraft mills are mostly located in relatively-affluent coastal regions (e.g. Shandong Province)

Katsigris, E., et al. (2004). focusses on supply from Russian Far East, Indonesia, Malaysia, Thailand, PNG, Myanmar, Vietnam, Laos and Cambodia .Raises concerns about ability to supply in the face of growing demand from China. Noted that China was a major player in Asia Pacific trade, and raised concerns about the impact on illegal logging and other unsustainable forest management practices

Kuuluvainen, J., et al. (1988) provides equations for supply and demand of sawlogs and pulp wood (where pulpwood total and pulpwood from thinnings are estimated as separate equations. The models used 2SLS to estimate each supply demand system, and made use of dummy variables and lagged dependent variables as explanatory variables.

Rees, L., and R. Tyers (2004) primarily looks at trade liberalisation measures and again uses a CGE model (GTAP) to investigate these changes. This application is not particularly relevant to the current study.

Simangunsong, B.C.H., and J. Buongiorno (2001). Did work on demand equations as part of the development of the Global Forest Products Model. This model uses econometrically estimated equations of demand for end products, whereas the demand for intermediate products is represented by activity analysis. The paper provides guidance on the best way to estimate equations for a number of countries simultaneously – pooling by OLS, with a static rather than dynamic model gave the best results of the methods tried. This paper provides estimates of price and income (GDP) elasticities for the following products: fuelwood, other industrial, sawnwood, plywood, particleboard, fibreboard, newsprint, printing paper and other paper. The authors noted that estimating a separate demand elasticity for each country gave very unstable results.

Sun, X., E. Katsigris, A. White (2004) highlights major ports and was written at a time when Russian log imports were much more important than currently.

Toppinen, A. and J. Kuuluvainen, (2009) contains reference to the international trade in roundwood, in particular between Russia and Finland. However this trade has dropped away since the Russians imposed an export tax on roundwood and the authors' comment that as this tax escalates roundwood trade is likely to decrease substantially.

There are also a number of papers on determining the location of mills which is relevant to New Zealand also. This is because the demand for wood in China is driven by domestic demand for wood products, and wood using export industries, which may be either Chinese owned or new investments in China by companies that previously had their investments in another of New Zealand's major markets.

They also make a distinction between econometric models and forest sector models and offer a critique of both methodologies. Econometric models use a partial equilibrium structure, whereas comprehensive forest sector models use mathematical programming to solve for a market equilibrium. The authors note that both modelling approaches have their drawbacks, with econometric models being affected by structural change and data quantity and quality issues. However they also state that large forest sector models have a high degree of complexity and so lack transparency, and also do not handle structural change particularly well. They cite a view that more simple models concentrating on a specific issue may be more cost effective and more practical to develop.

Wan, M., A. Toppinen, and R. Hanninen, (2010) provide useful end-use information on both the hardwood and softwood plywood industries. It demonstrates that hardwood plywood is the major part of the industry (85%). "Hardwood plywood is used for interiors, floor molding, wall panels, doors, windows and kitchen cabinets, while softwood plywood is used extensively in housing construction…" Plywood production is based in 4 provinces, Jiangsu, Zhejiang, Shandong and Hebei. Plywood exports have grown rapidly (to more than 10 million m3, see below) and are an important driver of log imports.

This paper is also important because it uses some recent advances in econometric theory (cointegration and error-correction models). The models were estimated with varying degrees of success, as is normal with econometric estimation.

Zhang Y., J. Buongiorno, and D. Zhang (1997) explains the historical development of the Chinese economy and highlights some data source alternatives to FAO. Models of per capita consumption of the main forest product groups were estimated with per capita income being the main explanatory variable. These worked well for wood panels and paper but not for sawnwood.

The authors also estimated a roundwood demand function where the explanatory variables were the consumption of paper and board production, panels production and sawnwood production.

The paper also highlights that fuelwood cannot be ignored since it was about one third of forest removals in 1992, and raises doubts about the ability of the domestic forests to supply industrial needs in China.

Jian Zhang and Jianbang Gan (2007) use a CGE model to answer the question of who will meet China's demand for forest products, particularly raw materials such as logs. The authors state that, because trade liberalisation has been studied extensively and has only a weak influence, they will look only at exchange rates. They state (citing Buongiorno et al.) that GDP, population growth and productivity improvements are important determinants of the demand for forestry products. They also state that a significant proportion of China's imported wood products are re-exported as products such as furniture (eg half of imported logs, sawnwood and panels is further processed and re-exported.

Therefore they suggest that the major driver of China's demand for forestry products is world economic growth, and Chinese exports will grow faster than world output. However part of the demand is driven by Chinese domestic market parameters. The authors expect that logging restrictions, and appreciation of the Chinese currency will only have a small impact compared to world economic growth. The Russians are seen as having a competitive advantage in the Chinese market. This analysis was carried out prior to the imposition of the log export tax. In general their model did not predict any major changes in the main importers or exporters

Zhang, D, and Y. Li, (2009) provide some excellent background on the drivers of China's trade in wood products (both imports and exports). It looks particularly at China's resource endowment and 1998 logging restrictions in natural forest. It depicts China as a resource scarce country with low labour costs, and notes that China imports not only for domestic consumption but for export also. It is also observed that China exports wood products rather than pulp and paper, and explains this as saying that China exports labour intensive rather than capital intensive forestry products. The analytical results confirm predictable impacts of exchange rates and logging restrictions on China's trade in wood products. The gravity model is the modelling framework used in this study and it predicts that China tends to import more from, and export more to, closer countries and more developed countries.

3.1.2 Market studies

Daniels, J. M. (2005) includes data to 2001 and covers exports of both logs and lumber to the primary Pacific Rim markets (Japan, Korea and China), and the border trade between USA and Canada. The report notes that the trade started with the Columbus Day storm of 1962 as a way of selling salvaged timber. The trade continued because Japan had a need to for high quality logs for construction. The trade with Korea started in 1971 and with China in 1980. In reviewing the Japanese trade, Daniels noted the following important determining factors for Japan's trade. In spite of having abundant forest resources, they are economically difficult to access.
Also after the war Japan rebuilt its sawmilling capacity and located it on the coast to provide the best location for use of imported logs. This ensured that log imports replaced the Japanese domestic log supply. At that stage they had a low labour cost relative to USA and Daniels argues this was a competitive advantage.

Japan also experienced rapid economic growth from the 60s to the early 1990s, led to a sustained high demand for new houses, and because Japan has a strong preference for wood housing this led to an increased demand for wood imports.

Three main sectors in Japan wooden frame housing

- Traditional post and beam construction
- Japanese light frame construction
- Prefabricated structures

Traditional post and beam had about 80% of the market. Argued that PNW logs were well suited to traditional post and beam construction. For this construction method Japanese grades and dimensions were required and it was easier to import logs. This also led to the export of higher quality logs to Japan (No 2 and better) whereas the domestic market took No 2 and worse.

Because ring count was part of the Japanese grade this was also important. Also mentioned that Japanese buyers were prepared to pay more for a reliable supply at a consistent price.

Korea

Again cut forests during WW2. Forest has been replanted but expected to remain a net importer of forestry products until 2020 at least. Korea was a significant producer and exporter of hardwood plywood (getting logs primarily from Indonesia), until Indonesia implemented a completed log export ban in 1981. The sawmilling industry still uses some hardwood logs but also uses softwood for construction and joinery applications.

Koreas GDP grew rapidly from 1982 due to domestic demand. The log trade from the PNW started in the 8=70s and peaked about 1990. The ensuing decline was due both to price spikes and the increased trade from NZ and Chile, and now Korea imports most of its need from New Zealand.

China

Difficult to get good data on domestic timber supply – China has planted a very significant area (Daniels cites 17.5 million ha, based on a 2000 FAO report). Log trade with China started in 1980.

Chinese demand peaked in the late 1980s then declined rapidly – for the same reasons as Korea. The main difference is that (at the time of writing this report), most of China's logs were sourced from Russia.

China has been a market for low cost logs traditionally, but the availability of foreign exchange has been a limiting factor. Where barter trade was possible (for example with Russia) this was favoured an contributed to the historical pattern of trade

Macro-economic factors influencing log and lumber trade

- Housing starts
- Business cycles
- Interest rates affecting investment
- Currency exchange rates

Luketina, L. (2014) provides a comprehensive point-in time description of the China market.

UNECE/FAO (2014) provides an accessible database for European data on wood products as well as a focus on USA. It also looks in some detail at resources and value added products.

Wang, G., et al. (2007) describe policy reforms in the management of forest resources in China. Describes the Six Key Forestry Programs, which target 96 million ha for afforestation. Other reforms are described.

3.1.3 Economic conditions and drivers

Economist Intelligence Unit (2015) describes the recent strategy announced by the Chinese government to "promote economic engagement and investment along two main routes": the New Silk Road Economic Belt which will run overland through Central Asia and to Europe and the 21st Century Maritime Silk Road – a sea route with stops in South East Asia, South Asia and Africa. This report assesses the risks of these two strategies. This report is important, because one of the key reasons identified by market commentators for the continued high demand for wood products in China is due to implementation of new large scale infrastructure projects such as these ones

3.1.4 Forecasts

This report (Gupta M., et al (2013)) was commissioned specifically for the same purpose as the current research being conducted for MPI. It provides an appropriate split of products for some products (panels and paper) and more detail than would be required in New Zealand for sawnwood. Market pulp is also not studied, although this would be necessary for New Zealand.

It also outlines the available data sets on demand drivers for Australian consumption of forestry products.

The paper presents models of consumption and imports for

- Sawnwood

- Wood based panels (in aggregate)
- Paper and paper board,

and exports of wood chips. These econometrically estimated equations are combined to forecast consumption and imports to 2050.

There is some detail on the structure of the econometric models used. Significant aspects were the use of first-differenced data, where the first step was to take the log of the original data. The models also use dummy variables to account for specific "one-off" events such as the introduction of GST, to handle unexplained trends in import data, and other events.

3.1.5 Harvested wood products

Hashimoto, S. and Y. Moriguchi (2004) provides some useful information on time series of conversion factors for a range of primary and secondary wood products. Units are in tera grams = 10E12 grams.

10E3 grams = kg
10E6 grams = tonne
10E12 grams = millions of tonnes

Ji, H., H. Yang, Y. Nie, Y. Hong (2013) used FAO data to model changes in carbon stock, using the different IPCC approaches. They show that the stock-change, atmospheric-flow and production approaches give very different views of China's change in carbon stocks – using the atmospheric flow approach China became a carbon source in 2000. Also point out the importance of estimating the end use pools such as buildings, wood furniture and books.

Yang, H., X. Zhang, Y. Hong (2014) cites useful data sources for Chinese forestry and wood products industries. The paper outlines the change in carbon stock as well as the total carbon stock from 1961 to 2012, using FAO data on production and trade, and the stock change approach from the IPCC methods. There appears to be some confusion between stock and flow concepts in this paper (e.g. commentary on Fig 5).

3.1.6 Production and investment in processing capacity

Lundmark, R. (2003**)** includes a useful discussion of the variables that influence investment in pulp and paper. It is unfortunate for the present study that Lundmark did not deal with pulp and paper separately. However the three main drivers for investment in pulp and paper were labour costs, market size and agglomeration effects. Agglomeration may be because a large part of investment expenditure is upgrades to existing capacity. Lundmark suggests that the paper industry is "output oriented", that is, more concerned with market conditions than input costs. The second paper comes to much the same conclusion but uses various types of least-squares regression rather than a logit model. Lundmark, R. (2001) highlights the importance of wastepaper supply in the location of paper mills – supporting the view that paper mills are located close to markets and pulp mills close to the resource.

3.1.7 Use of wood in construction

A number of potentially relevant references in this area have been identified. However none so far provide specific information on wood used in formwork. Because this is a very important current use of radiata pine (around 80% of the sawn timber and also a large proportion of the plywood) it will be important to do this probably with specific collection of data on construction sites in China.

3.2 Analytical methods

There are a number of analytical methods used by researchers to model markets and in particular the Chinese markets. The main ones are

- Econometric (partial equilibrium) models
- Forest sector models (solved using a mathematical programming framework)
- General equilibrium models
- Gravity models

Econometric models use a partial equilibrium structure, whereas comprehensive forest sector models use mathematical programming to solve for a market equilibrium. The authors note that both modelling approaches have their drawbacks, with econometric models being affected by structural change and data quantity and quality issues. However they also state that large forest sector models have a high degree of complexity and so lack transparency, and also do not handle structural change particularly well. They cite a view that more simple models concentrating on a specific issue may be more cost effective and more practical to develop.

These methods will be evaluated to determine which might be most suitable for the current task. Because the current task is specific to New Zealand's exports, it is likely that some sort of partial equilibrium framework should be favoured.

4. Wood products production and supply

4.1. Data and trends

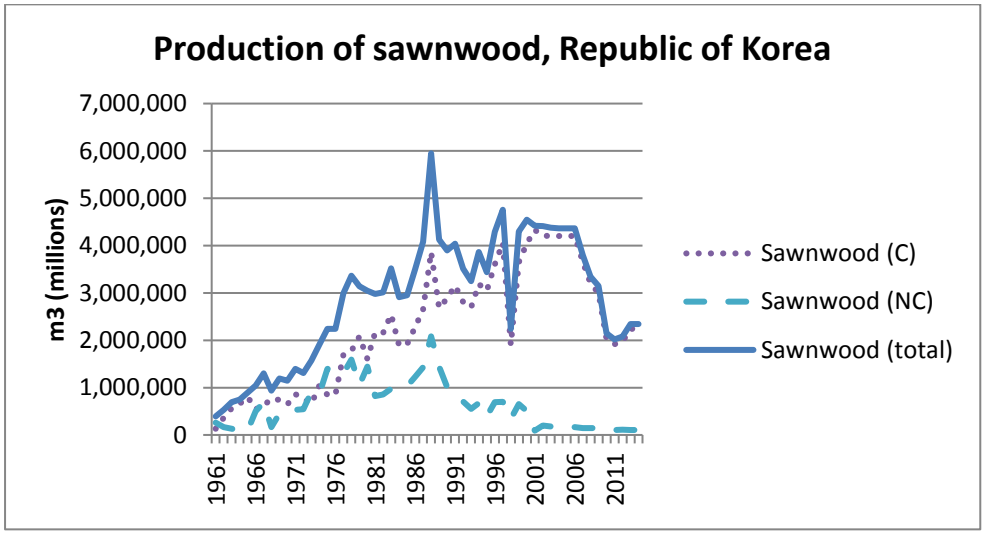
FAO has data on production for a range of products of interest. This project should focus initially on sawn timber, MDF and plywood.

4.1.1. Sawn timber

Japan and Korea were initially much more focused on utilising hardwood logs from Asia, Africa, South America and the Pacific; they are now almost entirely reliant on softwoods. As these sources were logged out or otherwise made unavailable, the industry shifted to softwood logs, using the same sawmill equipment as had been previously used for hardwood logs. Production has peaked in both of these countries – the industry is relatively old and modern mills are rare. In Korea, sawmills have historically been maintained to provide residue to the medium density fibreboard industry. Sawmills are often either owned by MDF companies, or have supply agreements or other arrangements that guarantee the supply of chip from the sawmill to the MDF company.

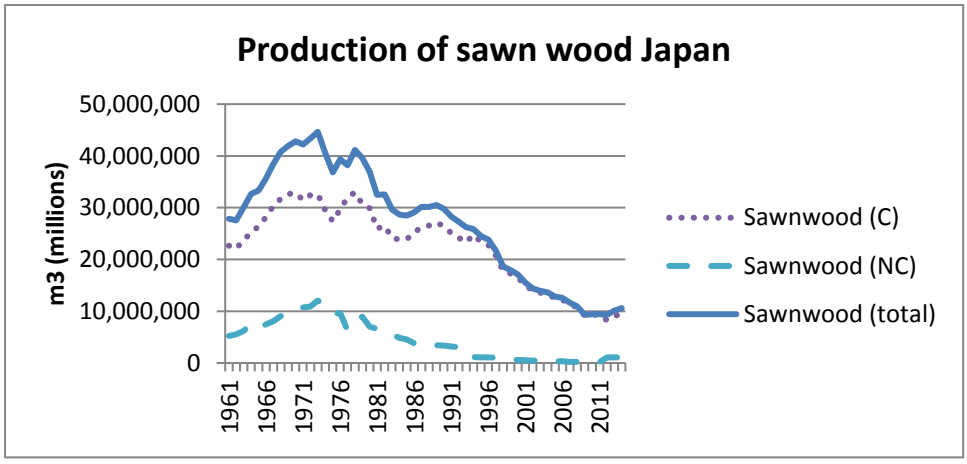
China's use of hardwoods has increased as production has increased, and India remains predominantly a producer of hardwood sawn timber, sourced from a number of tropical countries. China is the only country of these four that shows a strong increase in sawn timber production.

Figure 4.1: Production of sawn timber, Korea



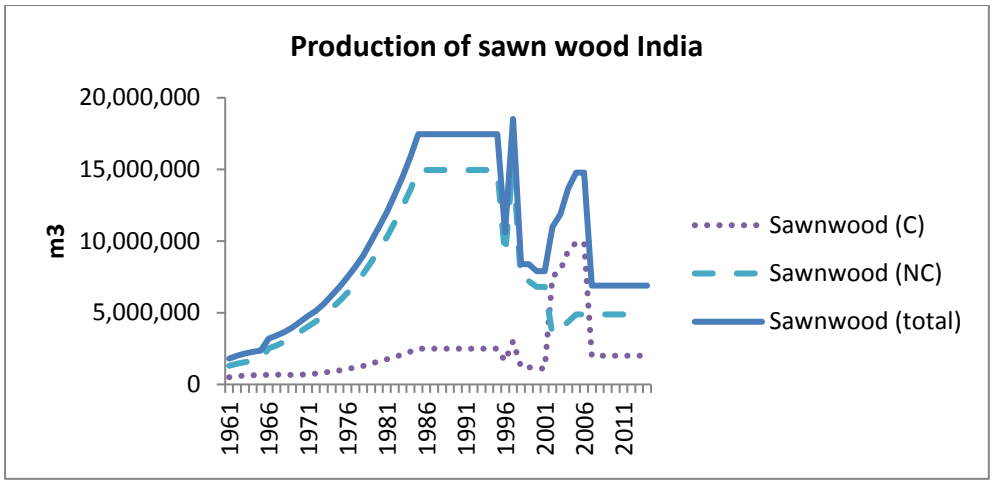
Source: FAO FAOSTAT

Figure 4.2: Production of sawn timber, Japan



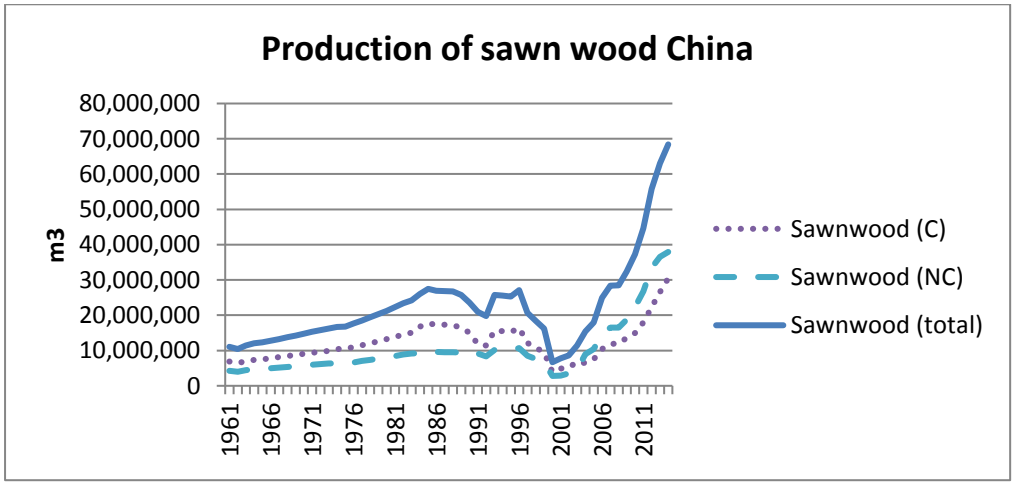
Source: FAO FAOSTAT

Figure 4.3: Production of sawn timber, India



Source: FAO FAOSTAT

Figure 4.4 Production of sawn timber China



Source: FAO FAOSTAT

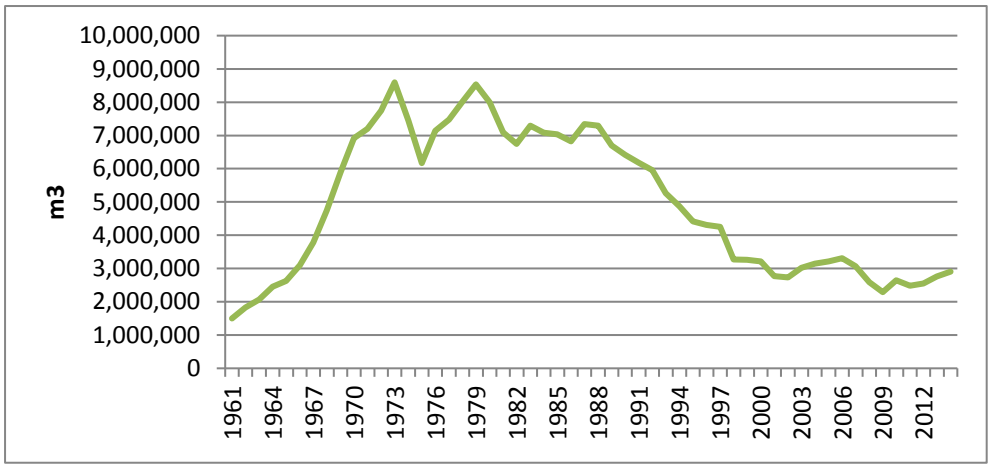
4.1.2. Wood based panels

4.1.2.1. Plywood

The wood based panels data are separated into plywood, which converts logs into veneer and then plywood, and particleboard and MDF which use residue from sawmilling (and pulp grade logs). It is likely the Indian plywood includes block-board, which is an entirely different process to plywood production. Plywood is produced from veneer (frequently from higher-quality logs) which is then "laid up" and pressed to form plywood. Block-board is made by taking slab-wood and re-sawing it into very small pieces which are assembled in a frame, and then overlaid with veneer. Products and end-uses are discussed more in the demand section of this report.

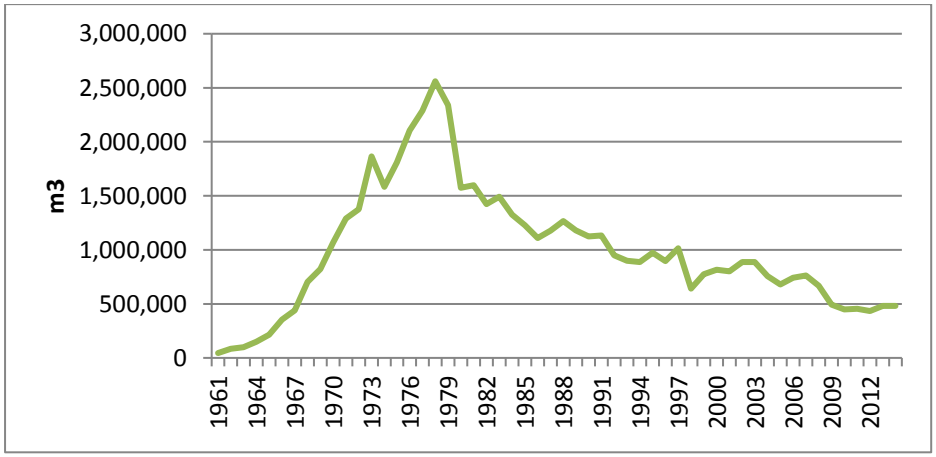
Plywood is a declining product in Japan and Korea (it was an industry based on South East Asian hardwood logs and low labour costs, and neither of these are available in these countries any longer. Plywood is a new product in India and China, although, as noted above, some of the plywood in India is block-board, produced as a by-product of the sawmilling industry.

Figure 4.5: Production of plywood, Japan



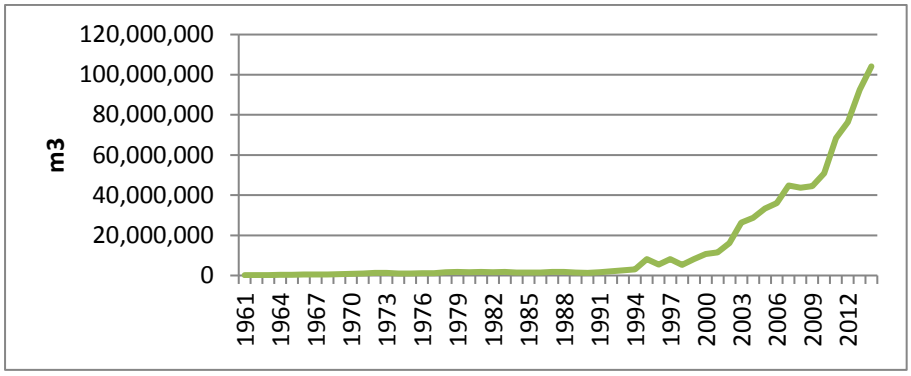
Source: FAO FAOSTAT

Figure 4.6: Production of plywood, Korea



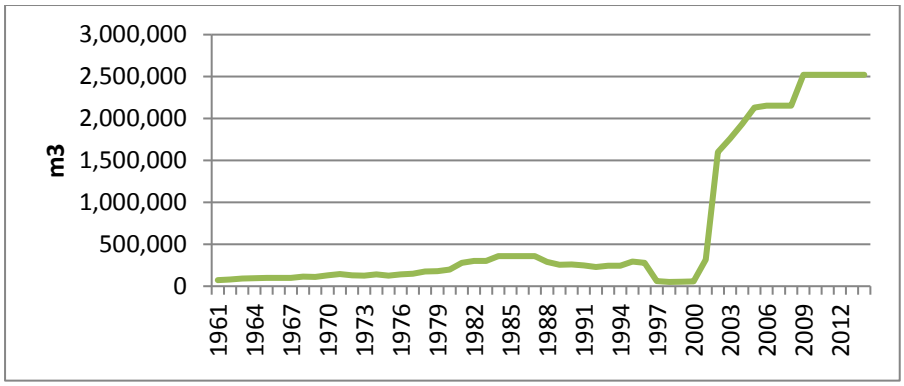
Source: FAO FAOSTAT

Figure 4.7: Production of plywood, China



Source: FAO FAOSTAT

Figure 4.8: Production of plywood, India

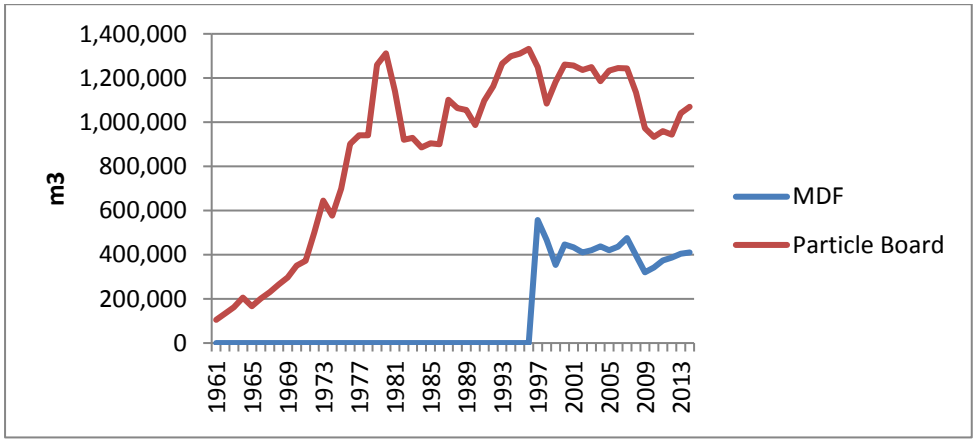


Source: FAO FAOSTAT

3.1.2.2 MDF and Particle Board

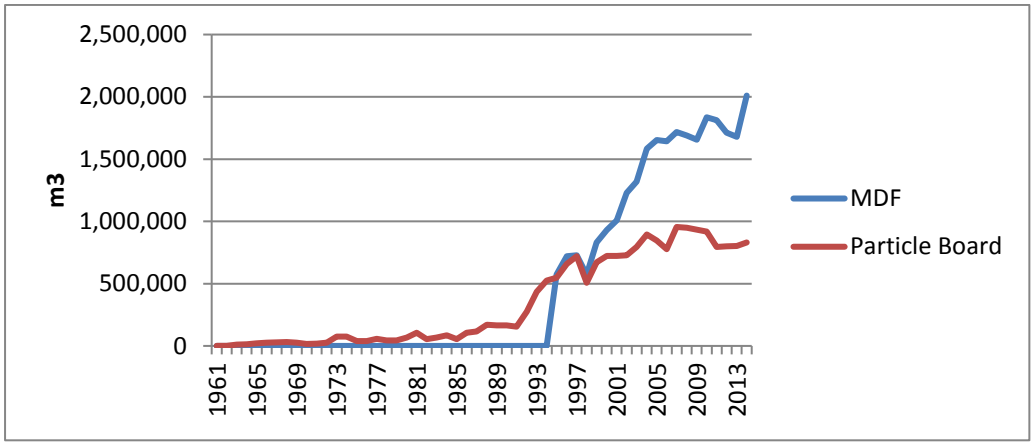
MDF and particleboard are major products in China, Korea and Japan. In India block board fills the niche occupied by wood panels to some extent. There has been very rapid expansion of capacity in MDF and to a lesser extent, particleboard in China and South Korea

Figure 4.9: Production of MDF and particleboard, Japan



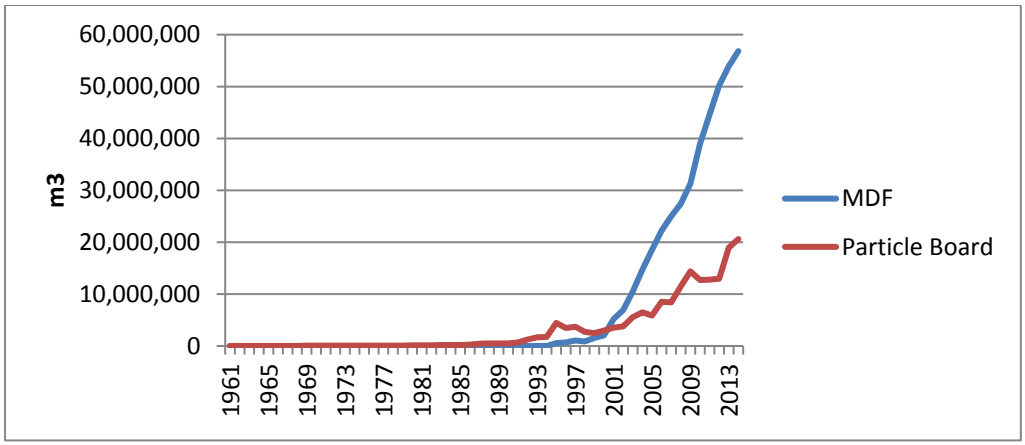
Source: FAO FAOSTAT

Figure 4.10: Production of MDF and particleboard, Korea



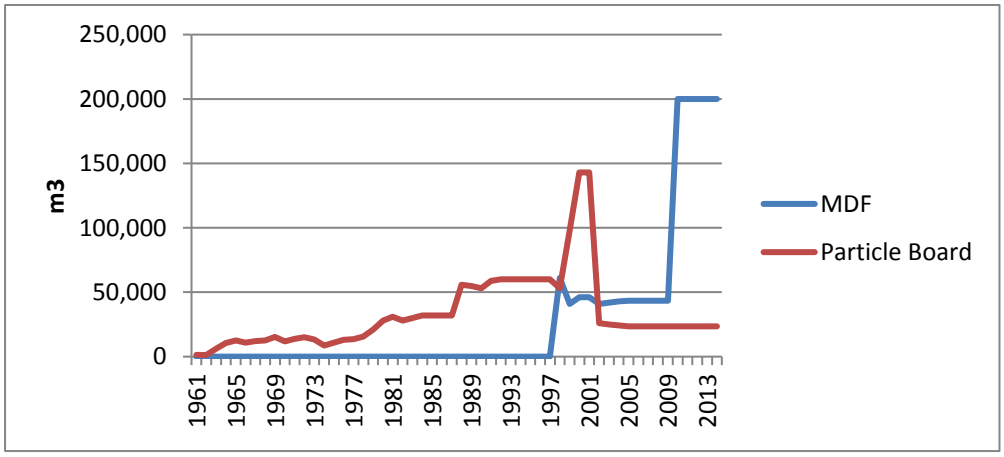
Source: FAO FAOSTAT

Figure 4.11 Production of MDF and particleboard, China



Source: FAO FAOSTAT

Figure 4.12: Production of MDF and particleboard, India

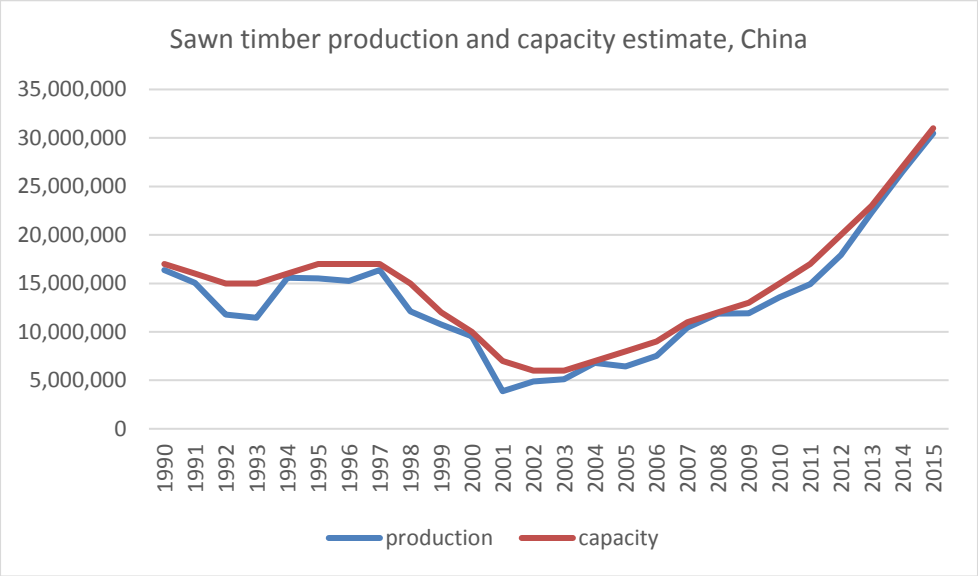


Source: FAO FAOSTAT

4.2. Estimation of industrial capacity

is possible to estimate capacity from production data, as shown below. Capacity estimates will also be useful to determine demand for logs versus demand for products in the model. The method commonly used is a "trend through peaks" estimation method. The key points are to identify peaks in production (which theoretically should correspond most closely to capacity at that time, and select a method to draw a reasonable trend line through these peaks. A potential method of estimating the trend in capacity is to fit a cubic spline between peak values –where the 'knots' of the cubic spline are selected as the peak production levels.

Figure 4.13: Estimation of industrial capacity



4.3. Modeling production and supply of wood products in New Zealand's major markets

4.3.1.Sawn timber supply, China

Sawmilling in China is generally a low-capital, high labour input business. The standard business model seems to involve provision of a building and equipment by a business person who has access to capital, with contract labour cutting the sawn timber as required. The labour is provided by internal migration from the poorer regions of China. It is a very flexible model – the capacity of the industry can move up and down relatively easily. The consequences of shutting down are relatively insignificant, as fixed costs are very low. The sawmill may be housed in a generic factory building which could be used for other industries. Or the mill is housed in a very cheap and relatively temporary building.

Sawmill economics are shown below in the table - these costs were derived from market visits to a number of sawmills in the main radiata pine processing areas in China in 2015. The model shows

that log cost is the only significant cost of production – even though sawmilling is highly labour intensive, the cost of labour per m3 sawn is very low.

This model:

1. Indicates economic variables to be included when modelling supply of sawn timber
2. It provides a benchmark to verify the public domain data from FAO and other sources

Data required to develop a model of sawn timber supply

- Log cost
- Labour cost
- Sawn timber output price
- Residue (chip) price

Labour cost data is provided from ILO, but unfortunately limited data are available.

http://www.ilo.org/ilostat/faces/home/statisticaldata/bulk-download?_afrLoop=54329277755932#%40%3F_afrLoop%3D54329277755932%26_adf.ctrl-state%3D1caw8ooftz_643

Import unit values for softwood logs and softwood sawn timber were used as proxies for sawn timber price and log price and the unit value for coniferous wood chips as the proxy for the value of residue. Note that in China the residue is processed as a separate operation (different business) – the sawmill sells slab to a business with a portable chipper (there is some aggregation of slab from a number of sawmills to a central site) which then sells the chip, usually for pulp. The rationale is: because the mills rely on imported logs they are located relatively close to the ports and so the cost of transport is not material. Also will be competing with

There is not the expected relationship between profitability of sawmilling and the increase in production. Because China is a command economy this may not exist. In fact there appears to be a better relationship between sawmill capacity and construction activity for the past 10 years or so.

Figure 4.14 Sawmill economics, China

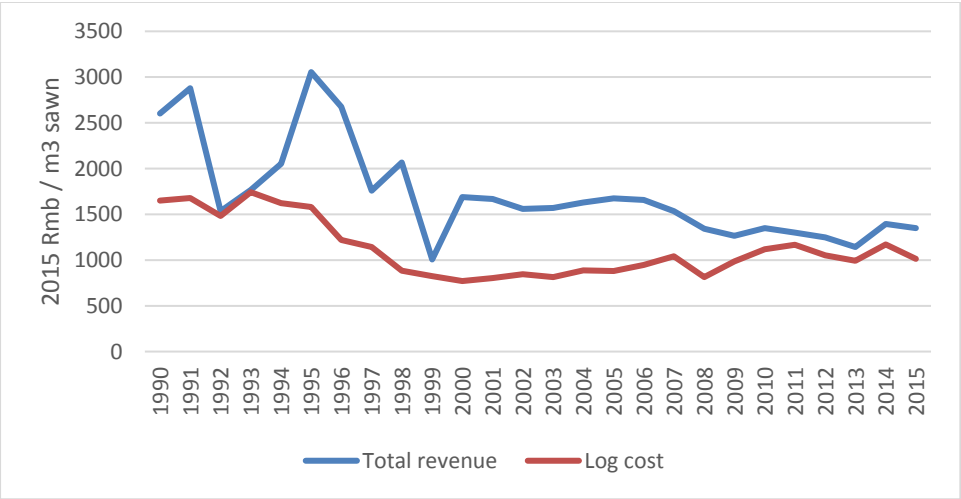


Table 4.1: Chinese sawmill economics, 2015

Production	20	m3/day sawn	
Conversion	60%	sawn	
	10%	sawdust	
	30%	residue	
Log input	33	m3/day log volume	
Log price	660	Rmb/m3	
Log cost	22,000	Rmb/day	
Labour cost	4000	Rmb /month	
Days per month	25		
Labour cost per person	160	RmB/day/person	
Number of people	7	for 2 band saw mill	
Mill labour cost	1,120	Rmb/day	
Sawmill costs		**per m3 sawn**	
Log	1100	Rmb/m3 sawn	95%
Labour	56	Rmb/m3 sawn	5%
TOTAL	1156	Rmb/m3 sawn	

4.3.2 Sawn timber supply, Korea, 2015

The sawmilling industry is being hit by imports of sawn timber from a number of sources, in particular, Chile, Europe and Russia. There were multiple grades of packaging timber produced by Arauco as well as material from CMPC and Masisa. Apparently the imported timber sets the price. Imported radiata pine sawn timber is predominantly targeted at the packaging market.

Radiata pine is still positioned as a low quality, low priced timber. The mouldings and millwork market seems to be occupied by MDF rather than solid wood species like radiata pine, and remanufacturing is not competitive in Korea compared with China

Overall, a flourishing log market in the past has not resulted in radiata now being positioned where its strengths lie, in Korea. It is still bought on price (quoted as the “cheapest wood in the world” by one end-user we met in Korea). Radiata pine is used as a feedstock for MDF, but mixed with other pine species.

It is used for temporary construction but other species are preferred for ground contact uses such as landscaping and outdoor wood. We could not see any evidence that its ease of preservative treatment is recognised by the Korean market (although we heard that radiata was treated in Korea).

The industry capacity in sawmilling is expanding in scale – smaller sawmills moving to the port area to minimise transportation costs - but seems to be doing this with old equipment. We saw one mill with three head rigs under the same roof and another with two. There was minimal use of new technology (scanning and sorting equipment) in mills of this type, and the timber is all sold green and rough sawn. Still high use of labour at a time when labour costs have increased marked compared with China. Widespread use of guest workers to provide labour in sawmills. On the other hand there are some modern sawmills with log sorting. The most common supply chain is agents buying from log exporters in New Zealand, traders are now relatively uncommon.

Like other markets, Korea is dynamic and changing. Recently there has been considerable consolidation in the sawmilling industry. There is a world class construction industry – Korean designs are used in other cold countries for apartments

4.3.3 Sawn timber supply, India

The Indian Sawmilling industry is very small scale and largely focused on hardwoods. "…about 80 percent of wood converted into sawnwood comes from various hardwood species and 20 percent from coniferous species. It is processed in over 60,000 small sawmilling units catering to local needs, most of them at a technologically low level…." (Pandey and Rangaraju, 2008)

"…In comparison with industrialised countries, sawnwood consumption in India is depressed and distorted by inadequate availability, coupled with high prices for quality material. The industry is also unable to modernise because of the daily struggle for raw material…" (Pandey and Rangaraju, 2008)

India is still predominantly a hardwood market, and a number of sawmillers have logging operations or sourced wood from Africe (eg South Sudan), Indonesia or Solomon Islands. A sawmill unit in India is slightly different to a unit in China. It has one horizontal band saw as the headrig and one or two vertical bandsaws for the re-saw. A unit employs 10 or 11 people. This is 1950s technology, but a lot of people that have tried more modern technology in India have failed. This technology was developed for hardwood sawing and sawing speed on the primary breakdown saw (the horizontal band saw) is slow. Nevertheless this saw is very flexible in the size of log that can be sawn.

We saw a range of grades (A grade to pulp logs) being sawn on this type of equipment. A sawmill unit required a skilled person on each saw, and each unit had a production controller who was measuring each log prior to sawing each flitch. Mostly the whole log was cut prior to the flitches being moved to the vertical band saw. We saw a couple of modifications to the set up. One was to saw two logs at the same time; the other was a centre with two band saws on the one unit.

Mills are cutting construction or packaging timber. These will come from the centre of the log. The first priority is to cut full length products for construction or packaging. Next they will cut shorter lengths (the off-sizes). The next operation is to recover wood from the wings or slab. This was often done with a third (smaller) band saw. This operation also included rip sawing and defecting, to produce two grades of block-board material (A grade – without wane, and B grade – with wane).

Mills are commonly recovering material from the sideboards to make block-board. This is a very common recovery operation for sawmills and seems to add about 10% to the recovery. The process is to re-saw what would be chip residue material in New Zealand. This material is assembled into a board by the following process:

1. Cut to size into pieces with dimensions
2. Edge glue and assemble using edge pieces and a temporary brace to hold it together.
3. Assemble with core veneer outside the blocks then a face veneer outside that.
4. Press in hot press and trim to size

Some mills in India have kilns or heat treatment plants because the export packaging market requires it. Therefore some otherwise unusable material goes to the boiler for heating the kilns.

The remaining material was firewood which was usually sold to other industries (although this market was dependent on the price of coal, which had recently dropped a lot meaning these industries had switched their boilers to coal. A small amount was burnt on site if the mill had kilns (usually these were used for heat treatment for phytosanitary purposes if the produce was export packaging). The sawdust was sold to middlemen and there were many end uses – particleboard, or incense or for white coal briquettes for burning by industries. The sawdust is used for a wide variety of uses. Not much wood seems to go to particleboard or MDF manufacture.

The construction end use is mostly for what is called battens. Most sawmills use a wide variety of timbers – they are usually familiar with both hardwoods and softwoods

Some operations have chosen to carry out further wood manufacturing. They are more doing what a joiner would do in New Zealand but using high tech equipment. Special mitre saws for doing door frames / door jambs. They might also have CNC machines and sanding equipment, melamine presses and spray booths. Some are working on apartment building fit-outs

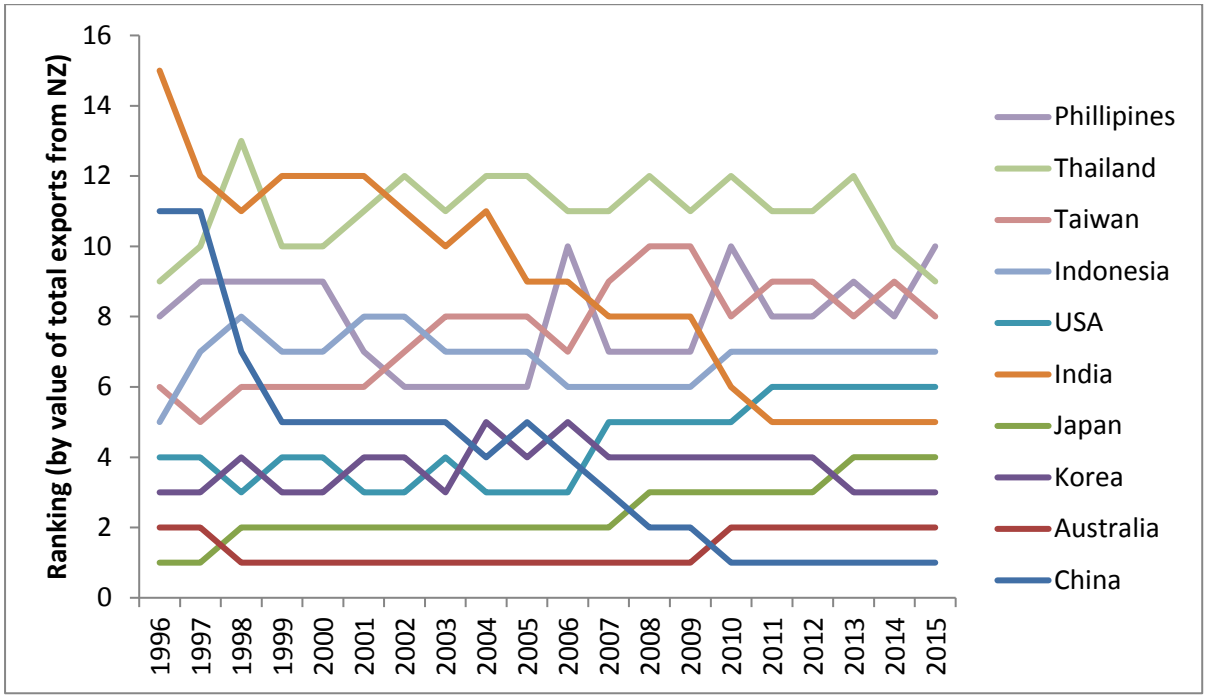
It was felt that packaging market had good prospects once GST was implemented by the Modhi government. This would mean the local taxes (which currently hinder interstate movement) would be removed. This would in turn lead to the development of large national distribution centres, and hence a much increased demand for pallets. Packaging (both for domestic and export) was another major part of this end use. Frequently done by specialised industries, which are often collocated with their customers, these customers make glass, machinery, pharmaceuticals. The pallets boxes and crates are made to the customer’s specification using a jig.

The construction industry conversely has been hit by the Modhi government crack-down on corruption. There was a tendency to make the payment for a new apartment 60% cheque and 40% cash allowing the purchaser to evade capital gains tax and stamp duty. There is a cash crunch in this industry right now which has led to a decrease in demand.

5. Consumption and drivers of demand

5.1 Trends in import demand

Figure 5.1: New Zealand's top 10 markets by value in 2015, and their rankings since 1996



Source: http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/wood-product-markets/

The key messages from Figure 5.1 are:

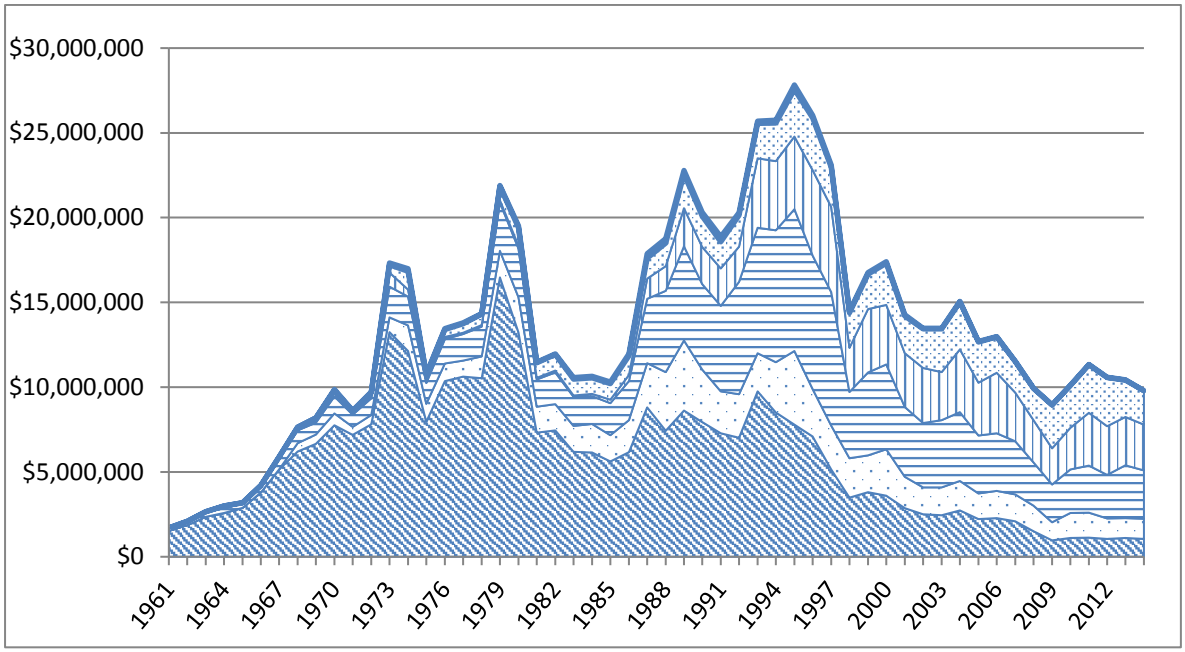
- Markets last a while (rankings change slowly)
- Markets are in the Pacific/Asia region
- A trend towards developing countries

This analysis will also give the opportunity to understand how the wood using industries in New Zealand's major markets have developed over time. Prediction of future market conditions should be undertaken with some knowledge of how New Zealand's markets have changed historically. We have a good record of markets since 1961 from FAO data.

New Zealand's log markets developed over time with Japan being the first market, Korea second, China third and India the most recent to emerge. The Japanese market for logs started in the late 1950s. Figures 5.2 and 5.3 below show that the Japanese and Korean markets were 90% logs in 1961 and only 10% logs in 2015. China and India are less developed and show different trends in imports.

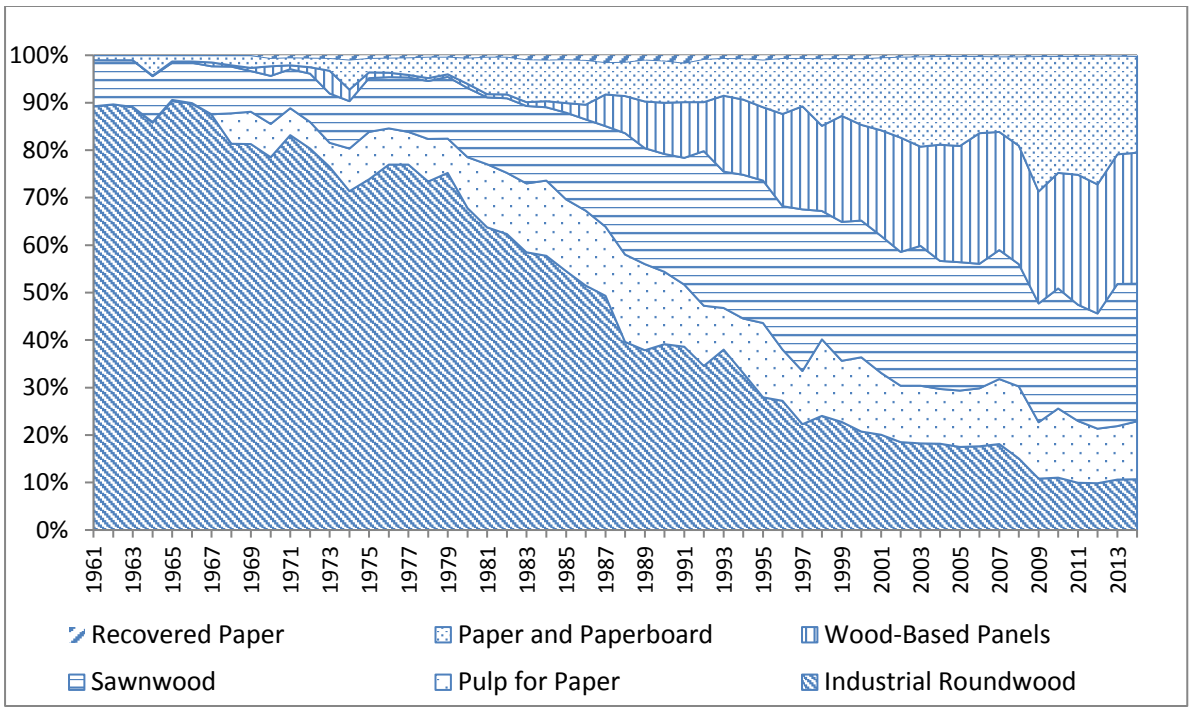
Existing developed country markets (Australia and USA, Figures 5.10 to 5.13) show a much more stable pattern of preference for different products, with little demand for logs.

Figure 5.2: Japan real value of imports by product (2014 $US CIF)



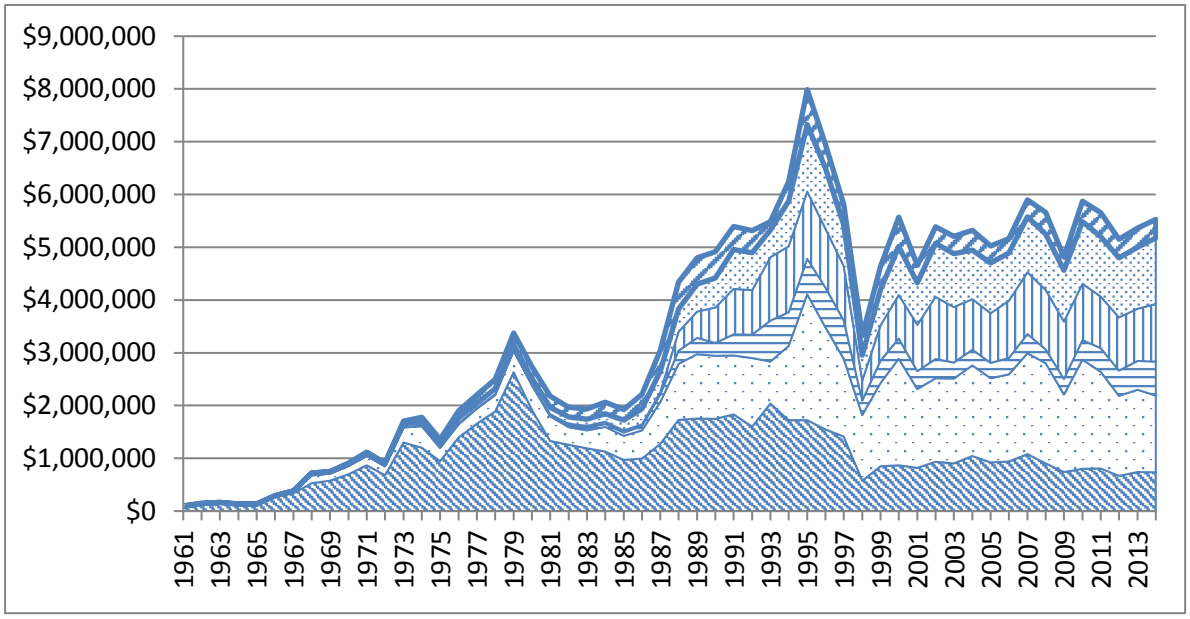
Source: FAO FAOSTAT, IMF International Financial Statistics

Figure 5.3 Share of import value, Japan



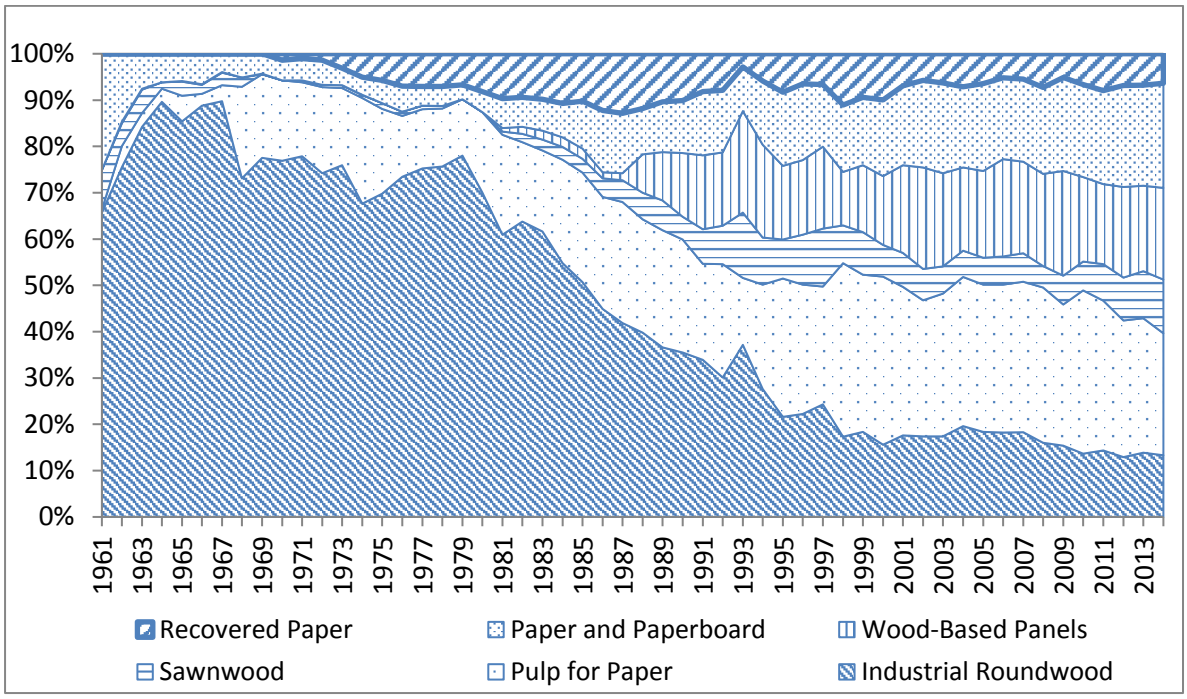
Source: FAO FAOSTAT

Figure 5.4: Korea real value of imports by product (2014 $US CIF)



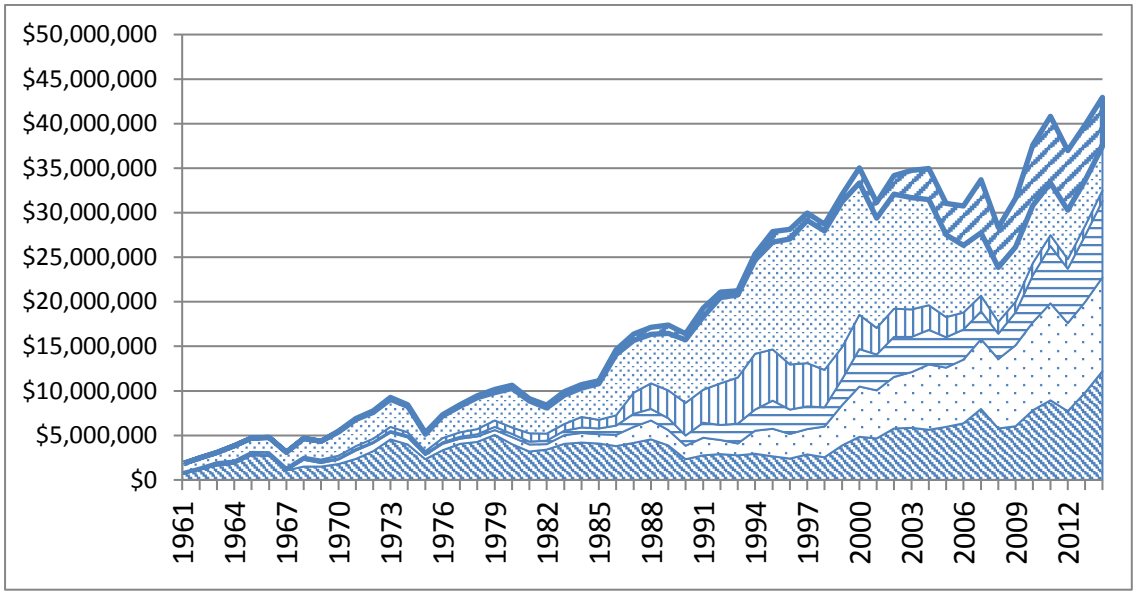
Source: FAO FAOSTAT, IMF International Financial Statistics

Figure 5.5: Share of import value, Korea



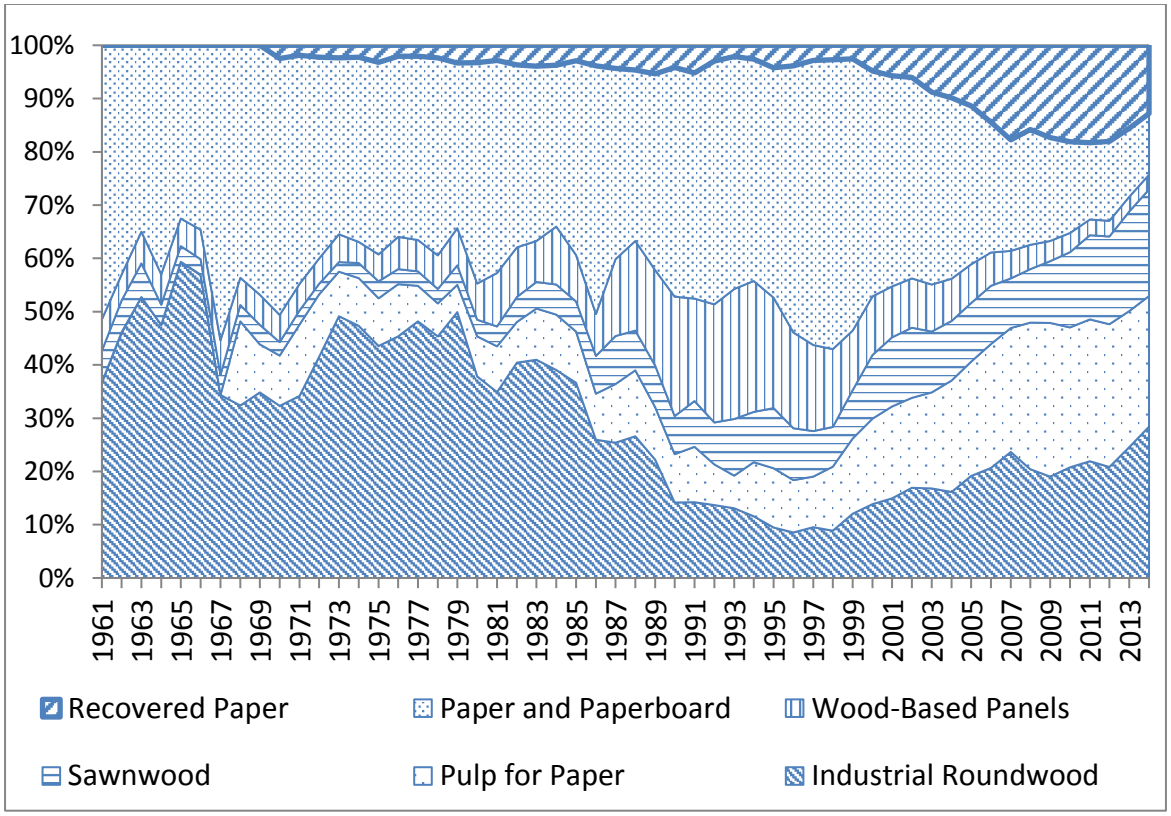
Source: FAO FAOSTAT

Figure 5.6: China real value of imports by product (2014 $US CIF)



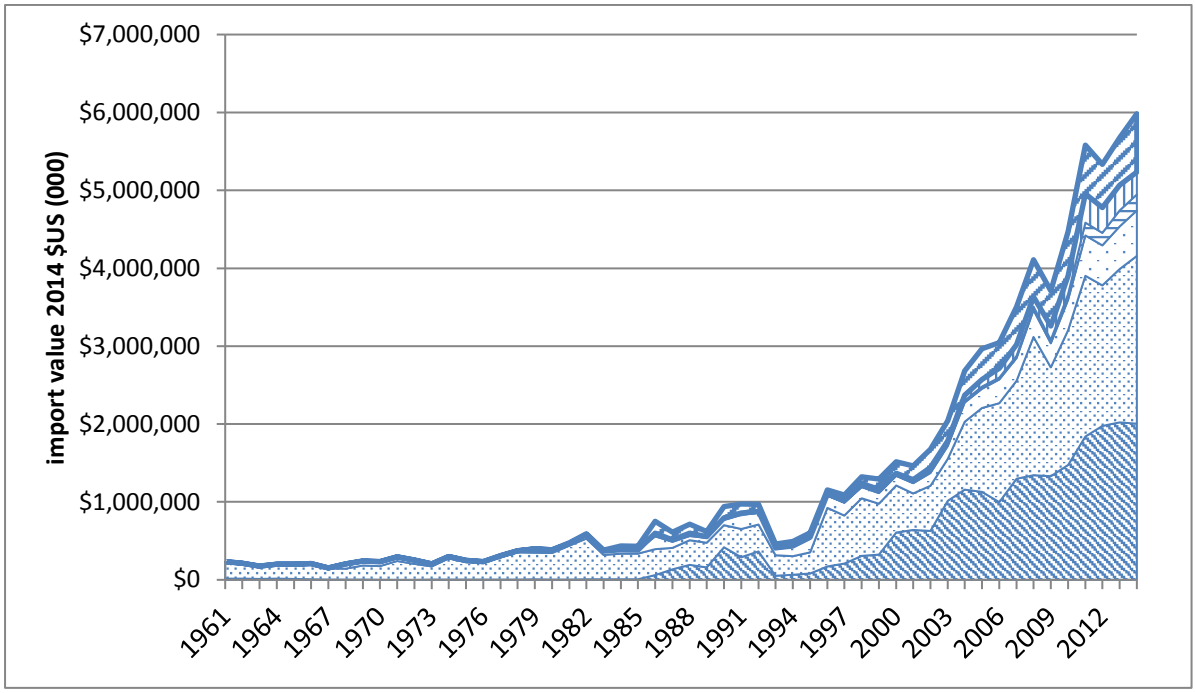
Source: FAO FAOSTAT, IMF International Financial Statistics

Figure 5.7: Share of import value, China



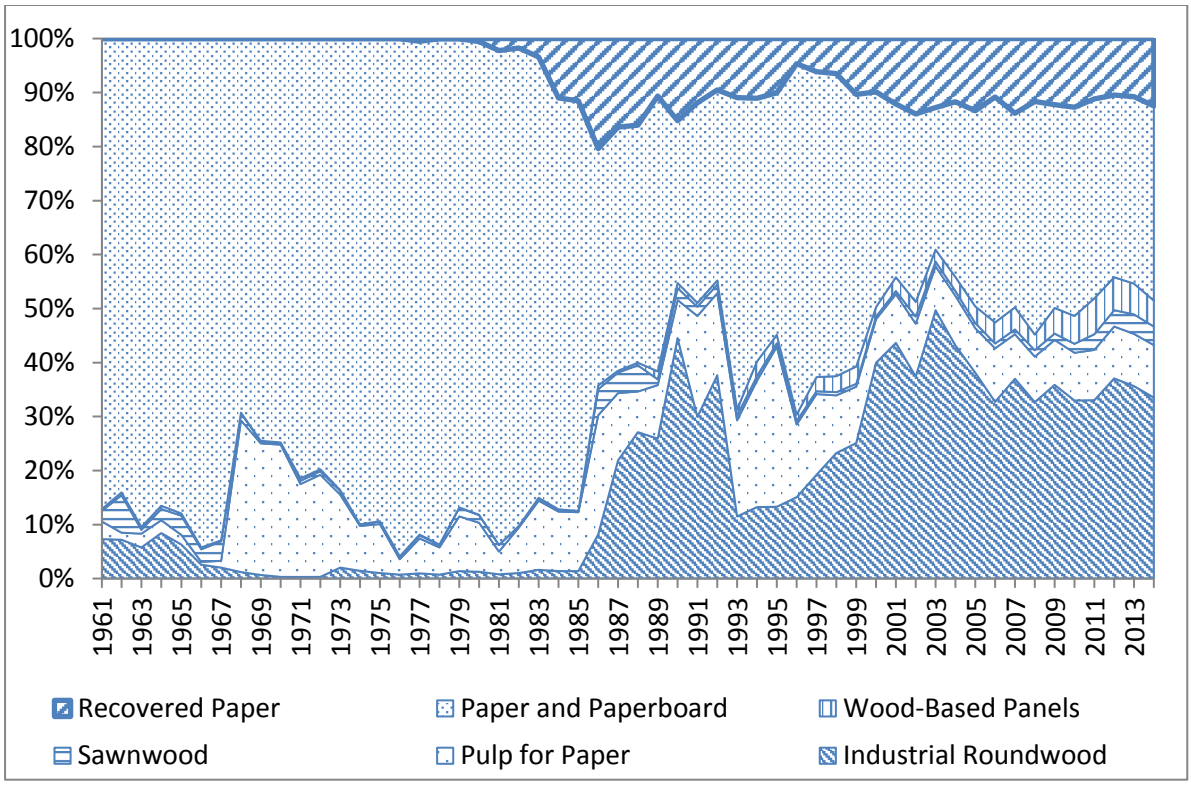
Source: FAO FAOSTAT

Figure 5.8: India, real value of imports by product (2014 $US CIF)



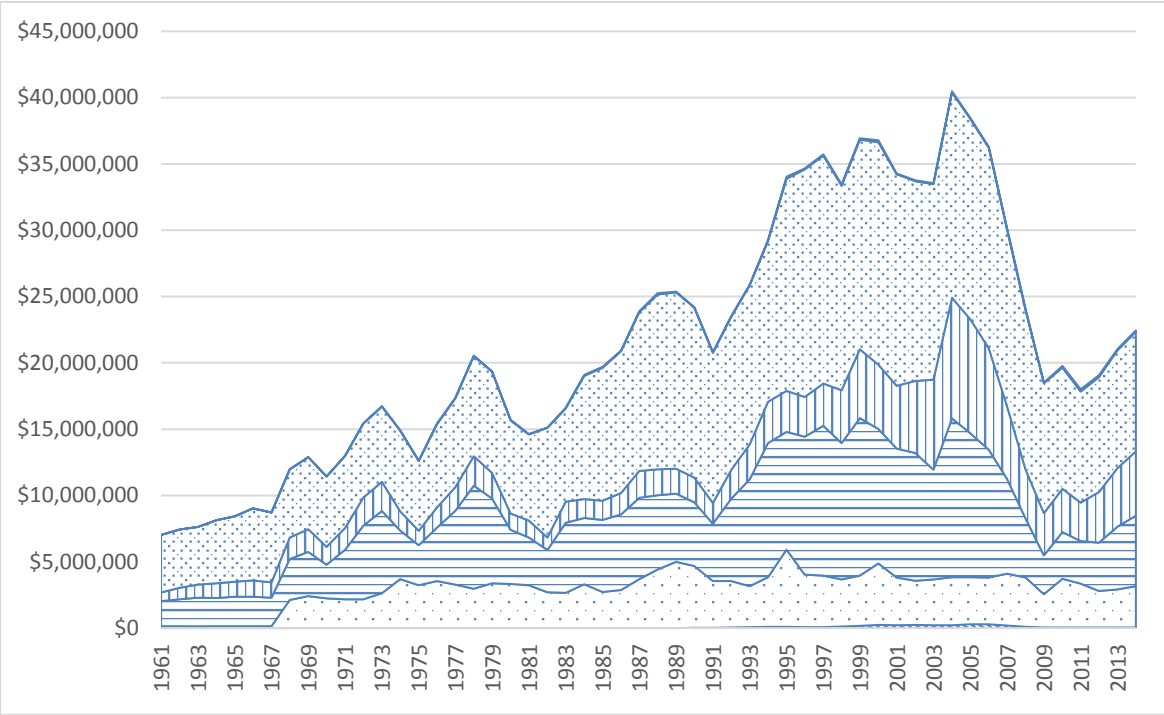
Source : FAO FAOSTAT, IMF International Financial Statistics

Figure 5.9 Share of import value, India



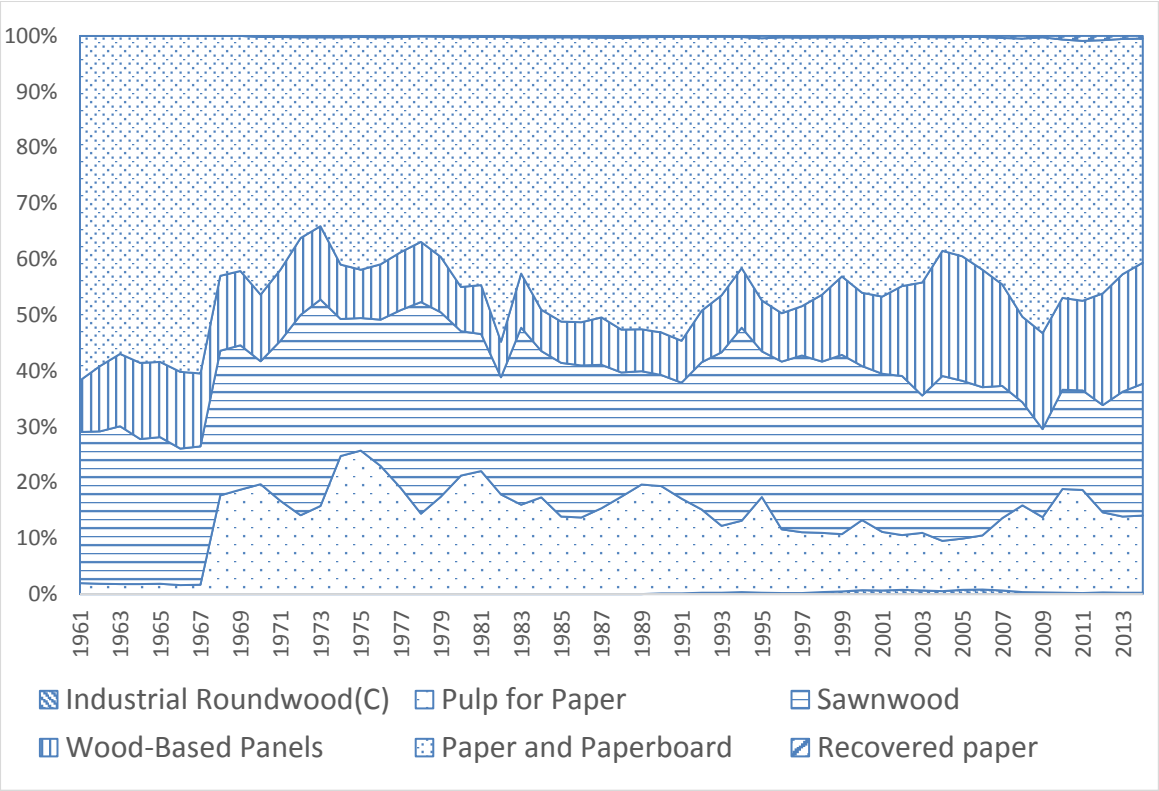
Source: FAO FAOSTAT

Figure 5.10: USA, real value of imports by product (2014 $US CIF)



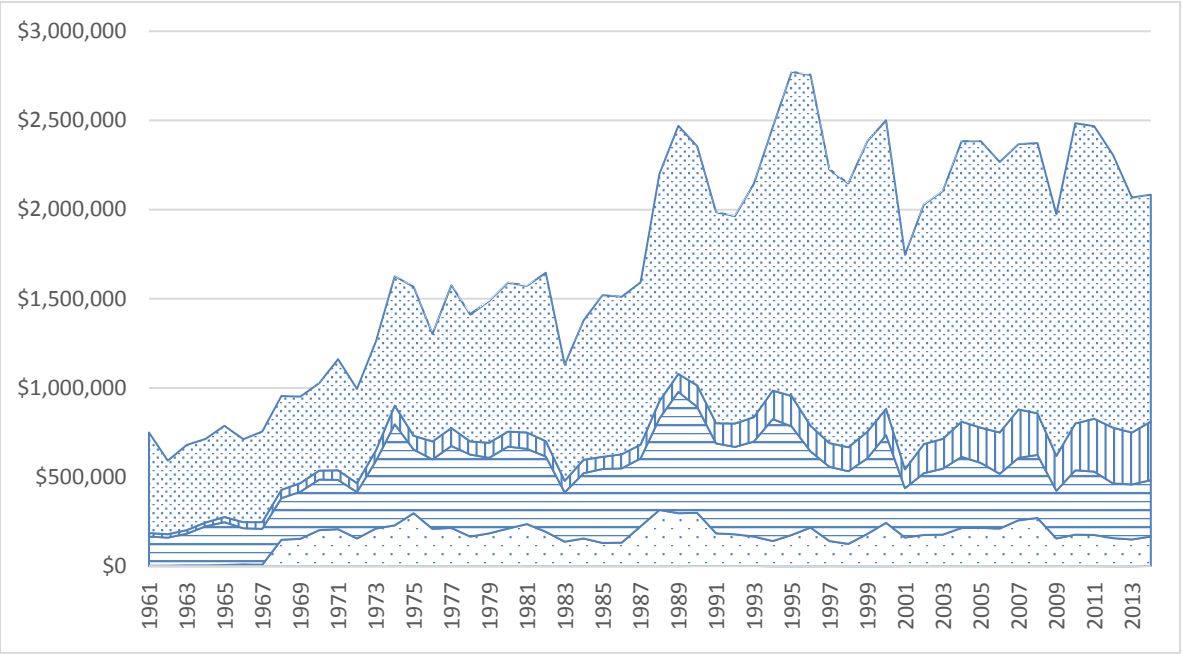
Source : FAO FAOSTAT, IMF International Financial Statistics

Figure 5.11: Share of import value, USA



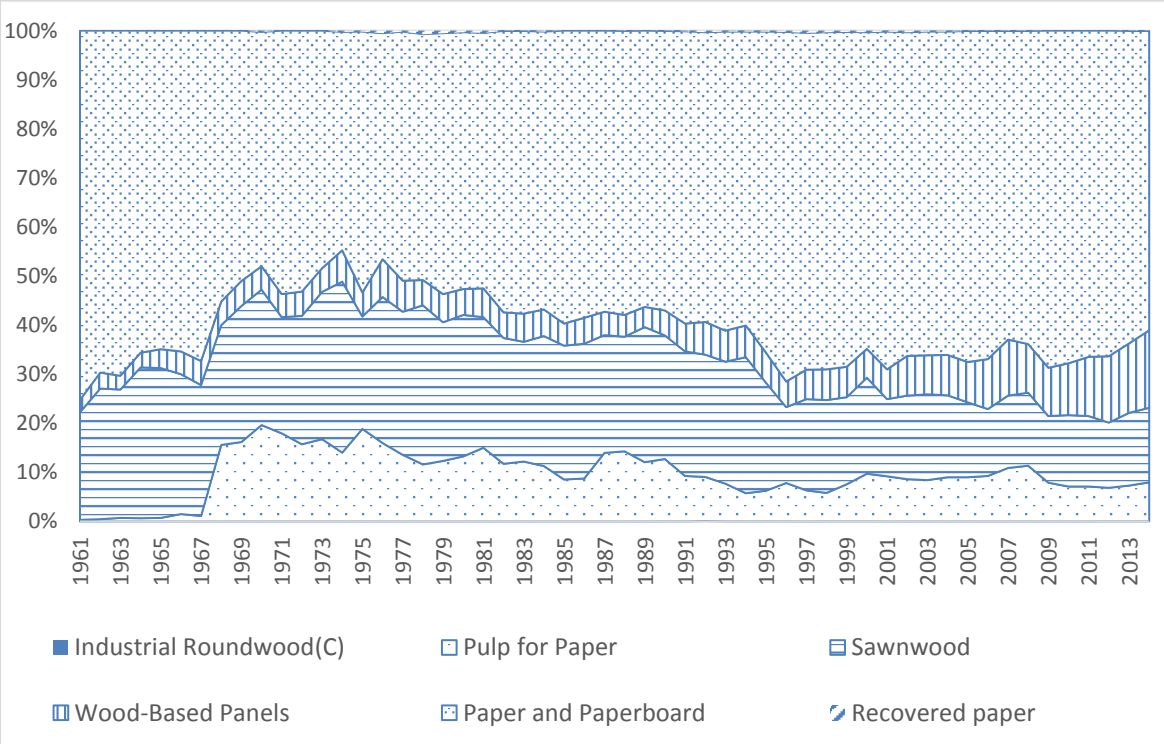
Source: FAO FAOSTAT

Figure 5.12: Australia, real value of imports by product (2014 $US CIF)



Source : FAO FAOSTAT, IMF International Financial Statistics

Figure 5.13: Share of imports, Australia



Source: FAO FAOSTAT

All of the developing markets show quite dramatic changes in the composition of demand.

- For these countries the drivers of import demand are infrastructure build (housing, commercial buildings, transport), packing for export and domestic use, and industries producing "value added" wood products such as furniture and joinery for domestic and export markets. As these economies have developed their demand has changed. In all cases except India (to date) the importance of logs has declined
- Developed markets tend to have been more stable in their import demand. In the case of USA and Australia, demand is only for pulp, paper, sawn timber and wood based panels (no logs or wastepaper)

5.1 Drivers of consumption in major markets

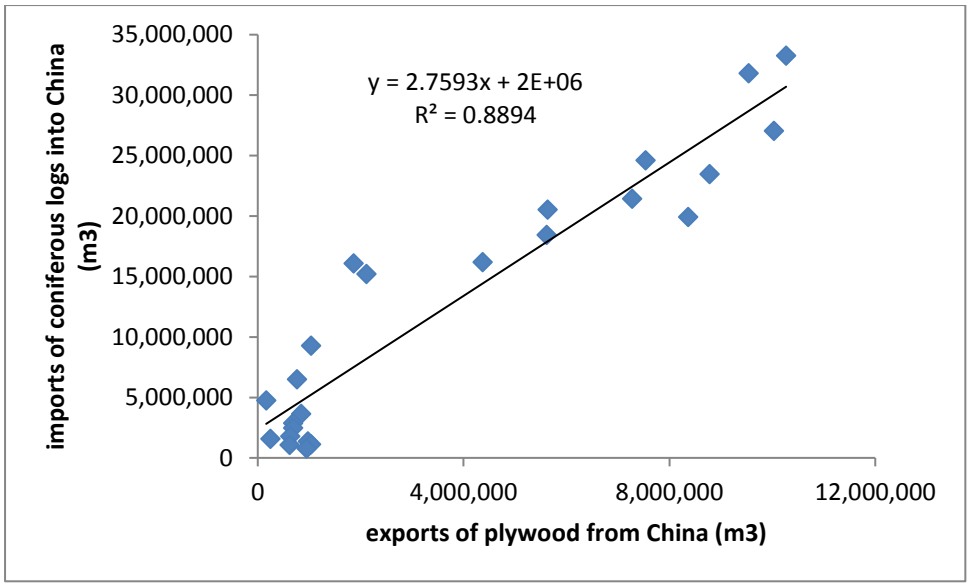
Consumption of forestry products is normally modelled using end use activity indicators. There are two main caveats to using this approach for the markets of interest.

1. There has been significant substitution away from the use of paper for communication, because of the invention of the internet, email and use of electronic transactions for billing. This will be discussed further below
2. These countries (particularly China), are frequently using wood products to manufacture other export products. Therefore the demand is not driven solely by domestically-located end-use activity indicators, but by the export markets for the products which use wood in their manufacture (e.g. furniture). There is also export of forestry products (e.g. plywood).

China is a resource-scarce country with low labour costs, and notes that China imports not only for domestic consumption but for export also (**Zhang, D, and Y. Li, 2009)**. It is also observed that China exports wood products rather than pulp and paper, and explains this as saying that China exports labour-intensive rather than capital-intensive forestry products. The analytical results confirm predictable impacts of exchange rates and logging restrictions on China's trade in wood products. The gravity model is the modelling framework used in this study and it predicts that China tends to import more from, and export more to, closer countries and more developed countries.

From FAO data 1990 to 2013 (below) we can see that there is a good relationship between softwood log imports and plywood exports. There is not such a good relationship with hardwood log imports.

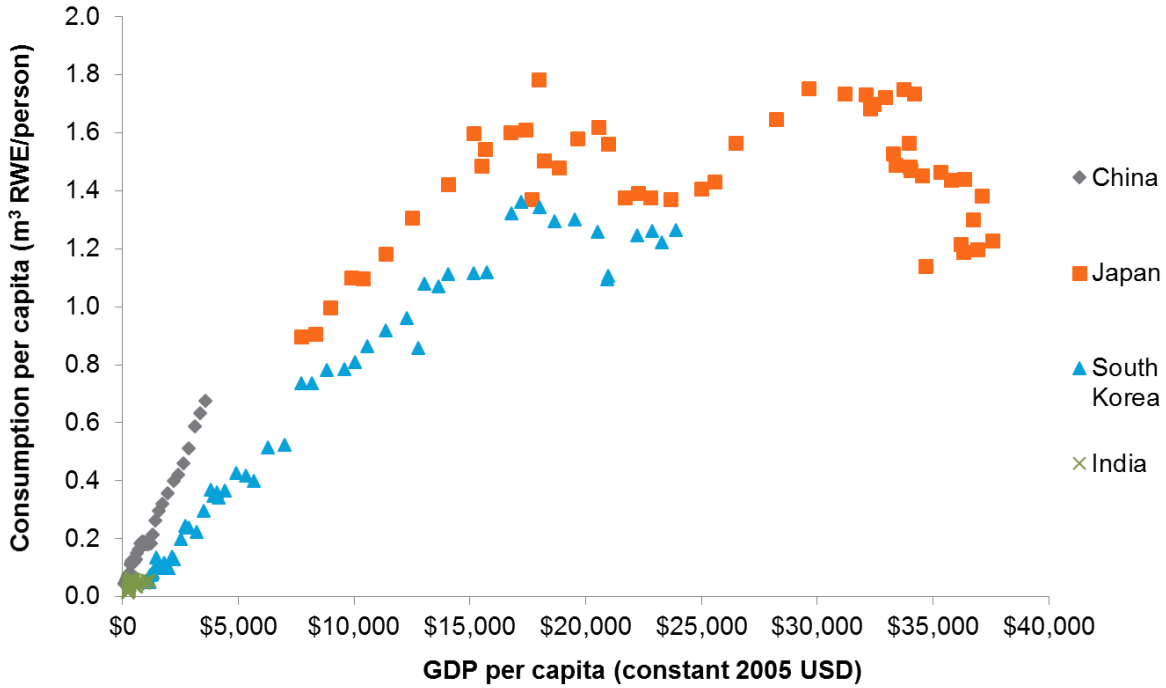
Figure 5.14: relationships between plywood exports and log imports



Source: FAO FAOSTAT

It is possible to look at consumption at a very aggregated level. If we convert products to roundwood equivalents we can look at total consumption per capita of wood products (sawn timber, wood panels and paper) in countries of interest.

Figure 5.15: Total per capita consumption (RWE) of sawn timber, wood based panels and paper

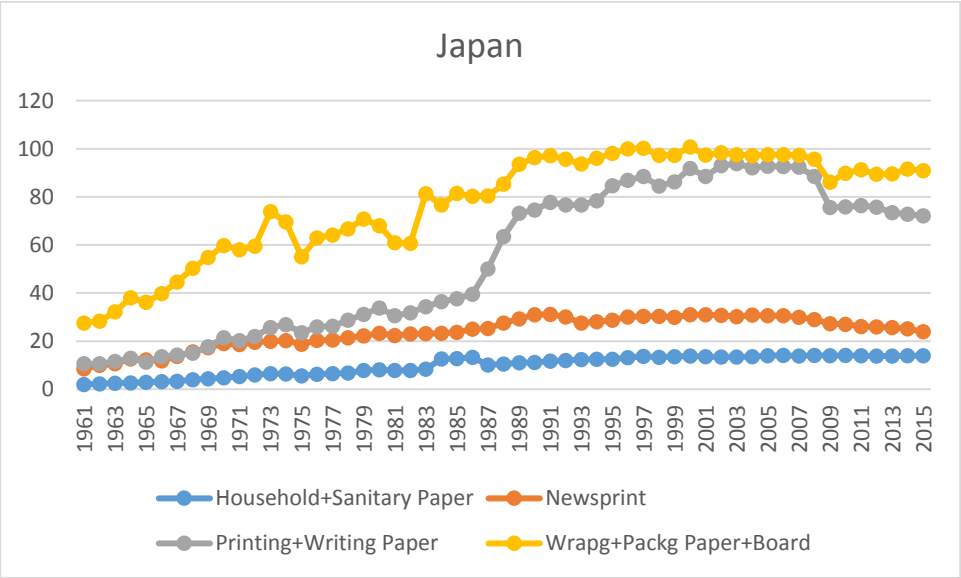


Source: Drummond (2015)

However this analysis shows that consumption per capita is monotonically related to per capita income up to about $20,000 US in real 2005 $, beyond that point there is some considerable fluctuation. This means we need to look into consumption in much more detail. We will look at per capita consumption by product, to determine if specific products are leading to the fluctuations beyond this point.

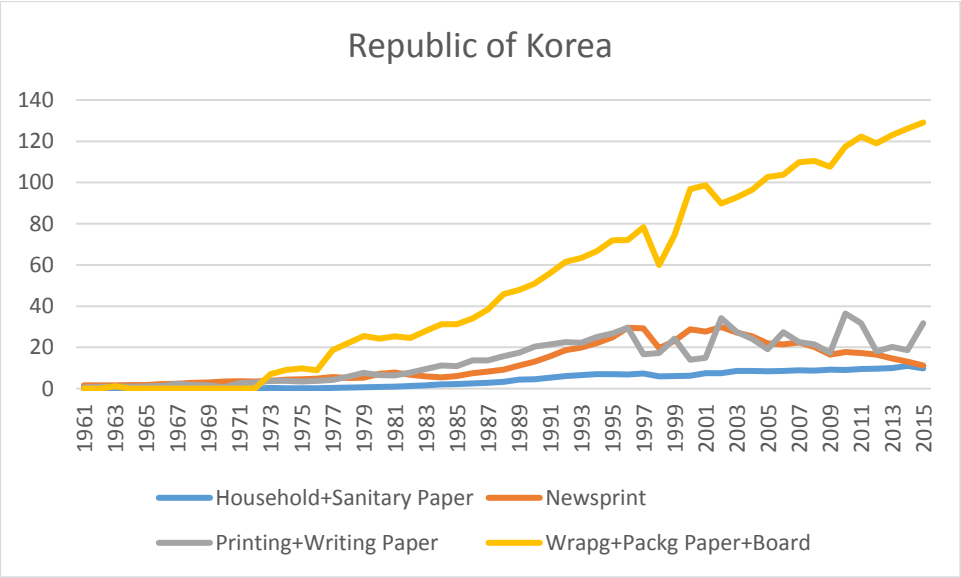
5.2.1. Drivers of consumption, paper products

Figure 5.16: Per capita consumption of main paper grades, Japan



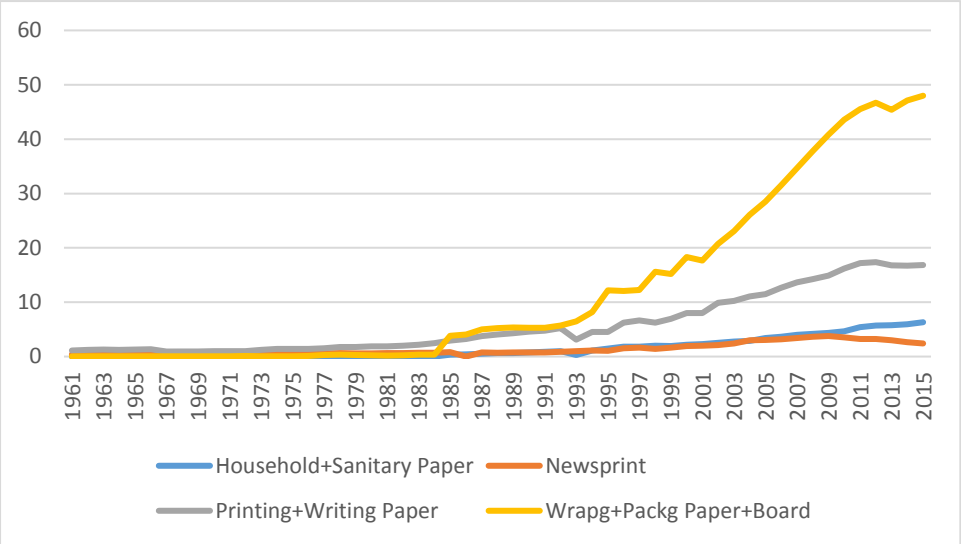
Source: FAO FAOSTAT

Figure 5.17: Per capita consumption of main paper grades, Korea



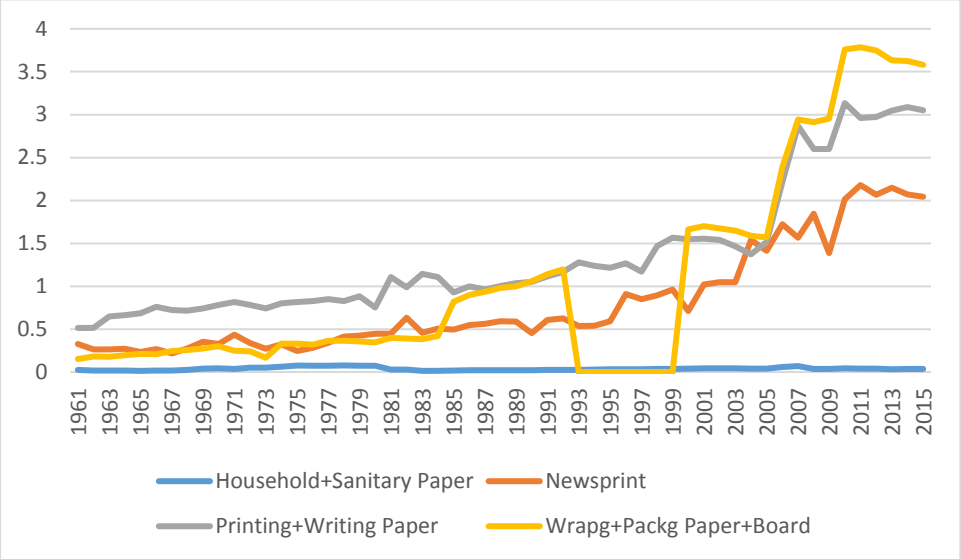
Source: FAO FAOSTAT

Figure 5.18: Per capita consumption of main paper grades, China



Source: FAO FAOSTAT

Figure 5.19: Per capita consumption of main paper grades, India



Source: FAO FAOSTAT

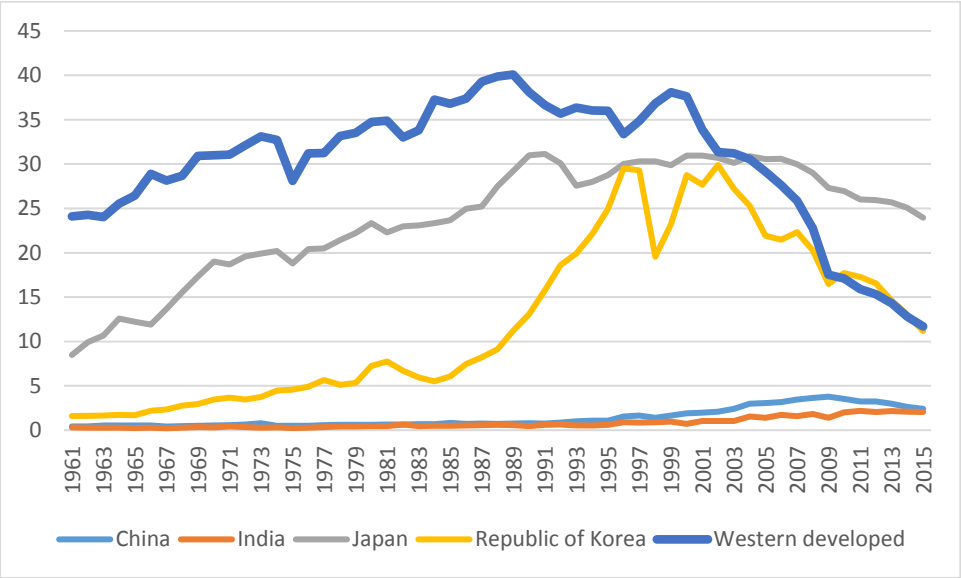
Can see from these results that in all cases newsprint consumption appears to have peaked.

Table 5.1: Consumption of newsprint in major markets

Country	Maximum	Year max occurred	Latest minus max	current as % of max	Max	Year max occurred	Latest minus max	current as % of max
China	3.78	2009	-1.38	-36%	17.37	2012	-0.53	-3%
Japan	31.14	1991	-7.20	-23%	93.79	2003	-21.71	-23%
Korea	29.89	2002	-18.70	-63%	36.43	2010	-4.77	-13%

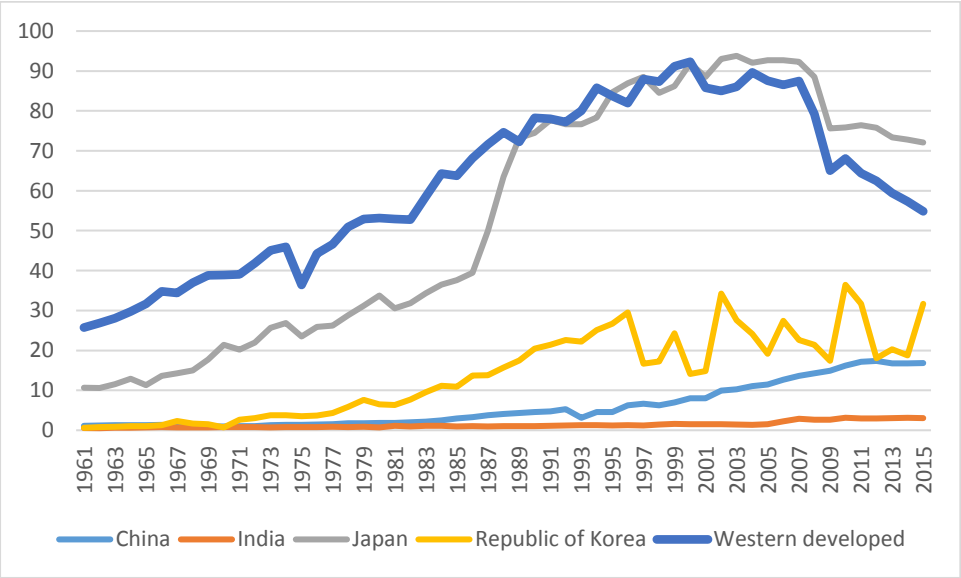
We can also compare consumption in our main markets with consumption in the Western developed world (a composite of North American and European consumption per capita). We can see that the developed world consumption of newsprint has declined from a peak of 40kg/person to just over 10 kg/person. The only market where consumption may still be increasing is India. The consumption of newsprint is dependent on the relative position of newspapers as a source of news and advertising. The accessibility of electronic media is a determining factor. For the other communications grades of paper the developed world decline has be very significant (from 92 kg/person to 55 kg/person).

Figure 5.20: Newsprint consumption compared with developed world benchmark



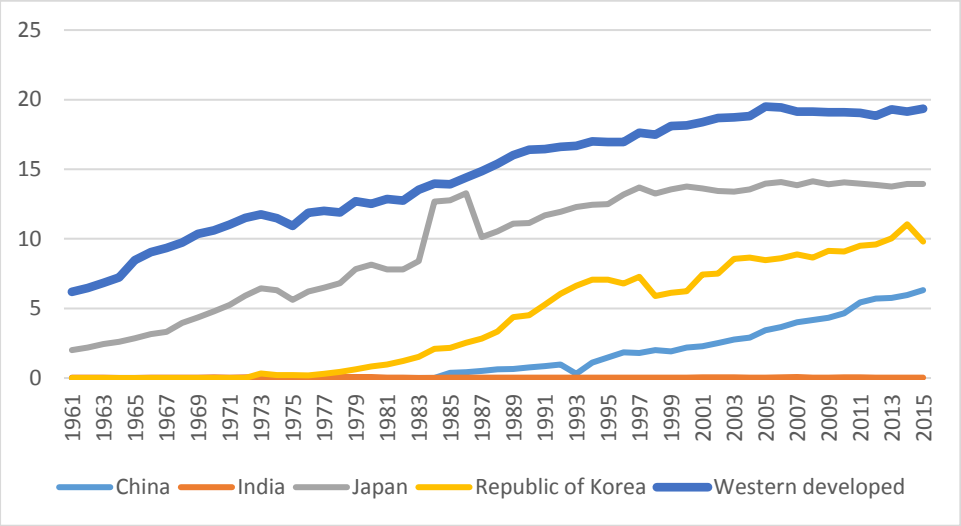
Source: FAO FAOSTAT

Figure 5.21: Printing and writing paper consumption compared with developed world benchmark



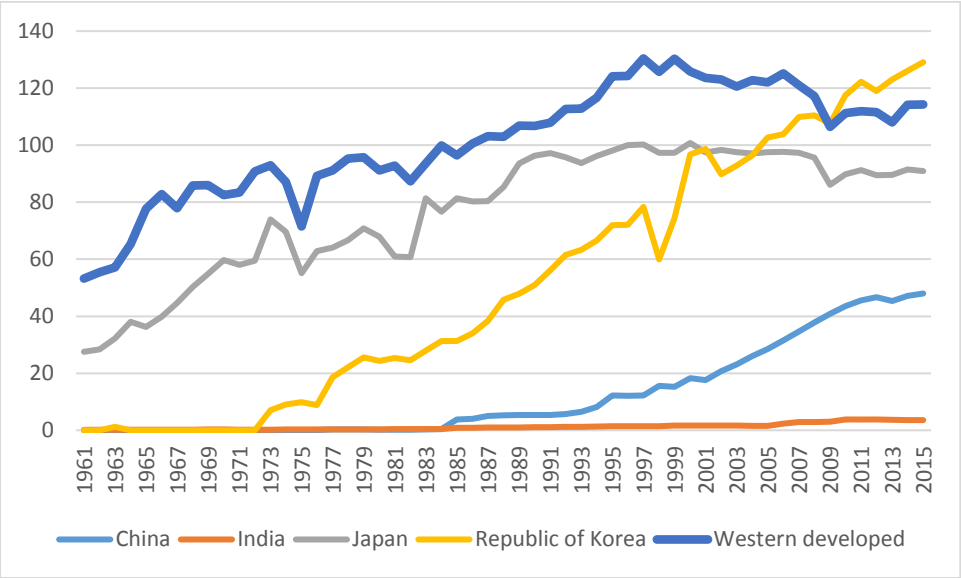
Source: FAO FAOSTAT

Figure 5.22: Household and sanitary paper consumption compared with developed world benchmark



Source: FAO FAOSTAT

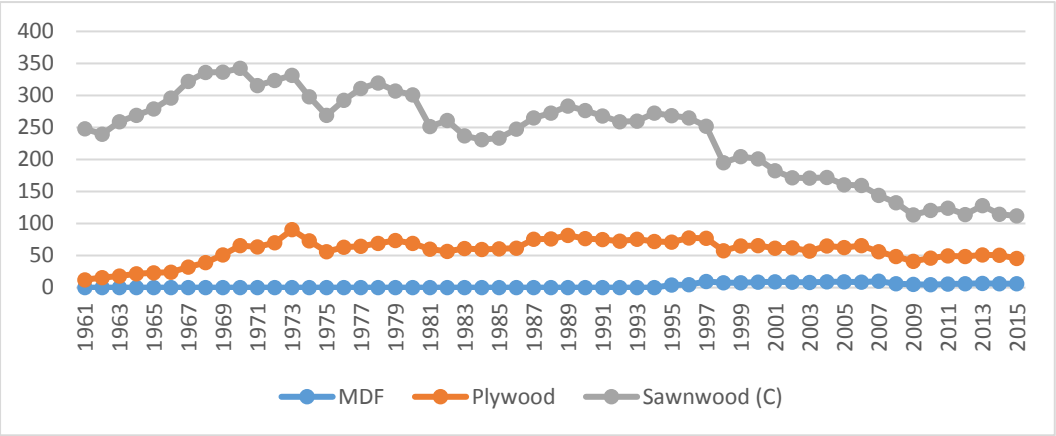
Figure 5.23: Wrapping and packaging paper consumption compared with developed world benchmark



Source: FAO FAOSTAT

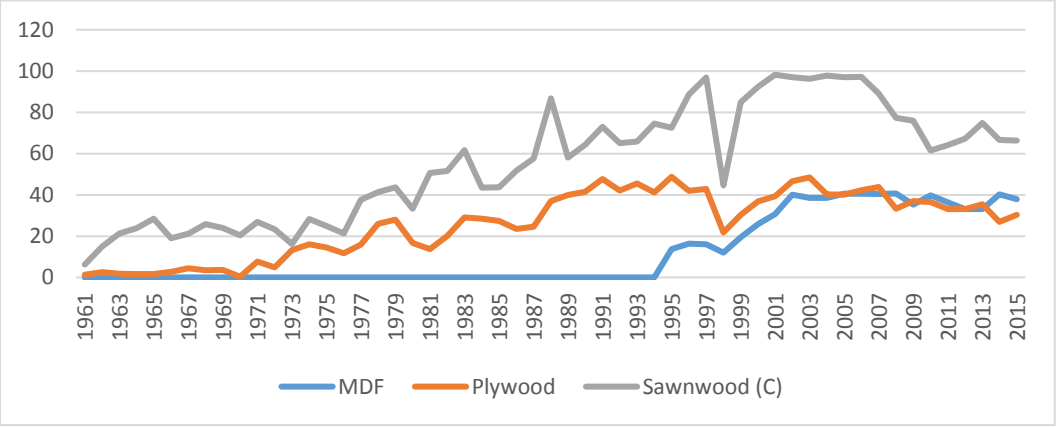
5.2.2 Drivers of consumption, sawn timber and wood based panels

Figure 5.24: Per capita consumption of sawn timber and wood-based panels, Japan



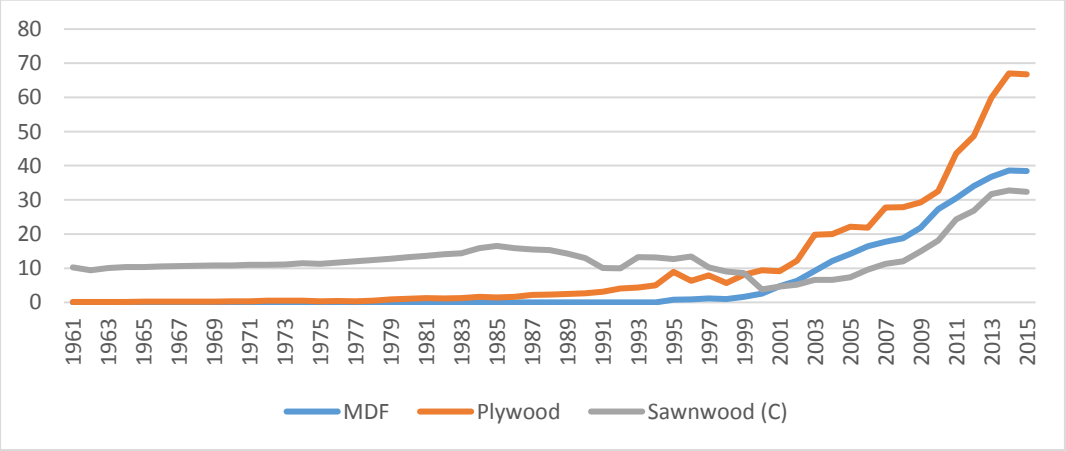
Source: FAO FAOSTAT

Figure 5.25: Per capita consumption of sawn timber and wood-based panels, Korea



Source: FAO FAOSTAT

Figure 5.26: Per capita consumption of sawn timber and wood-based panels, China



Source: FAO FAOSTAT

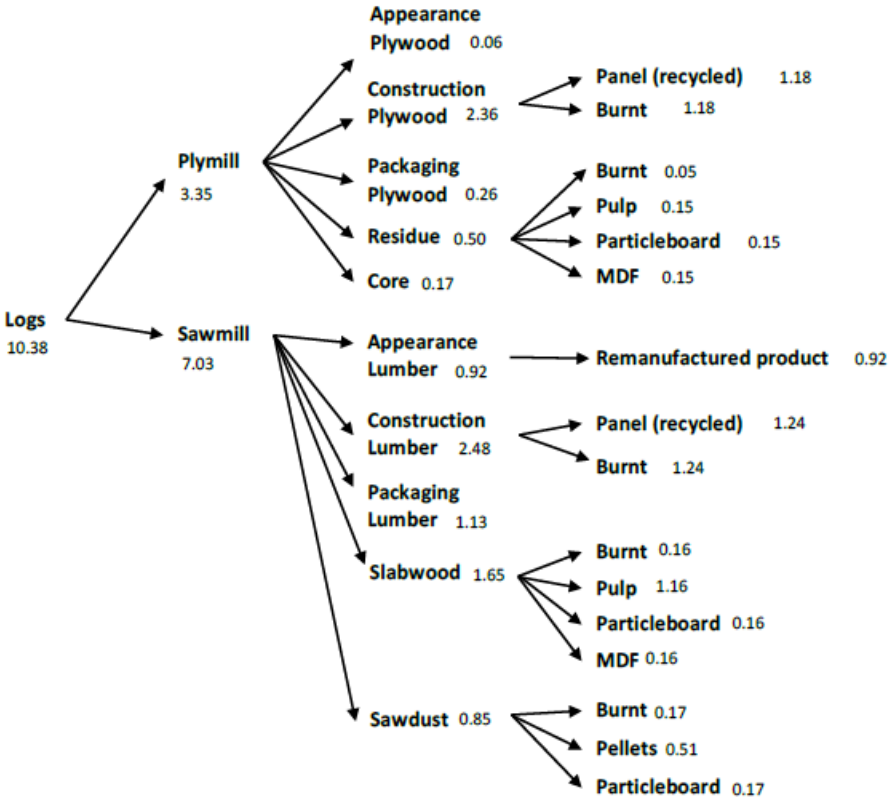
Table 5.2: Maximum consumption per capita of sawn timber and plywood

	Plywood				Softwood sawn timber			
Country	Maximum	Year max occurred	Latest minus max	current as % of max	Max	Year max occurred	Latest minus max	current as % of max
China	67.04	2014	-0.27	0%	32.77	2014	-0.39	-1%
Japan	90.35	1973	-44.53	-49%	342.32	1970	-230.40	-67%
Korea	48.75	1995	-18.47	-38%	98.21	2001	-31.93	-33%

Source: FAO FAOSTAT

The main drivers of solid wood demand in New Zealand's top four log markets are temporary construction, packaging and furniture

Figure 5.27: Enduse of New Zealand radiata pine logs, China



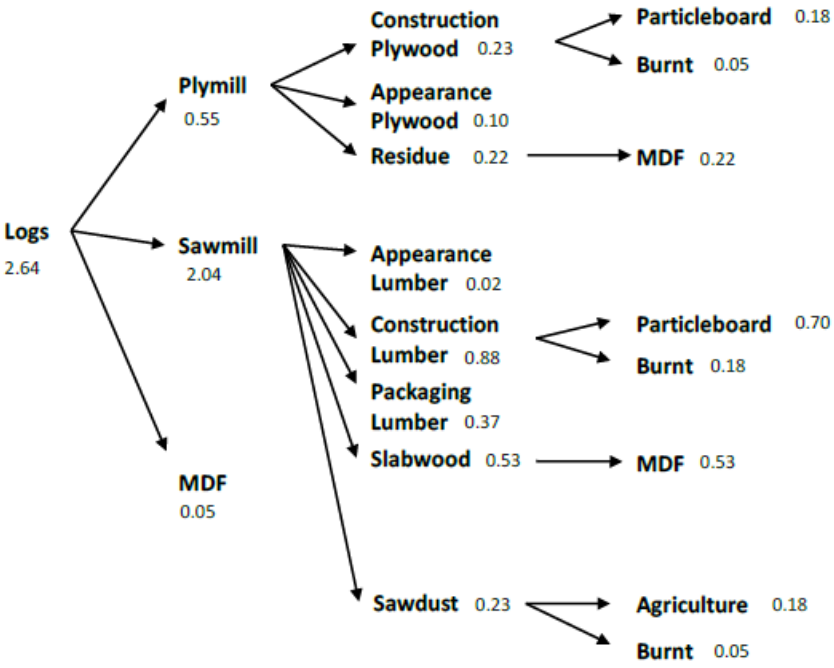
Source: Manley and Evison (2016)

For both plywood and sawn timber

Construction	4.84 million m3
Appearance	0.98 million m3
Packaging	1.39 million m3
TOTAL	7.21 million m3

Out of a total of 10.38 million m3 of logs imported from NZ

Figure 5.28: Enduse of New Zealand radiata pine logs, Republic of Korea



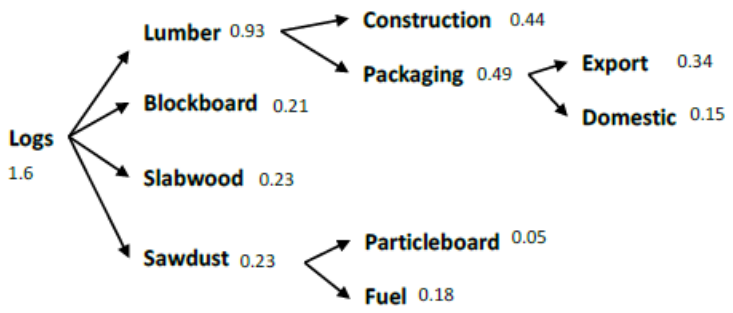
Source: Manley and Evison (2016)

For both plywood and sawn timber

Construction	1.11 million m3
Appearance	0.12 million m3
Packaging	0.37 million m3
TOTAL	1.60 million m3

Out of a total of 2.64 million m3 of logs imported from NZ

Figure 5.29: Enduse of New Zealand radiata pine logs, India



Source: Manley and Evison (2016)

For both plywood and sawn timber:

Construction	0.44 million m3
Appearance	0.21 million m3 (blockboard)
Packaging	0.49 million m3
TOTAL	1.14 million m3

Out of a total of 1.6 million m3 of logs imported from NZ

5.2 End use of wood products in New Zealand's major markets

5.2.1 China

Construction

Wood in construction mostly goes into temporary formwork. Reinforced concrete construction is the preferred method in China and internal walls are concrete also. This means a considerable amount of boxing is required. The two main products are plywood and sawn timber. Plywood is either film faced, or resin faced, and there are a number of dimensions of sawn timber that are used. Essentially the plywood is used to provide the form into which concrete is poured. The sawn timber provides ribbing for additional strength and stiffness (to keep the plyform from moving when the wet concrete is poured into the formwork).

There is also general use of wood for stair rails, hoardings and temporary walls, pathways and temporary flooring and other uses. This has not been quantified.

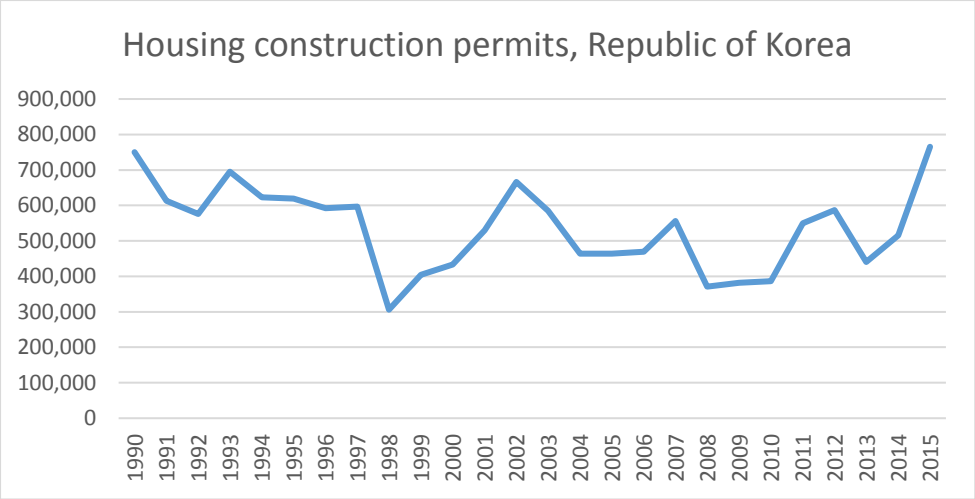
Construction indicators - there is a confusing array of numbers from the Chinese Statistical Agency

Future prospects

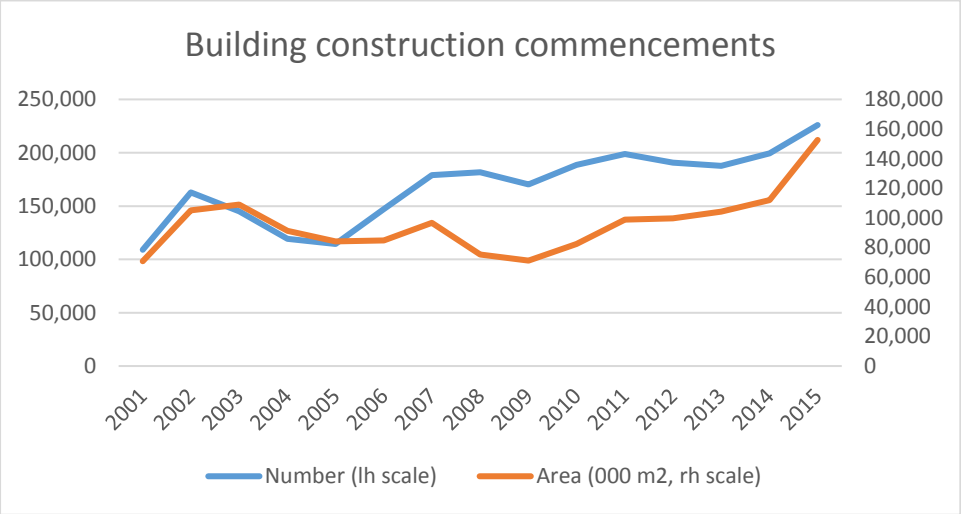
Developed countries do not use boxing in the same way for high rise buildings. First there is a greater use of steel (with wood infill walls) for high rise in other countries. Where reinforced concrete is used, other materials have become more common – for example steel shuttering for standard work (plywood is still used for one-off structures or where there needs to be a hole in the formwork for piping etc. This change seems to occur as labour costs increase – steel shuttering is reusable and less labour intensive.

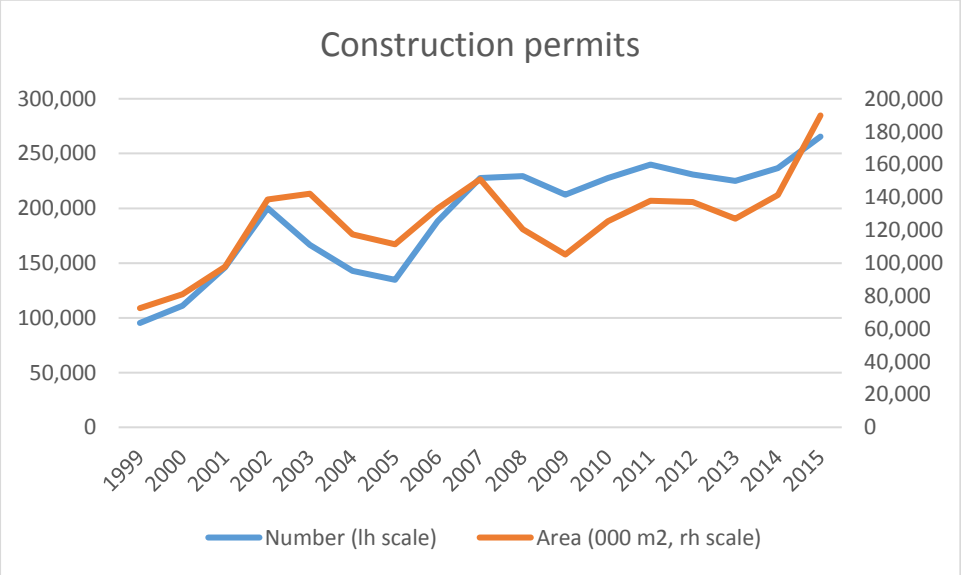
5.3.2 Republic of Korea

Construction data



Source: Kosis – http://kosis.kr/eng





5.4. Models of consumption (from Drummond, 2015)

5.4.1. Japan

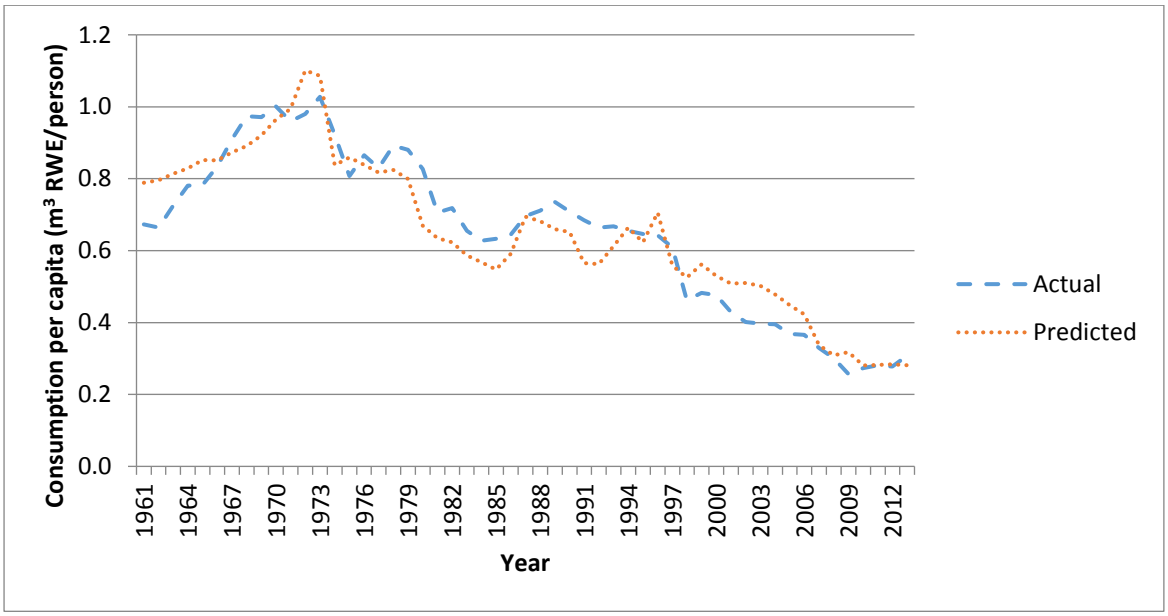
5.4.1.1. Sawn timber

$$Consumption\ per\ capita\ (sawn\ timber) = 0.8688^{***} + (-2.26 \times 10^{-7***} \times GDP\ per\ capita(¥)) + (2.891 \times 10^{-6***} \times Construction\ investment\ per\ capita(¥))$$

Table 5.1. Diagnostics for the model of sawn timber consumption in Japan

Diagnostic	***Value***
Degrees of freedom	50
Adjusted R^2	0.8931
F statistic	218.3
Durbin-Watson statistic	0.5993

Figure 5.13. Actual versus predicted sawn timber consumption for Japan



Source: Drummond (2015)

Sawn timber consumption in Japan is driven by two major factors, GDP per capita and construction investment per capita. Japan's consumption is most strongly correlated with construction investment per capita. Over the period 1961 to 2013 actual consumption decreased from a 0.67 m^3 RWE/person to 0.28 m^3 RWE/person. Significance of predictor variables is noted by the asterisks above the coefficients, Appendix 4 describes the notation. The model has an adjusted R^2 of 0.89 and a Durbin-Watson statistic of 0.60.

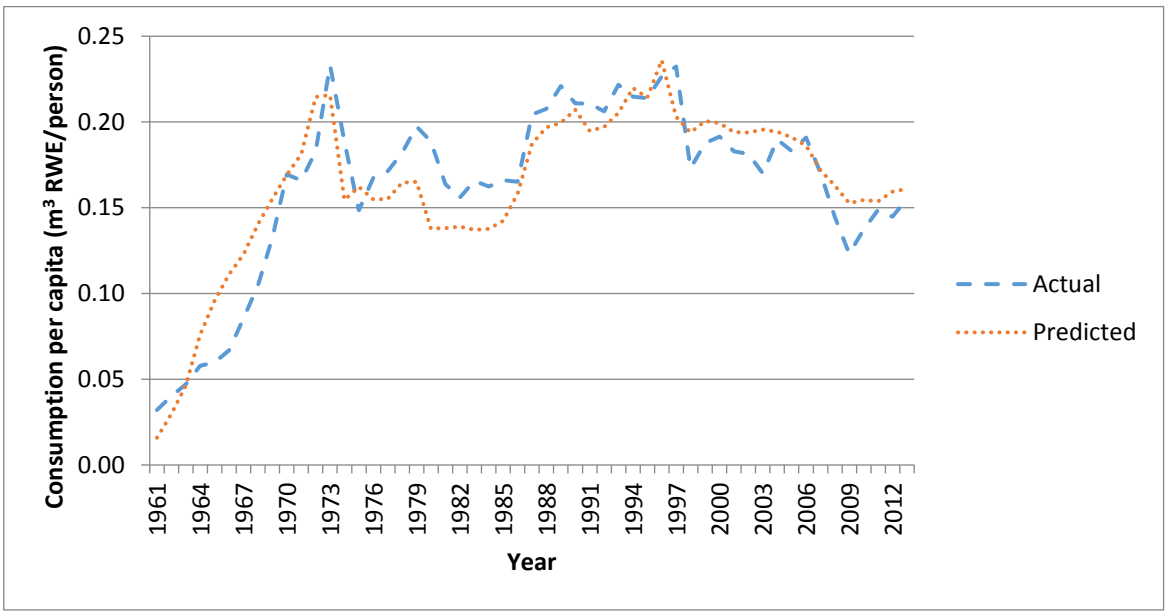
5.4.1.2 Wood based panels

$$\begin{aligned} Consumption\ per\ capita\ (wood-based\ panels) \\ &= 0.0543^{***} \\ &+ (-3.275 \times 10^{-7**} \times Wood-based\ panel\ price(¥)) \\ &+ (1.049 \times 10^{-8**} \times GDP\ per\ capita(¥)) + (6.858 \times 10^{-7***} \\ &\times Construction\ investment\ per\ capita(¥)) \end{aligned}$$

Table 5.2. Diagnostics for the model of wood-based panel consumption in Japan

Diagnostic	***Value***
Degrees of freedom	49
Adjusted R^2	0.8158
F statistic	77.77
Durbin-Watson statistic	0.7159

Figure 5.14. Actual versus predicted wood-based panel consumption for Japan



Source: Drummond (2015)

Consumption of wood-based panels in Japan was found to be influenced by three major factors, the real price of the product, income per capita and construction investment were all found to have a significant correlation with consumption. This model differs compared to the wood-based panel models for other countries in its inclusion of the construction activity variable. It is likely that this was significant in this model and not others due differences in the way the Japanese market uses wood-based panels. The model has an adjusted R^2 of 0.82 and a Durbin-Watson statistic of 0.72.

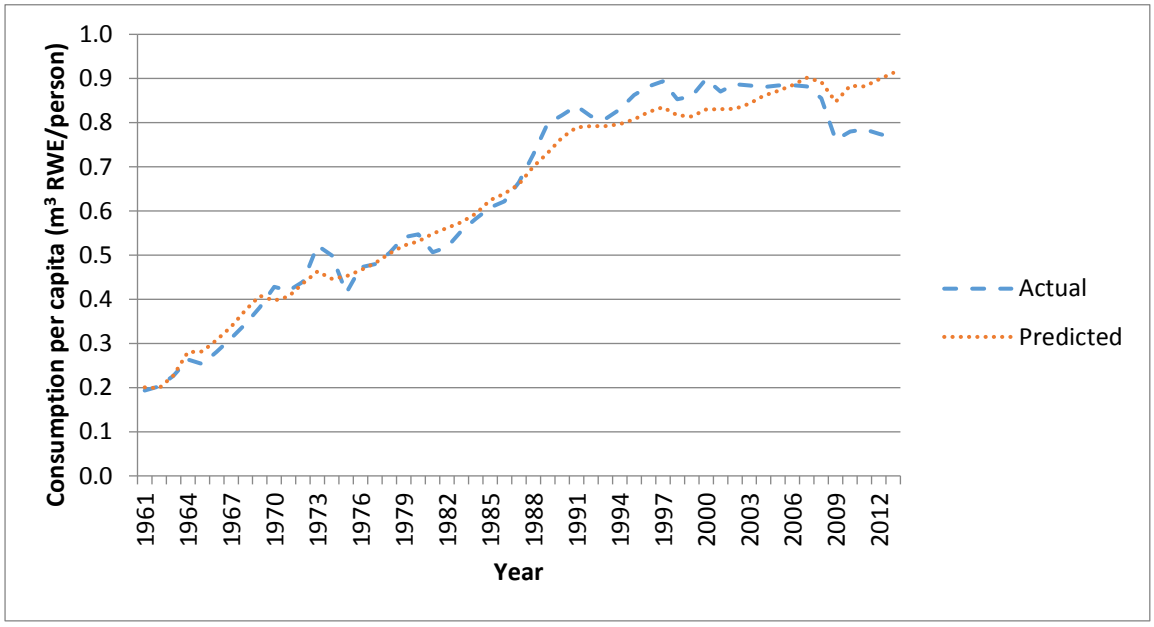
5.4.1.3 Paper and paperboard

$$Consumption\ per\ capita\ (paper\ and\ paperboard) = 0.06534^{\cdot} + (-7.23 \times 10^{-8} \times Paper\ and\ paperboard\ price(¥)) + (2.064 \times 10^{-7***} \times GDP\ per\ capita(¥))$$

Table 5.3. Diagnostics for the model of paper and paperboard consumption in Japan

Diagnostic	***Value***
Degrees of freedom	50
Adjusted R^2	0.9525
F statistic	522.7
Durbin-Watson statistic	0.2793

Figure 5.5: Actual vs predicted paper and paperboard consumption Japan



Source: Drummond (2015)

Japan's consumption of paper and paperboard products follows the same pattern as other developed countries where consumption has probably peaked and is now decreasing Product price was found to have an insignificant p-value however it was included in the model as price is a key driver of demand. GDP per capita is more predictive. The model has an adjusted R^2 of 0.95 and a Durbin-Watson statistic of 0.28, indicating the presence of auto-correlation.

5.4.2. South Korea

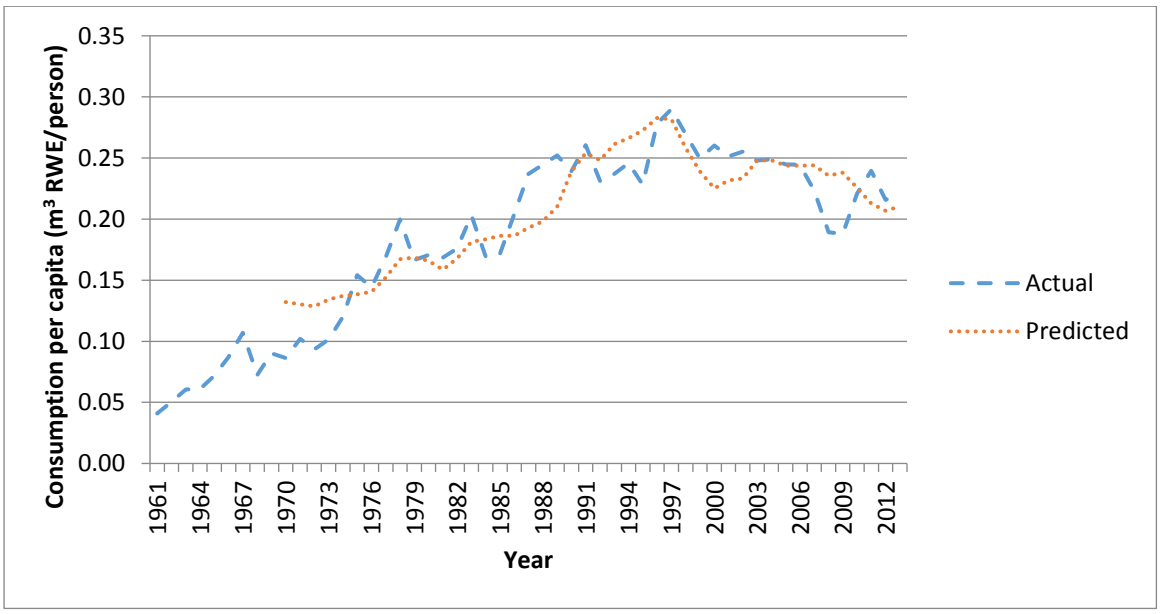
5.4.2.1 Sawn timber

$$\begin{aligned}\boldsymbol{Consumption\ per\ capita\ (sawn\ timber)} \\ &= \mathbf{0.1051}^{***} + \left(-\mathbf{3.531} \times \mathbf{10}^{-\mathbf{9}***} \times \boldsymbol{GDP\ per\ capita}(₩)\right) \\ &+ \left(\mathbf{1.702} \times \mathbf{10}^{-\mathbf{7}***} \times \boldsymbol{Construction\ GDP\ per\ capita}(₩)\right)\end{aligned}$$

Table 5.4. Diagnostics for the model of sawn timber consumption in South Korea

Diagnostic	***Value***
Degrees of freedom	41
Adjusted R2	0.7699
F statistic	72.92
Durbin-Watson statistic	0.6659

Figure 5.6: Actual vs predicted sawn timber consumption, Korea



Source: Drummond (2015)

Demand for sawn timber in South Korea decreased over the fifteen year period leading up to 2013. There was a steady increase in demand from 1961 and 1997 from a level of 0.04 m^3 RWE/person to 0.29 m^3 RWE/person. Since 1997 consumption has decreased to 0.22 m^3 RWE/person and if South Korea follows Japan, this trend will continue in the future. The model used per capita wealth and value added to GDP by construction per capita as explanatory variables. The model could be based only on the period 1970 to 2013 as industry-specific GDP data was not

available before 1970. The model has an adjusted R^2 of 0.77 and a Durbin-Watson statistic of 0.67. This model has the lowest R^2 of all models produced indicating that more work may be required in future to determine more suitable drivers of change in this market.

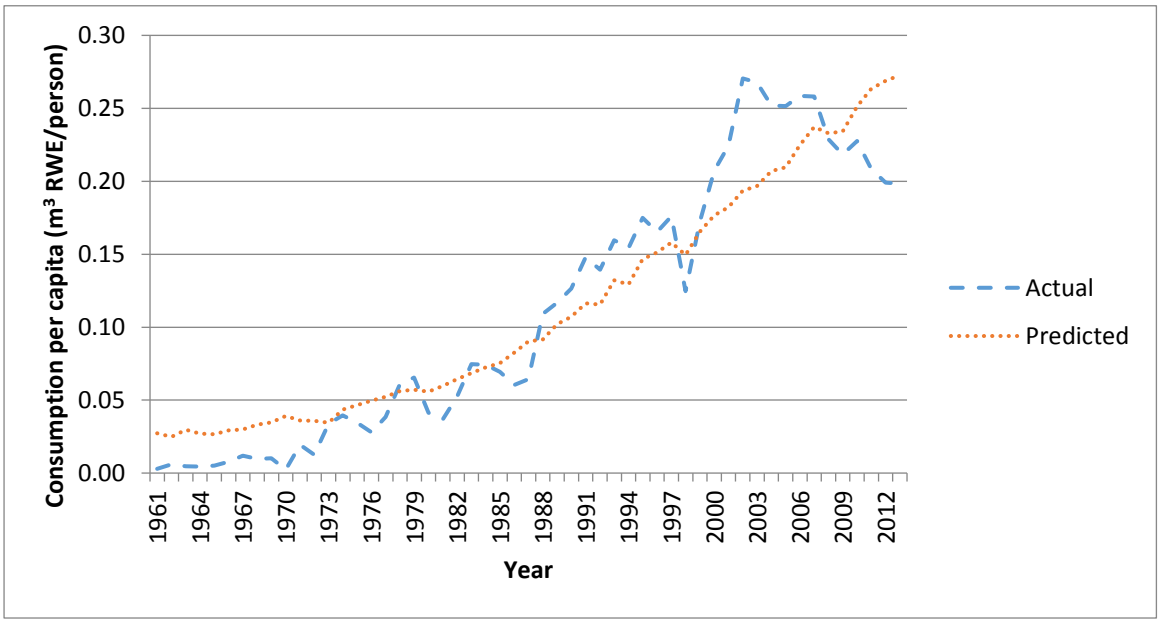
5.4.2.2 Wood based panels

$$\begin{aligned} &Consumption\ per\ capita\ (wood - based\ panels) \\ &\quad = 0.02936^{\cdot} + (-2.774 \times 10^{-8} \times Wood - based\ panel\ price(₩)) \\ &\quad + (9.394 \times 10^{-9***} \times GDP\ per\ capita(₩)) \end{aligned}$$

Table 5.5. Diagnostics for the model of wood-based panel consumption in South Korea

Diagnostic	***Value***
Degrees of freedom	38
Adjusted R2	0.8715
F statistic	136.6
Durbin-Watson statistic	0.2929

Figure 5.17. Actual versus predicted wood-based panel consumption in South Korea.



Source: Drummond (2015)

Wood-based panel consumption in South Korea has been steadily increasing over time and in recent years it has started to decline. South Korea's strong production of MDF domestically contributes to their consumption of wood-based panels being greater than Japan's. In 1961 South Korea's consumption of wood based panels was minimal, however by 2013 Korea was consuming more than Japan did at its peak.

The model for wood-based panel consumption in South Korea incorporates product price and per capita income to predict consumption. The model appears to over predict consumption early in the period before under-predicting after 1987 and again over predicting in the most recent five year period. The model is not successful at predicting turning points in consumption and also shows autocorrelation with a Durbin-Watson statistic of 0.29.

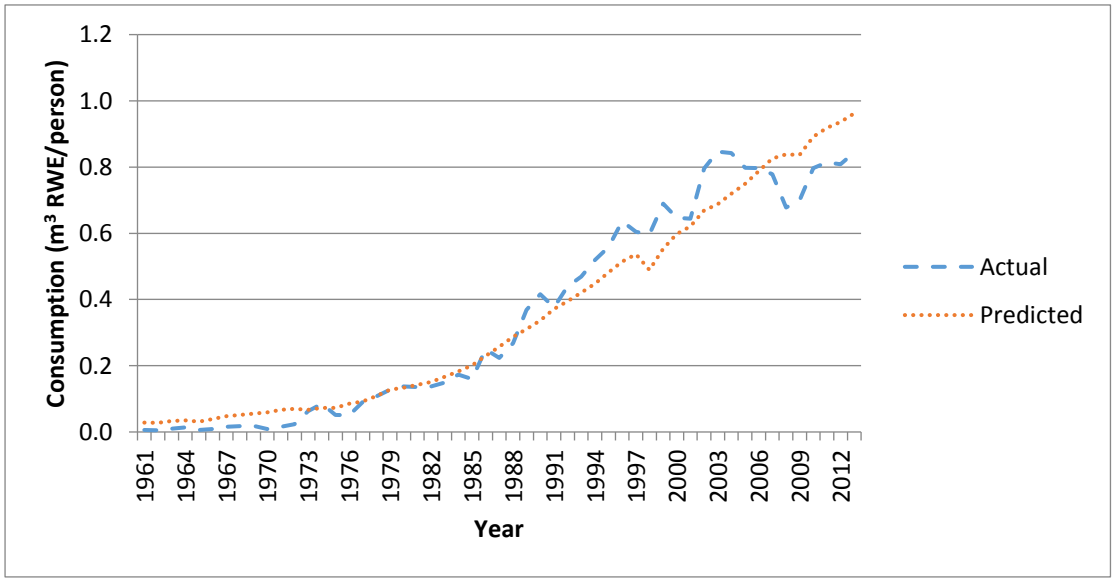
5.4.2.3 Paper and paper board

$$\begin{aligned} Consumption\ per\ capita\ (paper\ and\ paperboard) \\ &= 9.502 \times 10^{-4} \\ &+ (-1.895 \times 10^{-8} \times Paper\ and\ paperboard\ price\ (₩)) \\ &+ (3.587 \times 10^{-8***} \times GDP\ per\ capita\ (₩)) \end{aligned}$$

Table: Diagnostics for the model of paper and paper board consumption in Korea

Diagnostic	***Value***
Degrees of freedom	50
Adjusted R2	0.9484
F statistic	478.4
Durbin-Watson statistic	0.3248

Figure 5.18. Model of actual versus predicted paper and paperboard consumption in South Korea



Source: Drummond (2015)

Paper and paperboard consumption has increased steadily with development in South Korea. This supports evidence that consumption of paper and paperboard is closely related to income with the trend closely following the trend in GDP per

capita growth shown in Figure 5.10. Model performance is quite good the model shows autocorrelation with a Durbin-Watson statistic of 0.32.

5.4.3. China

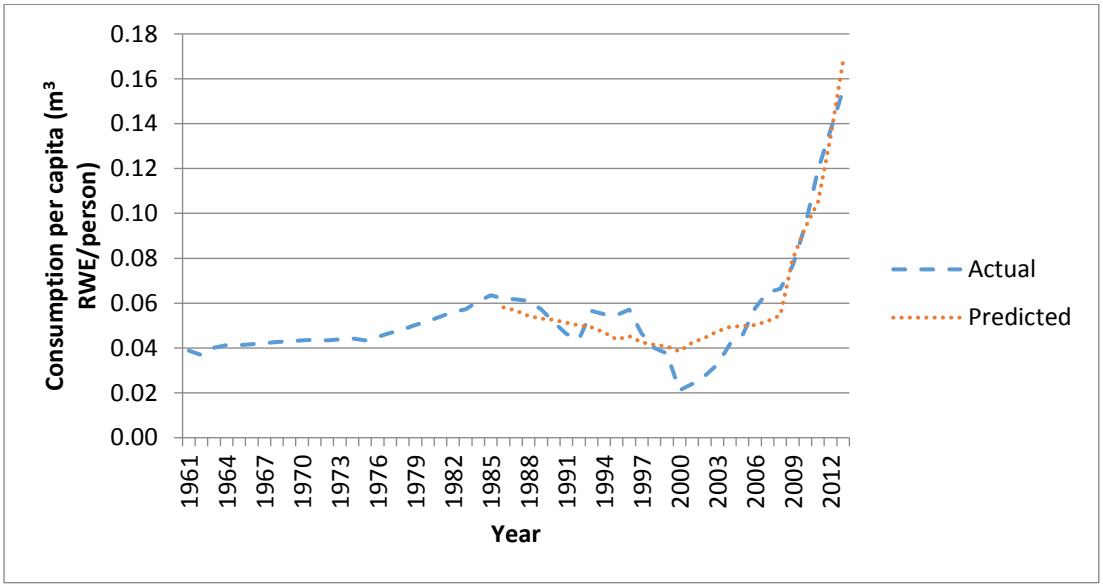
5.4.3.1 Sawn timber

$$\begin{aligned} Consumption\ per\ capita\ (sawn\ timber) \\ &= 0.07156^{***} + (-8.382 \times 10^{-6***} \times GDP\ per\ capita(¥)) \\ &+ (2.583 \times 10^{-5***} \times Value\ of\ construction\ completed(¥)) \end{aligned}$$

Table 5.7. Diagnostics for the model of sawn timber consumption in China

Diagnostic	***Value***
Degrees of freedom	25
Adjusted R2	0.8982
F statistic	120.2
Durbin-Watson statistic	0.6192

Figure 5.19. Actual versus predicted sawn timber consumption in China



Source: Drummond (2015)

Between 1961 and 2013 consumption of sawn timber in China increased by almost 300% from 0.039 m^3 RWE/person to 0.155 m^3 RWE/person. Consumption was fairly stable at low levels until the early 2000s when it decreased suddenly before increasing almost exponentially to 2013 levels.

The model developed to predict consumption of sawn timber in China uses GDP per capita and, as for all sawn timber models a construction activity predictor, in this

case the value of construction completed. The model fits the data well with an adjusted R^2 of 0.90 and has a Durbin-Watson statistic value of 0.62 indicating undesirable levels of autocorrelation.

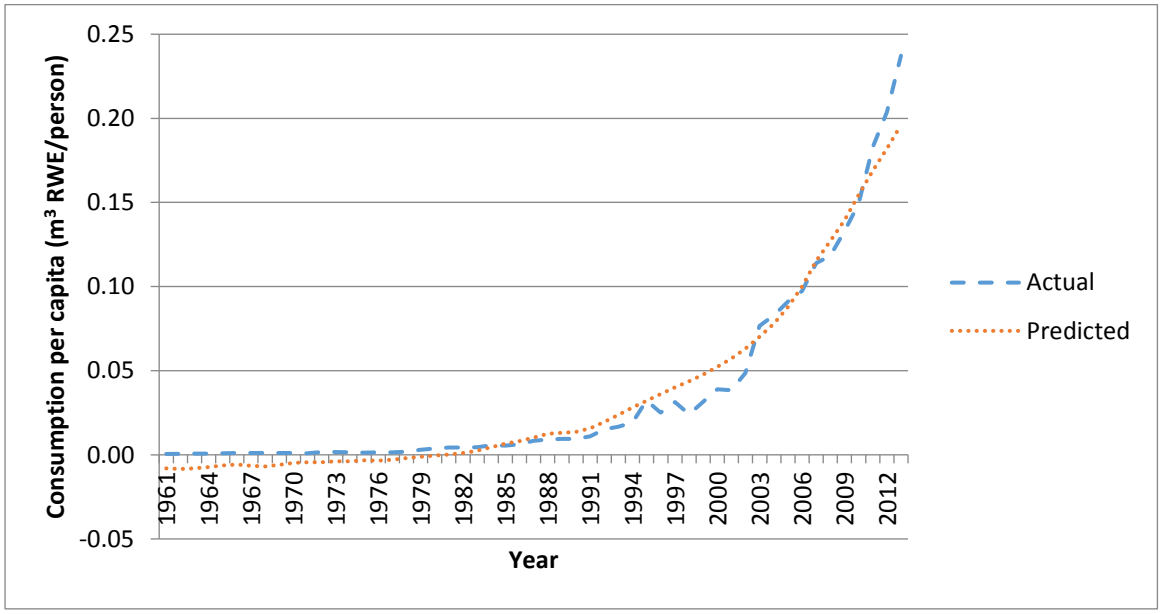
5.4.3.2 Wood based panels

$$Consumption\ per\ capita\ (wood - based\ panels) = -0.01329^{***} + (8.34 \times 10^{-6***} \times GDP\ per\ capita(¥))$$

Table 5.7. Diagnostics for the model of wood-based panel consumption in China

Diagnostic	***Value***
Degrees of freedom	51
Adjusted R2	0.9693
F statistic	1644
Durbin-Watson statistic	0.3436

Figure 5.20. Actual versus predicted wood-based panel consumption in China



Source: Drummond (2015)

Consumption of wood-based panels in China has increased rapidly and has reached a level greater than South Korea's consumption of the product in 2001. This is interesting as China had a much lower income per capita in 2013 ($3,583 USD) than South Korea did in 2001 ($15,732 USD) yet the two countries had the same consumption of wood-based panelsIn modelling China's consumption income per capita was the only predictor variable used as analysis found that all other predictor variables were statistically insignificant when it came to predicting consumption of

wood-based panels. The model underestimates the consumption in the most recent data predicting 0.20 m^3 RWE/person when the actual consumption was 0.24 m^3 RWE/person in 2013. This aside, the model is generally effective in estimating consumption with an adjusted R^2 of 0.97 and a Durban-Watson statistic of 0.34 indicating adverse autocorrelation.

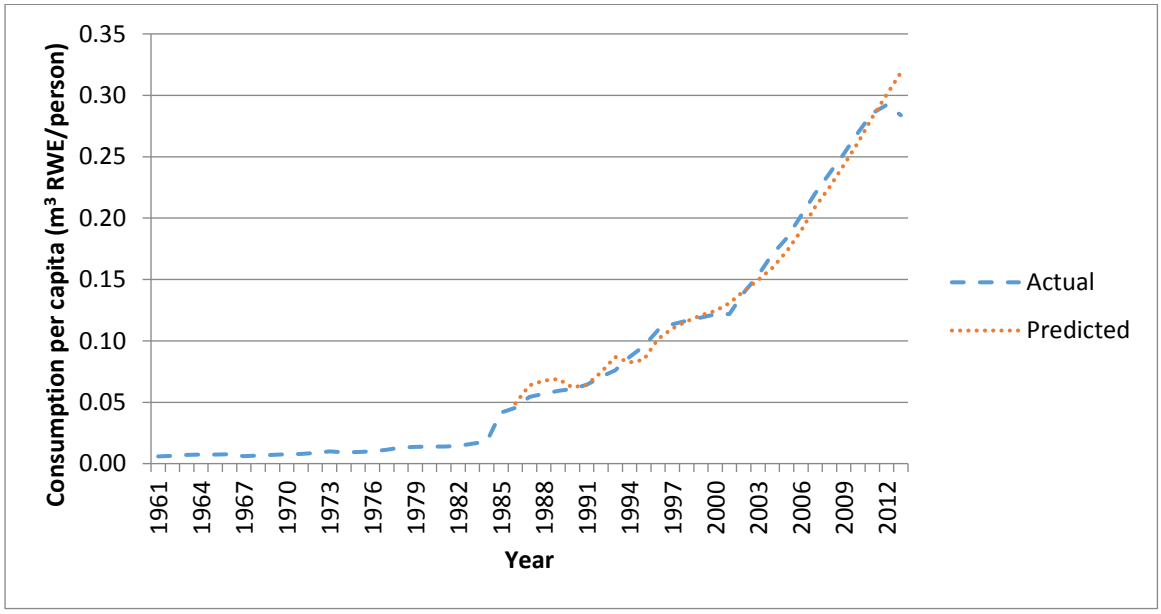
5.4.3.3 Paper and paperboard

$$\begin{aligned} Consumption\ per\ capita\ (paper\ and\ paperboard) \\ &= 0.06359^{***} \\ &+ (-4.22 \times 10^{-6*} \times Paper\ and\ paperboard\ price(¥)) \\ &+ (1.13 \times 10^{-5***} \times GDP\ per\ capita(¥)) \end{aligned}$$

Table 5.9. Diagnostics for the model of paper and paperboard consumption in China

Diagnostic	***Value***
Degrees of freedom	25
Adjusted R2	0.9826
F statistic	765.4
Durbin-Watson statistic	0.5457

Figure 5.21. Actual versus predicted paper and paperboard consumption in China



Source: Drummond (2015)

China's consumption of paper and paperboard follows a trend not dissimilar to that of the consumption of wood-based panels with very slow growth initially and then a rapid, almost exponential increase. Growth truly began in the mid-80s when,

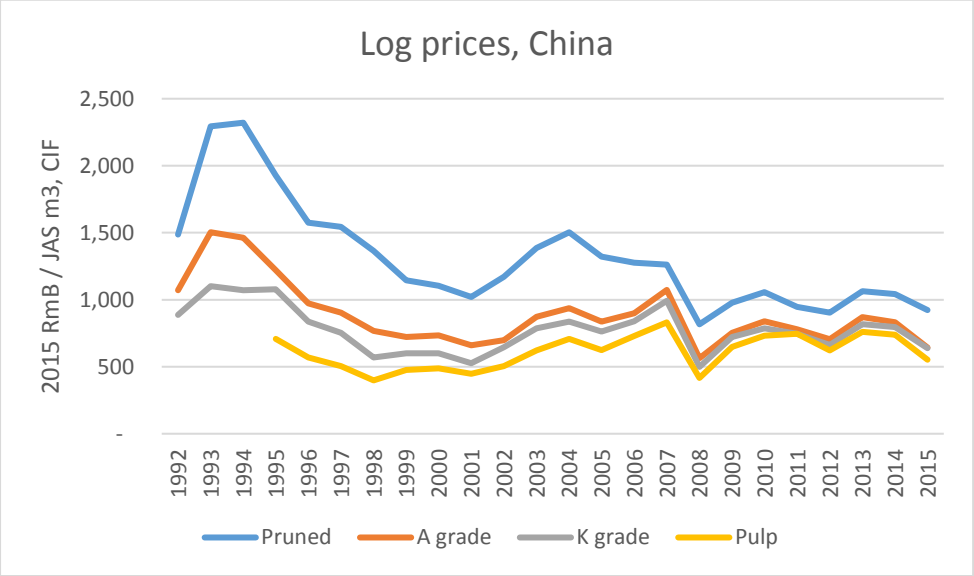
between 1984 and 1985, the consumption of paper and paperboard doubled, a point elaborated upon in the discussion section. Consumption steadily increased from this point onwards until the last period, between 2012 and 2013 when consumption decreased slightly. It is difficult to associate this with any particular factor as it only occurred over a single period and could be attributed to random variation.

The model developed for paper and paperboard consumption in China used product price and GDP per capita as predictor variables. As seen in Figure 5.21, the model predicts consumption well across the period with the greatest deviation being in the last year data was available, 2013. The result is a model with an excellent representation of the data with an adjusted R^2 of 0.98 and, as with all of the models it has an undesirable level of autocorrelation with a Durbin-Watson statistic of 0.55.

5.5 Prices

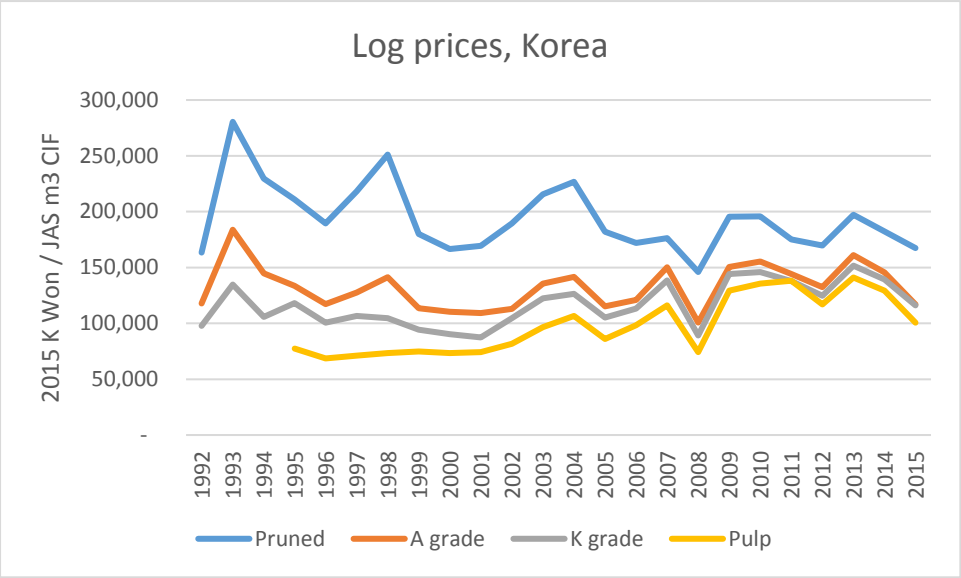
Prices in market have been derived from New Zealand export log prices (fob, from MPI) plus an estimate of freight costs (from industry sources), and exchange rates (IMF). These derived prices in market (CIF) were then adjusted for inflation using a producer price index (from IMF), except for China where a CPI was used because no long term PPI index was available

Figure 5.22: New Zealand radiata pine log prices in China



Source: http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/wood-product-markets/

Figure 5.23: New Zealand radiata pine log prices in Republic of Korea

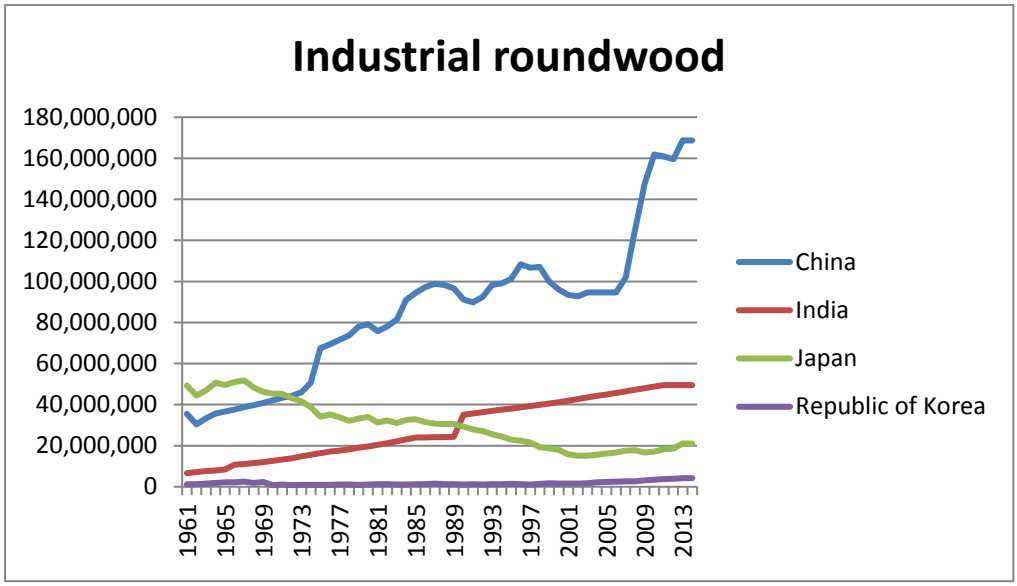


http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/wood-product-markets/

6 Resource supply

6.1 Harvest

Figure 6.1: Industrial Roundwood production in New Zealand's major markets



Source: FAO FAOSTAT

Industrial round-wood harvest was around 243 million m3 in these four countries in 2014 according to FAO.

Table 6.1: Production 2015 in major markets

Installed capacity Japan Korea China and India (m3) (2015)	
Sawmilling	88,258,000
Plywood	110,051,000
MDF and PB	81,978,500
TOTAL	280,287,500

Source: FAO FAOSTAT

In order to use these data to understand material flows and the implications for the demand for New Zealand forestry products, we need to know:

1. What are the implied log requirements for each of sawmilling and plywood manufacture?
2. What is the residue production implications of each of these log requirements?
3. What are the implied log import requirements, based on reported harvest levels, assumed proportions of solid wood logs in harvest, and the calculated log requirements above?

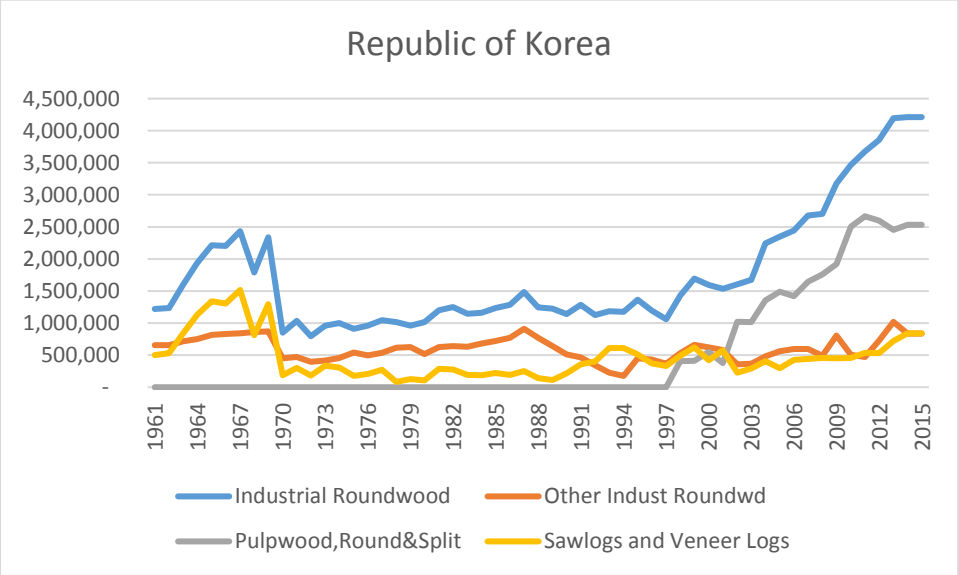
6.2 Wood harvest by log product, 1961 to 2015

FAO data shows the estimated resource supply in the four markets of interest. We are interested in total industrial Roundwood, which is made up of

- Saw logs and veneer logs
- Pulpwood round and split
- Other industrial Roundwood (Poles piling posts pit props etc)

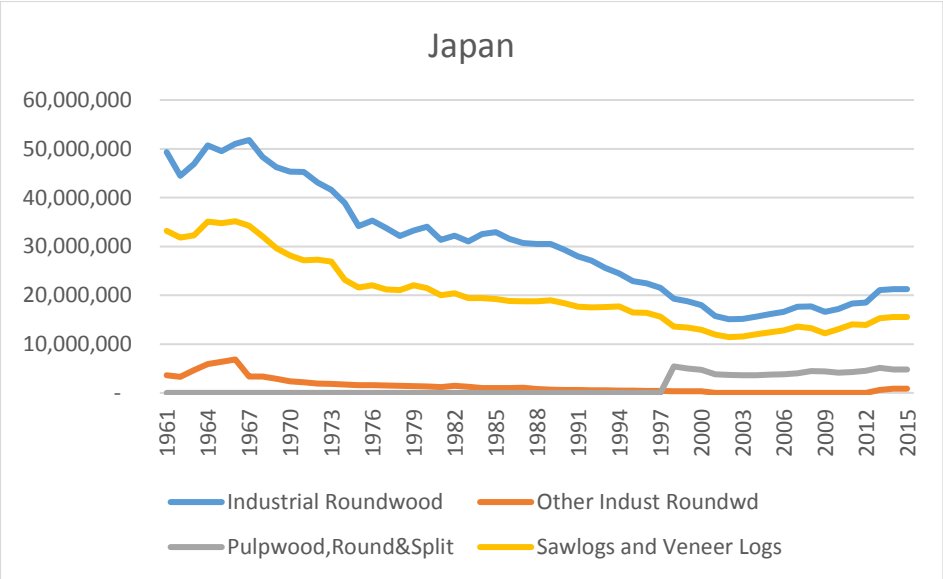
From 1998 these data are consistent, for earlier years there is nothing in pulpwood, and sawlogs +other industrial Roundwood does not add up to (and is less than) total industrial Roundwood. The reason for this disparity is not known.

Figure 6.2: Log production, Korea



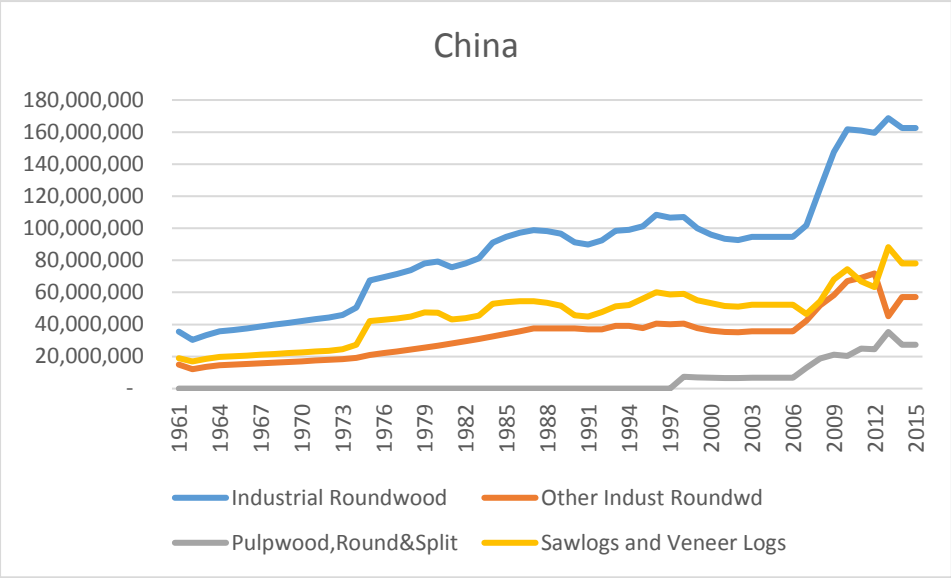
Source: FAO FAOSTAT

Figure 6.3: Log production, Japan



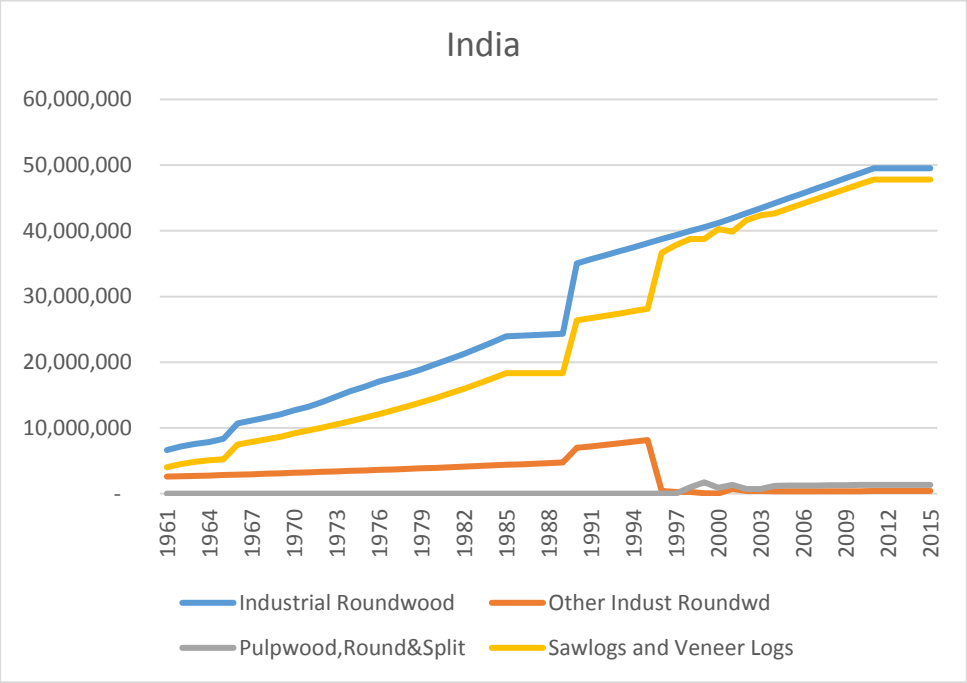
Source: FAO FAOSTAT

Figure 6.4: Log production, China



Source: FAO FAOSTAT

Figure 6.5: Log production India



Source: FAO FAOSTAT

All the countries studies are wood deficit regions. Log imports and solid wood processing can be carried out in this case as a means of obtaining fibre furnish for either wood panels (MDF and particleboard) or pulp for paper.

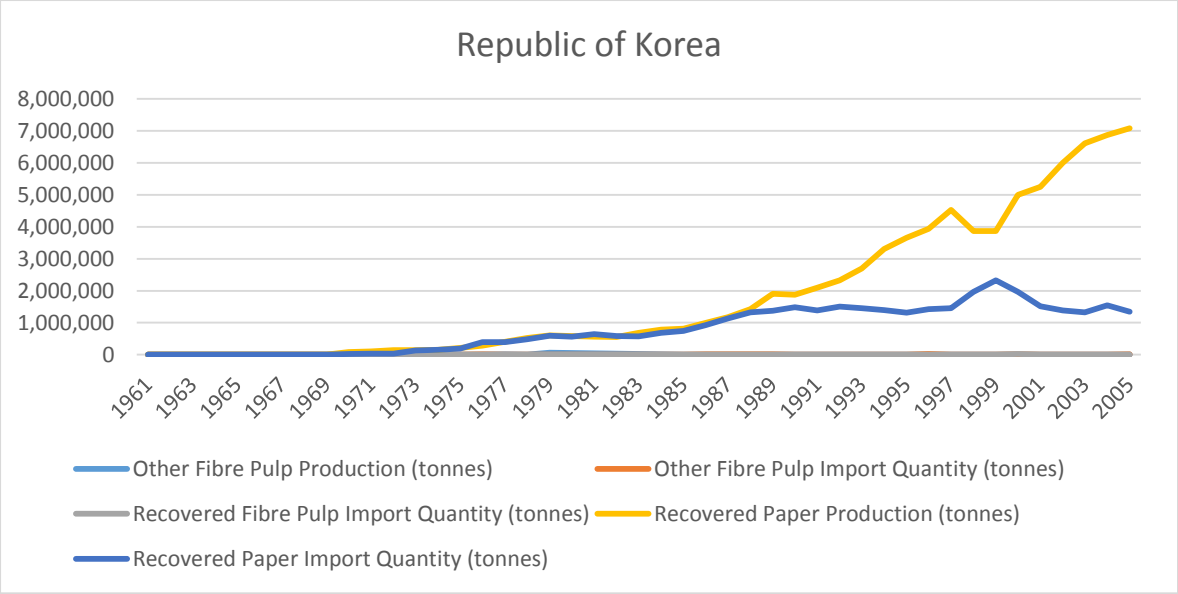
In the case of Republic of Korea, the MDF industry is the driver for log imports. In China clean chip will mostly go to pulp mills (and the long distances these chips travel indicate a serious wood shortage). This also means that in China, MDF and particleboard mills must exist on a lower quality fibre resource (recycled wood waste and small size and poor quality wood material from forests).

6.3 Other sources of fibre

An important source of fibre for resource-poor regions with large populations is recovered paper. This can be "manufactured" locally or imported.

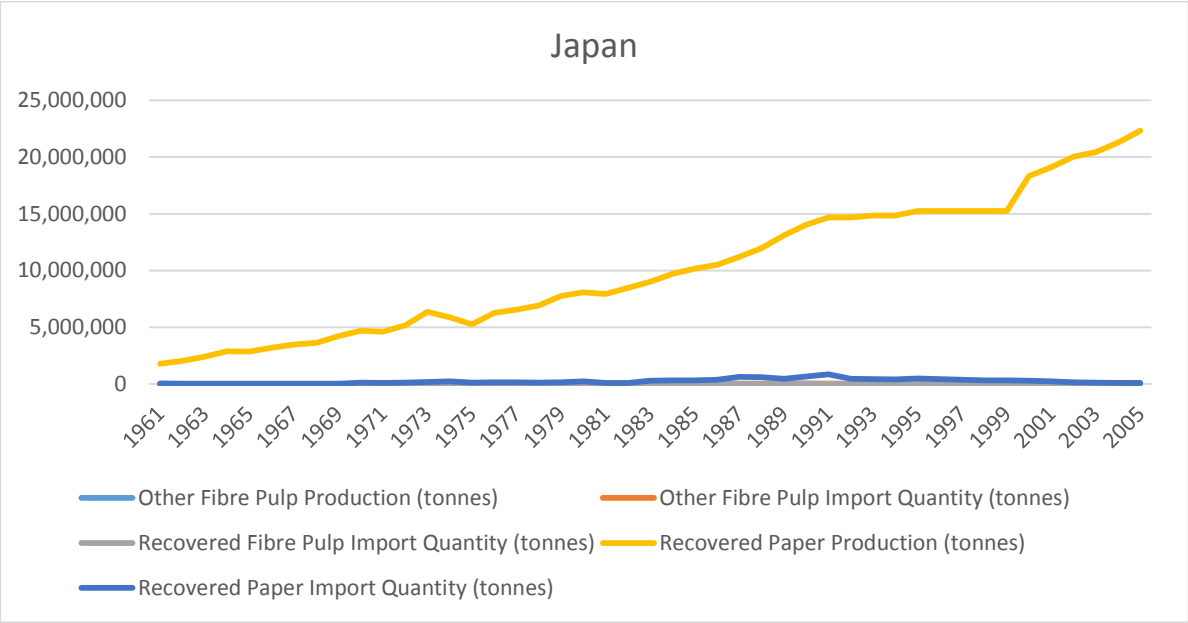
In Japan, domestically source recovered paper makes up almost all of the supply. Korea gets about 20% of its supply from imported recovered paper. China and India have further diversified sources of fibre, including significant amounts of non-wood fibre.

Figure 6.6: Other fibre sources, Korea



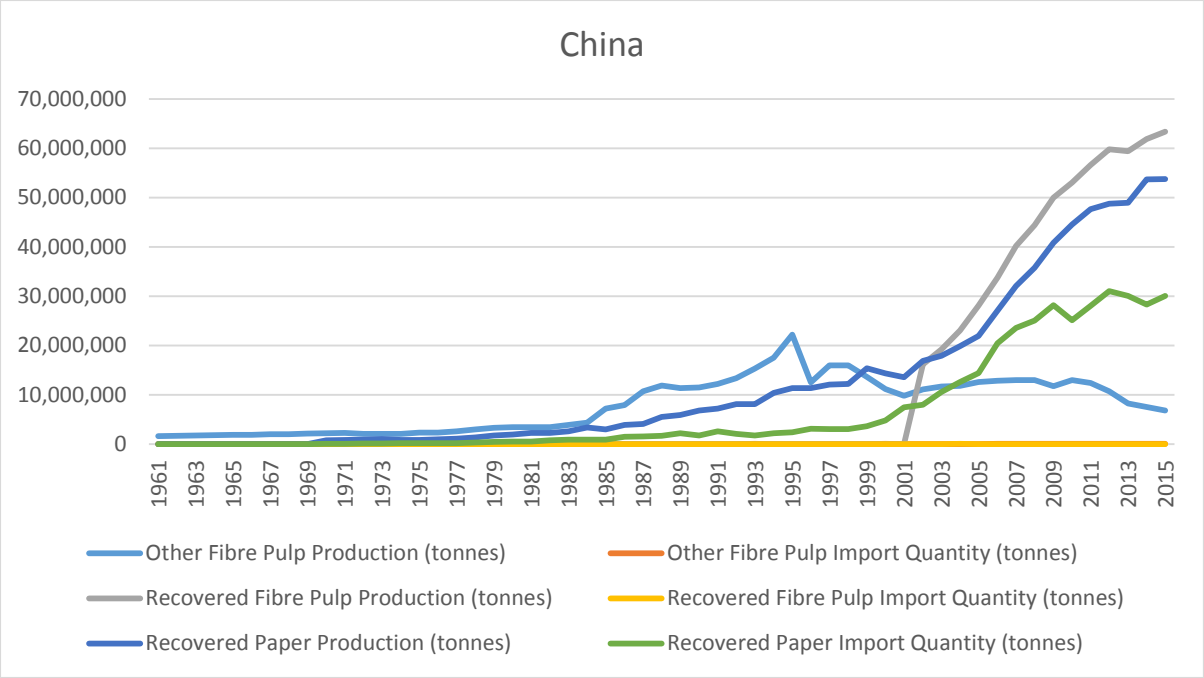
Source: FAO FAOSTAT

Figure 6.7: Other fibre sources, Japan



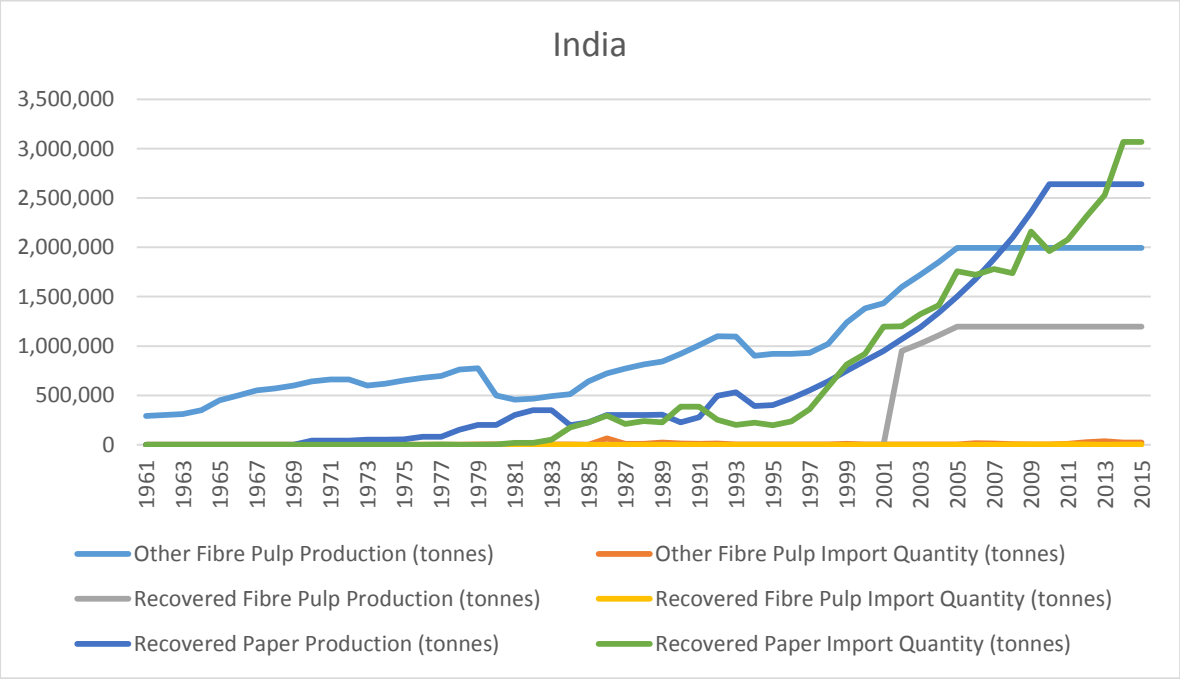
Source: FAO FAOSTAT

Figure 6.8: Other fibre sources, China



Source: FAO FAOSTAT

Figure 6.9: Other fibre sources India



Source: FAO FAOSTAT

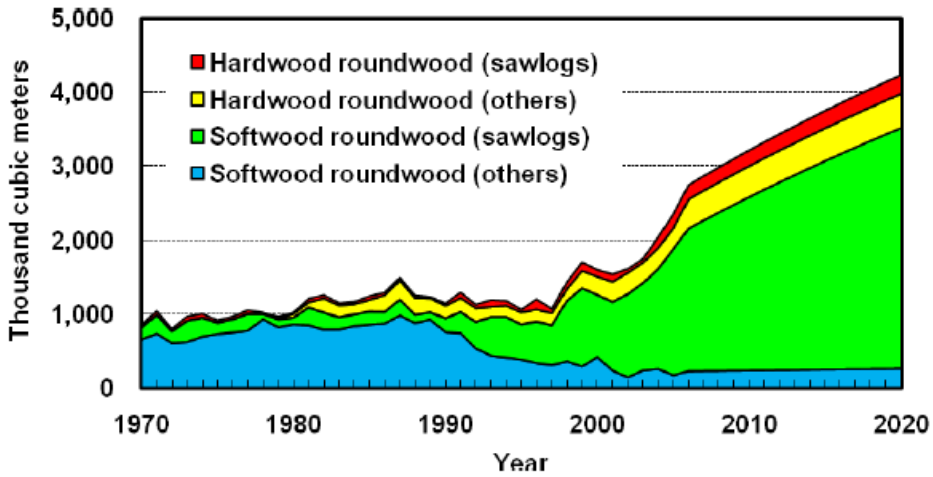
6.4 Forecasts of future domestic harvest

All countries are emphasising non-timber uses in the forward-looking statements.

6.4.1 Korea

FAO (2012) expected harvest in Korea to increase to 4.2 million m3 by 2020 (of which 3.5 million m3 would be softwood. The data above show this harvest level was already reached by 2014

Figure 6.10: Resource projections: Republic of Korea



Source: FAO (2012)

Table 6.2. Supply/demand balance, Republic of Korea (roundwood equivalent)

			Observations		Projections		
			2000	2005	2010	2015	2020
Demand (1,000 m³)	Total		20,170	22,856	24,045	25,066	26,456
	Lumber		6,795	6,215	6,624	6,918	7,413
	Plywood		2,872	3,247	3,637	3,948	4,364
	Fiberboard		1,195	2,317	2,528	2,728	3,003
	PB		0	0	0	0	0
	Pulp wood		8,835	10,614	10,792	10,970	11,150
	Others		473	463	464	503	526
Supply (1,000 m³)	Total		20,170	22,856	24,045	25,066	26,456
	Imports	Sub-total	18,578	20,506	20,830	21,316	22,222
		Products	11,841	14,235	14,746	15,468	16,611
		Logs	6,737	6,271	6,084	5,848	5,611
	Production		1,592	2,350	3,214	3,750	4,234

Note: 1. Figures above are the converted values in roundwood equivalent volume, excluding trade volume of recovered paper, paper and paperboard and secondary wood products.
2. 100 percent of PB is made of wood wastes, so the converted value is zero.
3. Imports of products refer to net imports (imports minus exports).

Source: FAO (2012)

6.4.2 Japan

Harvest is only expected to increase modestly from 21 million m3 in 2015 to 29 million m3 in 2025

Table 6.3 Target of wood supply

(Unit: Timber volume: million m ^{3})

		(Actual) 2004	(Target) 2015	(Reference) 2025
Wood supply		17	23	29
Breakdown of reference	Forest for water and soil conservation		16	18
	Symbiotic forest with people		1	1
	Forest for resource cyclic use		6	10

Source: FAO (2010)

Table 6.4 Demand for wood by end use

(Unit: million m ^{3})

Category of use	Use amount		Total demand	
	(Actual) 2004	(Target) 2015	(Actual) 2004	(Target) 2015
Materials for timber	11	14	37	33
Materials for pulp/chip	4	5	38	41
Materials for plywood	1	3	14	15
Others	1	1	2	2
Total	17	23	91	91

Note: Others include pickets, logs for Shiitake mushroom, and fuel-wood.

Source: FAO (2010)

6.4.3 China

Official statements about China's future wood supply may be more aspirational than based on solid resource data and numerical projections – for example:

"…By 2020, the total forest area will reach more than 220 million ha, the forest stock volume will reach 14.5 billion m^3 and the average annual growth increment in fast-growing and high-yield forest bases nationwide will be about 15 m^3/ha. With further improvement in forest breeding and cultivation technology, there is promise for growth to realize an average annual increment of 20 m^3/ha in fast-growing and high-yield forest bases. By 2020, China's annual harvest will be increased on the basis of current management levels to meet 70-80% of the domestic demand of timber, i.e. 304 million m^3. Under reasonable forest management, the standing stock volume per ha can reach the world's average level with annual allowable cut of around 420 million m^3. Such an increase will mainly result from the improvement of forest quality. Increases in annual increment and gross stock volume will provide potential room to markedly increase the sustainable forest harvest. Besides, thanks to the improvement of quality seeds and intensive management of timber forests, the output per unit area will be increased and thus more timber can be produced, while the forest area is kept relatively stable…." (FAO, 2009b)

On the other hand, there appears to be a trend developing in China where the Federally-owned forests (in the north and north east) are being used for non-timber purposes (announcements were made to the effect that logging was ceasing in federally owned forests recently). The cooperative forests are in the Yantze region and in the south of China and these are expected to be the focus of wood supply in the future. Because there do not appear to be any area/age class based forecasts of future availability, this is a major uncertainty in understanding the future domestic wood supply/demand balance in China

6.4.4 India

There is no clear statement of resource supply in FAO (2009a). "In wood production, the concept of annual allowable cut (AAC) has often been given low consideration" (FAO, 2009a). There is a suggestion that considerable overcutting is occurring, but the implications for future resource supply from domestic sources are not quantified.

Pandey and Rangaraju (2008) forecast that India's demand for wood (in RWE) will increase from 58 million in 2000 to 153 million m3 in 2020 (this is an increase of around 5% per annum) and more than half will come from "non-forest" sources. In the Indian nomenclature, forest is regarded as government owned forests whereas non-forest is farm-based plantations, often small scale.

The importance of "trees outside the forest" is also highlighted by Pandey (2008a). "The total growing stock of wood in TOF in India is 1.616 billion m3….the estimated growing stock of India's forest is about 4.7 billion m3. TOF therefore constitutes …almost one third of the country's forest…"

Table 6.5: India Timber Supply demand balance

	DEMAND			SUPPLY			ESTIMATED DEFICIT
	Long rotation	Short rotation	TOTAL	Long rotation	Short rotation	TOTAL	TOTAL
2000	31	27	58	14	15	29	-29
2010	47	48	95	27	43	70	-25
2020	69	84	153	49	61	110	-43

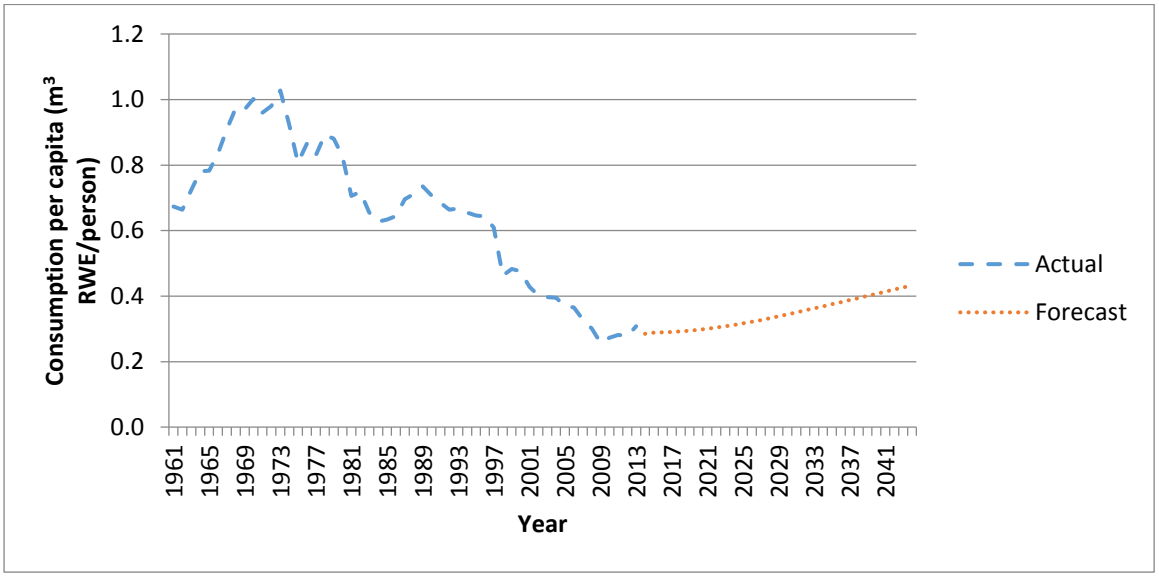
Source: Pandey and Rangaraju (2008)

7. Forecasting consumption using econometric models

7.1. Forecasting consumption in Japan (From Drummond 2015)

This section presents forecasts for the three aggregate product categories in Japan, sawn timber, wood-based panels and paper and paperboard, as an example of how this research can be applied, however further work is required to ensure forecasts of explanatory variables are fit for purpose.

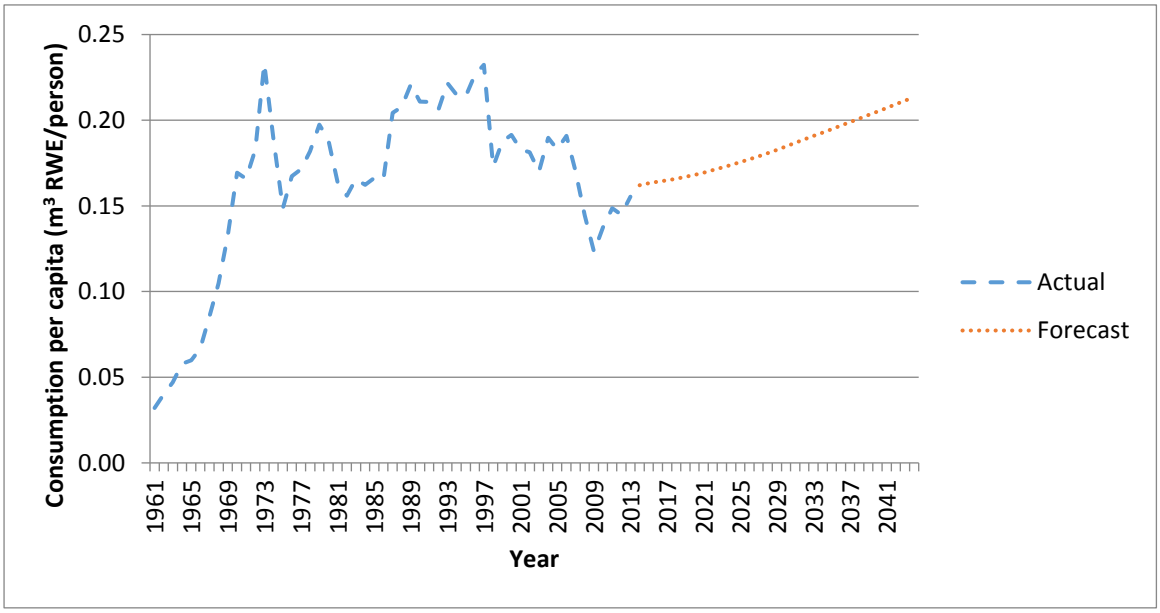
Figure 7.1: Actual sawn timber consumption and sample forecast to 2044 for Japan.



Source: Drummond (2015)

The forecast data from 2014 to 2044 used an estimated GDP per capita growth rate of 0.2%/annum across the period reflecting Japan's already high level of development (IMF, 2015). Furthermore, construction investment was assumed to follow this same trend. This produced an increasing forecast for the consumption of sawn timber in Japan as construction investment has a greater positive influence on consumption compared to the negative GDP per capita influence which is an order of magnitude smaller.

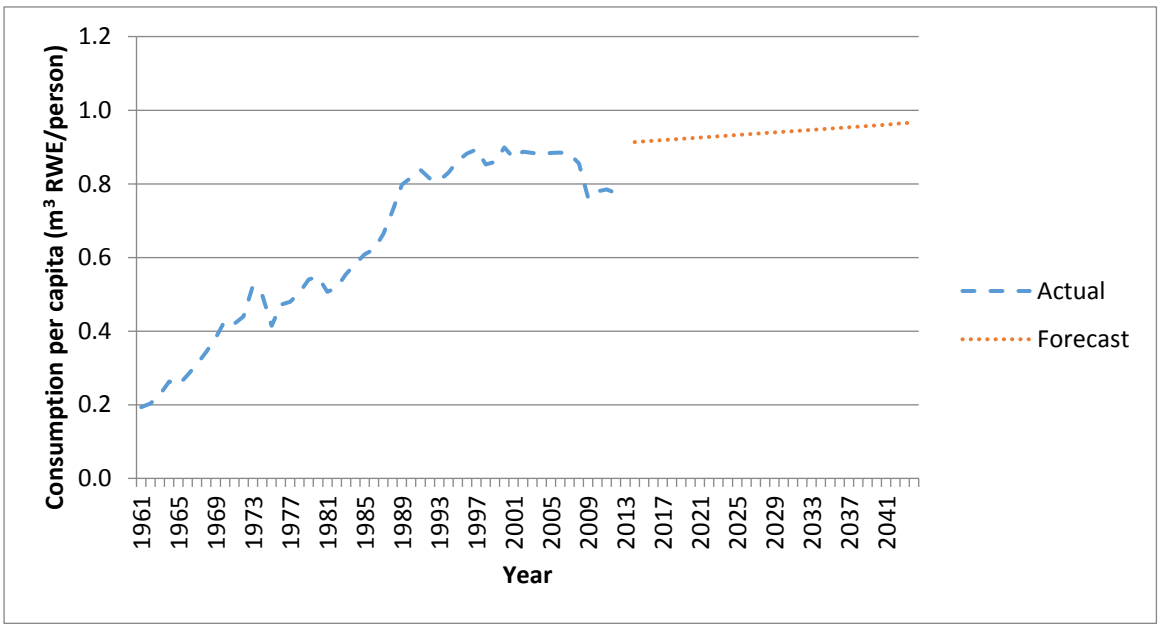
Figure 7.2: Actual wood-based panel consumption and sample forecast to 2044 for Japan.



Source: Drummond (2015)

The forecast for wood-based panel consumption in Japan assumed the same per capita increase in GDP and construction activity as for sawn timber, 0.2%/annum. This model also used product price which was assumed to remain constant in real terms across the forecast period. The model shows a steady increase in the consumption of wood-based panels over the thirty year period. Consumption is forecast to increase to 0.21 m^3 RWE/person by 2044 up from 0.16 m^3 RWE/person in 2013. As with sawn timber this increase is driven largely by the anticipated increase in construction activity.

Figure 7.3: Actual paper and paperboard consumption and sample forecast to 2044 for Japan



Source: Drummond (2015)

A forecast of paper and paperboard consumption in Japan is also included in the graph for the period 2014 to 2044. The model predicts that paper and paperboard consumption will remain relatively constant over the thirty year period only increasing slightly. There is potential however that the model is over predicting consumption as there are a variety of factors now decreasing demand for communication paper categories, a point expanded upon in the discussion section. The forecast estimates a 25% increase over the observed value in 2013 of 0.77 m^3 RWE/person. The model does not predict the decrease in recent years well and is over predicting consumption at 0.91 m^3 RWE/person in 2013, 18% higher than the actual value. The model estimates that by 2044 Japan's consumption of paper and paperboard products will be 0.96 m^3 RWE/person.

The total consumption of all wood products in Japan is estimated to be 1.60 m^3 RWE/person by 2044. Under this assumption and using population projections, estimated to be 112.6 million people in 2044, the total volume of round-wood required to service the individual product demand was found to be 180.4 million m^3 (FAO, 2015).

7.2 Estimating market share of NZ in total import demand for each country

This is very difficult to do analytically, largely because a number of non-analytical factors will come into determining the actual mix. It is also probably true that the data are not either comprehensive enough, or correct enough to do a good job of this. It is suggested that simple rules should be used to estimate the market share, based on existing relationships and diversification. The rationale is that existing relationships will lead to customer and supplier loyalties.

Also the change in capacity will determine demand. The Chinese market is the main one where competition exists and a truly economic solution might prevail on the demand side – the supply side appears to be very much part of the command economy.

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Appendix: Product definitions, FAO data

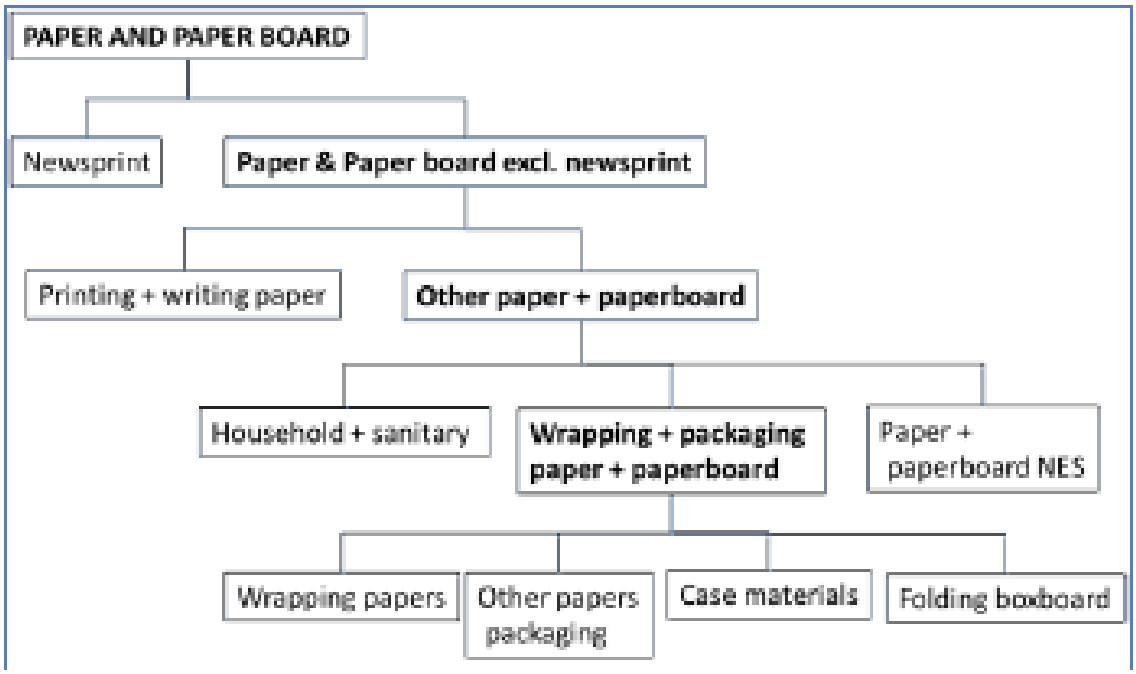


Figure 4. Paper and paper-board classification

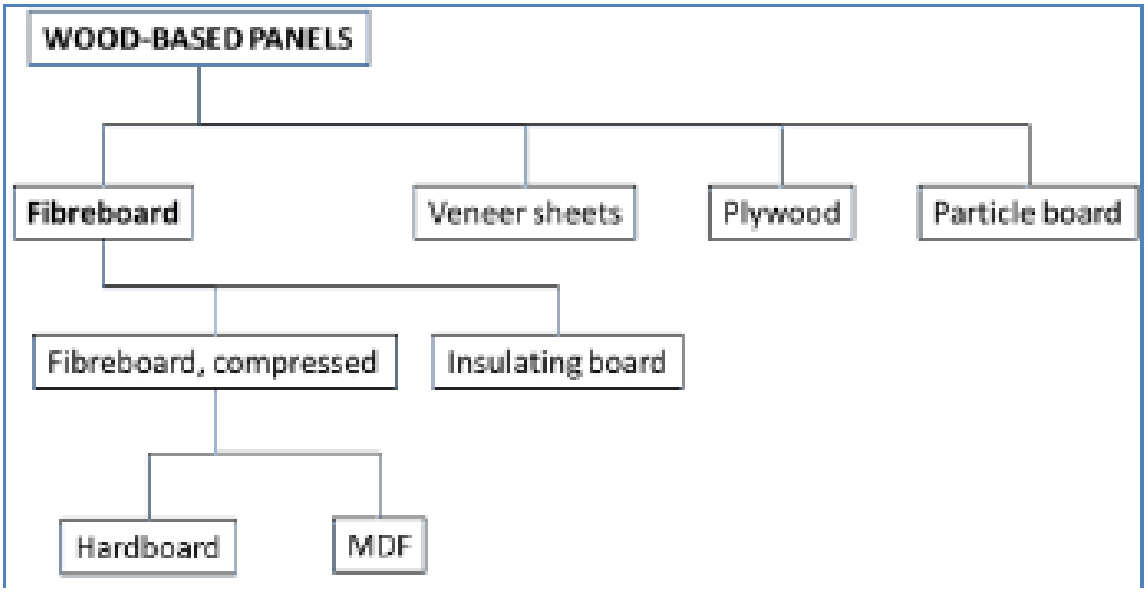
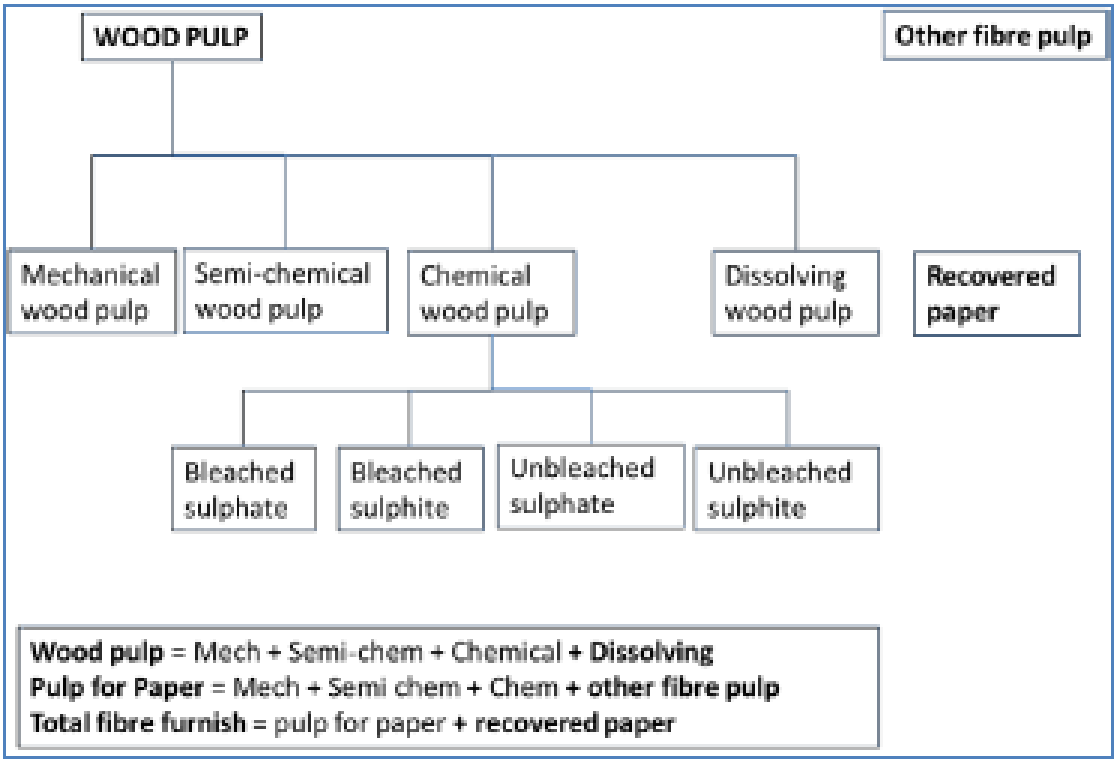


Figure 3. Wood-based panel classification


WOOD PULP
Other fibre pulp
Mechanical wood pulp
Semi-chemical wood pulp
Chemical wood pulp
Dissolving wood pulp
Recovered paper
Bleached sulphate
Bleached sulphite
Unbleached sulphate
Unbleached sulphite
Wood pulp = Mech + Semi-chem + Chemical + Dissolving
Pulp for Paper = Mech + Semi chem + Chem + other fibre pulp
Total fibre furnish = pulp for paper + recovered paper