Market Integration of Domestic Wood and Imported Wood in Japan: Implication for Policy Implementation

Yoshihiko Aga

A thesis
submitted in partial fulfillment of the
requirements for the degree of

Master of Science

University of Washington

2013

Committee:
John Perez-Garcia
Bruce Bare
Ivan Eastin

Program Authorized to Offer Degree:

School of Forest and Environmental Sciences

Table of Contents

Page

List of Figures

Page

List of Tables

Page

Acknowledgement

I would like to gratefully and sincerely thank John Perez-Garcia for his strong encouragement, insightful suggestions, patience, and friendly humor during my graduate studies at University of Washington. I am also grateful to other committee members, Ivan Eastin and Bruce Bare, for their productive advice to improve my research. I would like to express my appreciation to Clara Burnett and CINTRAFOR for providing us a wonderful study environment. I am heavily indebted to the Japanese Government, which provided me with plenty of time and funds for my study through the Japanese Government Long-Term Fellowship Program. I also thank the staff and colleagues in the Forestry Agency of Japan who kindly provided me with valuable data and information. I also appreciate all CINTRAFOR colleagues, Ben Roe, Daisuke Sasatani, Indroneil Ganguly, Jake Grossman, John Simeone, Tait Bowers, Sebastian Tramon, Ziyi Liu, for being great company for the last two years. Finally, I thank my wife Mariko for her understanding and support.

1. Introduction

Historically Japan has been one of the largest importers of wood products in the world. Wood imports increasingly have replaced the share of domestic wood since the 1960s, when the Japanese government liberalized wood imports by removing tariffs on most wood products in order to meet the skyrocketing demand for wood. Wood self-sufficiency in Japan plunged from over 90% in the 1950s to below 50% by the end of 1960s, and kept declining to a low of 18.2% in 2002.

Meanwhile, a large area of domestic plantation forests planted in the post-war period has matured reaching harvestable age of over 50 years old. Beginning in the early 2000s, with this increasing domestic timber resource, the Japanese government has adapted several policy measures aimed at increasing the supply and use of domestic wood.

The most recent initiative includes the Forest and Forestry Revitalization Plan (hereafter referred to as "the Revitalization Plan") developed in 2009 by the Ministry of Agriculture, Forestry and Fisheries (MAFF), which aims to increase domestic wood supply and achieve the wood self-sufficiency rate of 50% by 2020 through a combination of reforms and subsidies designed to expand timber supply and increase the use of domestic wood in construction (Eastin, 2011). Corresponding to the development and implementation of the measure, several concerns have been raised on the policy's effect on the competitiveness of imported wood in the Japanese market. Eastin (2011) points out that the measure by the Japanese government would have a serious adverse impact on the competitiveness of U.S. wood products in Japan and undermine the ability of U.S. manufacturers and exporters to compete in Japan.

The potential effect of the Japan's policy on the Japanese wood market, however, should be understood based on the competitive situation and substitutability of domestic and imported wood. Without a sound understanding of the relationship between these domestic and imported wood, any preliminary conclusions regarding the effects could be misleading. Thus the objective of this study is to understand the competitive relationship between domestic and imported wood in the Japanese market, and subsequently to make inferences on the impacts of the Japanese Revitalization Plan policy on domestic and imported wood markets.

Concept of Market Integration

In this study, a competitive relationship between domestic and imported wood was tested using the idea of market integration. Markets are said to be integrated if, at equilibrium, the law of one price (LOP) holds and no arbitrage opportunity exists as a necessary condition for price efficiency. The LOP is a test for market integration, and is assumed to hold in several trade models for wood products (Nagubadi et al., 2001). If the LOP is upheld then trade models that assume price equilibrium to hold among homogenous products can be used to study the effects the Revitalization Plan would have on Japanese and other nation's wood markets in terms of change in volume traded, whereas if the LOP does not hold to be true, then the use of these trade models would not be appropriate and any results yielded by those models may not be correct.

According to Baulch (1997), markets are integrated if prices in different markets move together and their price differential equals the transfer costs that include transportation and transaction costs. If there is an equilibrium relationship between two markets, the prices in these markets cannot diverge by more than a small amount in the long-run (Engle and Granger, 1987). In order to find this price behavior, the assumption that product prices in different markets do not behave independently has to be tested.

The degree and extent of market integration has several implications for markets (Thorsen, 1998). It may give important information concerning the competitive strengths and weaknesses of individual markets. Strong integration may imply that any policy decision made by significant agents, such as industry or government, on any market will directly affect all the markets involved. Conversely, weak integration or lack of integration among markets may indicate that political measure targeted to influence a market would not be transmitted to other markets.

Thesis Outline

This study is organized into nine chapters. Chapter two addresses the background to the recent political and economic situation affecting wood markets in Japan. This is followed by the study hypothesis and literature review in Chapters three and four. Chapter five details the method employed in this study to examine market integration. A description of the data and preliminary analysis is then presented in Chapter six. After detailing this study's results in Chapter seven, Chapter eight offers a discussion on these results as well as on implications for the implementation of Japan's policy. Lastly, Chapter nine summarizes this study's main findings and produces a concluding section.

2. Background

Overview of Japan's Economy and Wood Demand

Japan's wood demand has been affected largely by its domestic economic situations. It is closely tied to domestic housing starts, which is the largest end-use demand sector for lumber (MAFF, 2011a). Japan's economy greatly changed over time after World War II, and it can be divided largely into three periods identified by economic growth.

From around 1956 to 1973 the average annual GDP growth rate was 9.2 % (Figure 2-1). This was a period of high economic growth and rapidly expanding timber demand. Timber demand skyrocketed from 45 million cubic meters (in log-equivalent volume) in 1955 to the record high of 117 million cubic meters in 1973. The huge increase in timber demand was supported by a huge demand increase in all applications including lumber used for housing construction, plywood used for civil engineering, and pulp and chip used for paper production (Figure 2-2).

Two consecutive oil shocks in the early and late 1970s substantially damaged the economy, and shifted the economic growth rate downward. Despite the economic downturn during the beginning of the period, Japan's economy maintained moderate growth with an average annual GDP growth rate of 4.1% between 1974 and 1990. The moderate growth could be attributed to the so-called bubble economy era spanning from 1986 and 1990, which was caused by yen's appreciation against the U.S. dollar after the Plaza Accord in 1985. The appreciation of yen, which caused economic damage to Japan's exporting industry, led the Bank of Japan to lower interest rates in an attempt to stimulate the economy. As a result people began to invest more in real estates, which led to higher levels of construction activity. It is against this backdrop of increasing demand for housing construction that wood demand weakened after the oil shocks started to recover rapidly around 1986. Wood demand increased for almost 20% in the three years between 1986 and 1989, from 95 million cubic meters to 114 million cubic meters.

Japan's economic bubble burst in 1990 triggered by a sharp decline in stock prices on the Tokyo Stock Exchange. The subsequent decade is referred to as the lost decade since the Japanese economy began to deteriorate during this time. Despite this economic crush, wood demand in the early 1990s remained relatively high thanks to a still increasing demand for pulp and chips, although the demand for lumber continued to decrease as housing starts declined. The sluggish economy was worsened by the increase in a consumption tax rate from 3% to 5% and by the Asian Financial Crisis, both happening in 1997. Wood demand plunged after 1997 as new housing starts experienced a huge decline, since people rushed to buy houses before the tax increase and stayed away from home purchases afterward.

It has been said that the lost decade turned into two lost decades, as low economic growth continued throughout the 1990s and into the first decade of the 2000s. Although Japan's economy recovered from 2002 through 2007, with over 2% annual GDP growth rate, it again entered into a recession after being hit by the global financial crisis in 2008. The recovery from the crisis, which coincided with a regime change from the Liberal Democratic Party (LDP) to the Democratic Party of Japan (DPJ) after the general election in 2009 brought about some increase in Japan's economic growth, but the Tohoku earthquake in 2011 and the Fukushima Daiichi nuclear disaster greatly affected subsequent economic growth. During the most recent decade, gross demand for wood showed a steeper downward trend than the previous decade, although the recovery from the financial crisis contributed to some increase in demand after 2010.

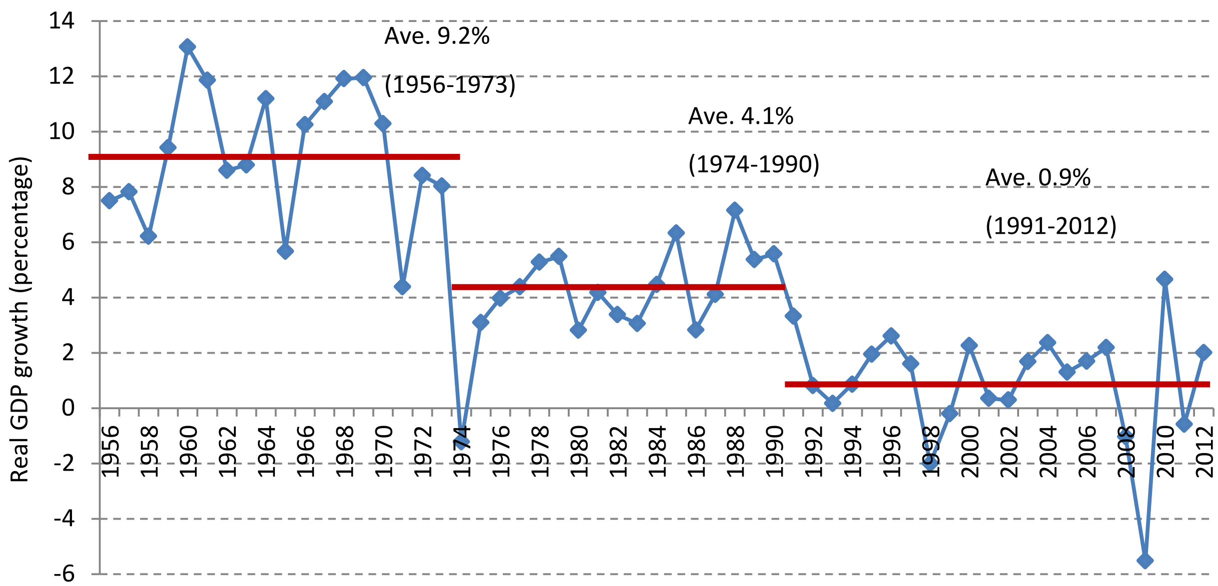

Figure 2-1. Japan's annual real GDP growth rate.
Source: Cabinet Office, 1998 (for 1956-1980), 2009 (for 1981-1994), 2011(for 1994-2011), 2013(for 2012)

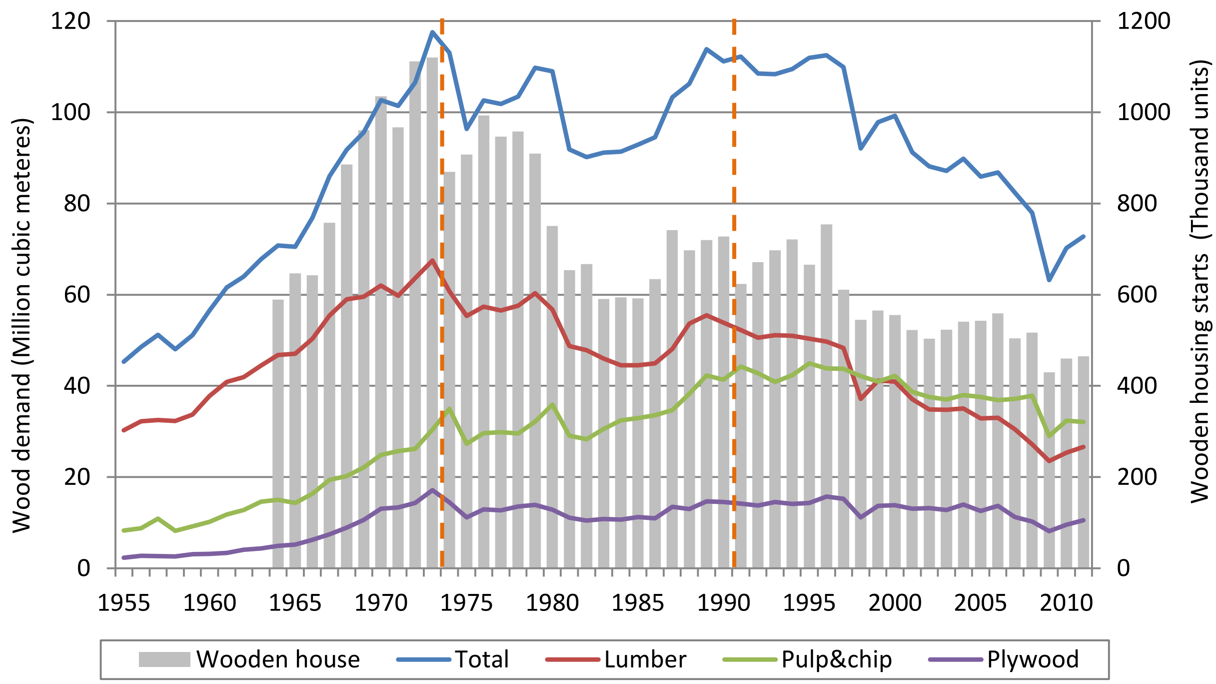

Figure 2-2. Wood demand (in log-equivalent volume) by application and wooden housing starts in Japan.
Source: Forestry Agency, 2012;MLIT, 2011

Wood Supply and Self-sufficiency

The liberalization of wood imports in the 1960s adversely affected Japan's domestic forestry sector in the subsequent decades. Supply of domestic wood continued to decline since the middle of the 1960s and it was replaced by imported wood. Increased demand for wood observed in the high economic growth period was almost entirely absorbed by an increase in imported wood. Eventually, self-sufficiency, which is defined by the Forestry Agency of Japanese government as the ratio of domestic wood supplied over the total wood consumed domestically in log-equivalent volume, decreased from almost 90% in the beginning of the 1960s to less than 50% in 1969, and to as low as 30% in the 1970s (Figure 2-3).

Although the decrease in wood imports after the oil shocks contributed to some resurgence in self-sufficiency in the early 1980s, accelerated wood imports during the bubble economy era due to the strong yen after 1985 as well as steady increase of wood import in the subsequent period resulted in an ever-decreasing self-sufficiency rate.

Only since 2003 has the supply of domestic wood started to increase. Contrastingly wood imports began to show a downward trend since the early 2000s and the level has dropped substantially in 2009 when Japan's economy was in a deep recession after it was hit by the global financial crisis. These opposing factors allowed the self-sufficiency rate to increase from its record-low level of 18.2% in 2002 to a high of 26.6% in 2011, up 7.4% in the last 9 years.

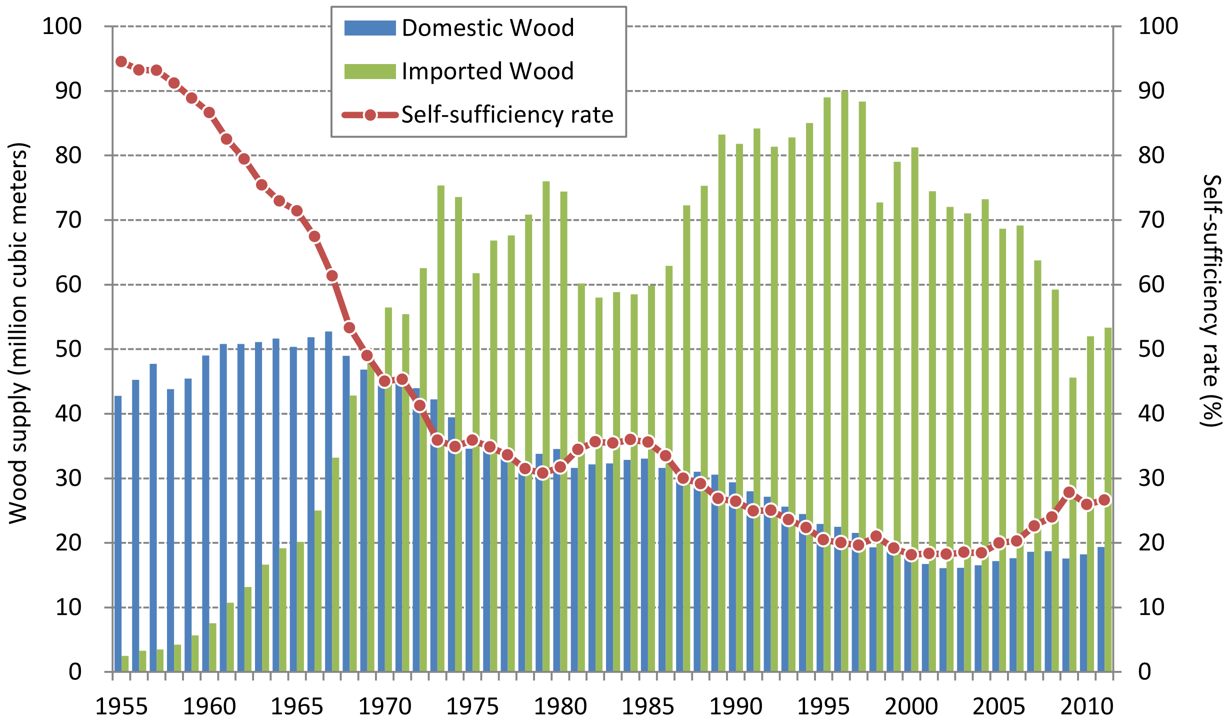

Figure 2-3. Wood supply by origin and self-sufficiency.
Source: Forestry Agency, 2012
Note that the volume of imported wood includes both the volume of imported logs and the log-equivalent volume of imported products.

Domestic Forest Resources and Timber Supply

As Japan's forest resources were depleted during WWII, there was much effort placed to implement reforestation programs in the postwar period so as to restore forests on deforested lands. The reforestation programs were expanded further to also replace natural forest areas as wood prices increased beginning in the 1960s. From the 1950s through the early 1970s, the annual area reforested was between 300 and 400 thousand hectares.

Since houses in Japan were constructed traditionally using wood, the reforestation activity was strongly characterized with its heavy preferences for softwood species. Among several native softwood species, *sugi* (Japanese (red) cedar, *Cryptomeria Japonica*) was the most preferred as it grows straight and faster than other species, followed by *hinoki* (Japanese cypress, *Chamaecyparis obtusa*) which grows much slower than *sug*i but has greater strength. These two species account for 45% and 25% respectively of total domestic plantation forests in terms of area as of 2007. Japanese red pine (*Pinus densiflora*) and Japanese larch (*Larix kaempferi*) were less preferred than *sugi* and *hinoki*, but still have substantial areas of plantation forests dedicated to them from the 1950s through 1960s, resulting in a share of 9% and 10% of the current plantation areas respectively.

The area of reforestation declined substantially since the 1970s and has been only around 30 thousand hectares per year since the 2000s. This drastic change in the area of reforestation resulted in an uneven distribution of age class of plantation forests (Figure 2-4): about 70% of the area of plantation forests centers in the range of 31 years and 60 years, whereas plantation forests younger than 30 years comprise only 22% of the total. Given that plantation forests are usually harvested between 50 to 60 years old, the current age class distribution suggests that more domestic timber should become available during the coming decades.

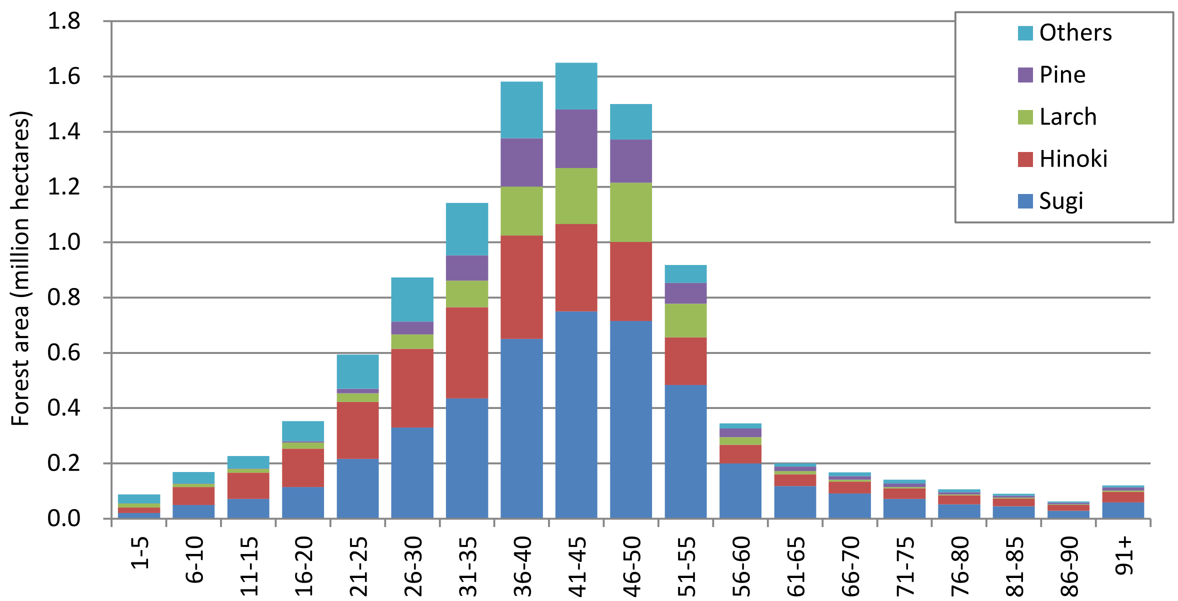

Figure 2-4. Area of plantation forest by tree species in Japan, as of 2007.
Source: Forestry Agency, 2007

Figure 2-5 shows the volume of domestic logs consumed to produce each wood product. The largest demand sector is the lumber industry, which has consistently comprised around 60% to 70% of the total volume of logs demanded, followed by pulp and chips which used to comprise over 30% of total demand but has been around one quarter since the middle of the 1990s. While demand for domestic logs for plywood production had been historically low, due to its reliance on imported logs from Southeast Asian countries up to the 1980s and subsequently from Russia since the 1990s, currently it has been increasing rapidly since the first decade of 2000s and now comprises 14% of total log demand as of 2012.

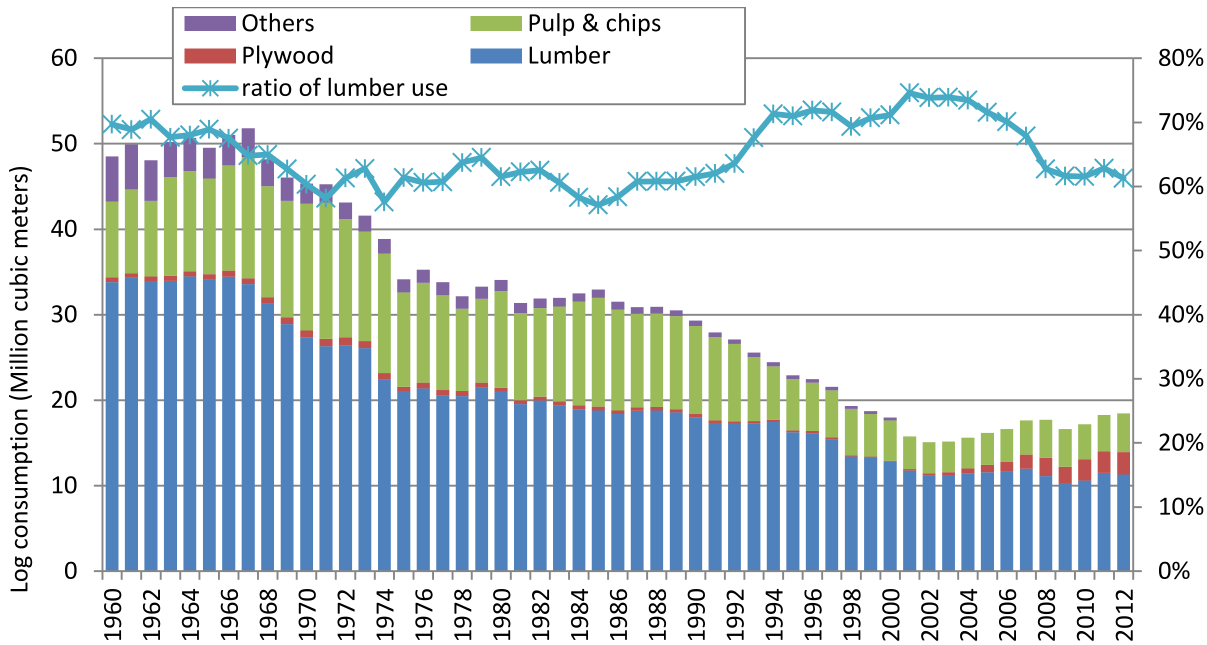

Figure 2-5. Log consumption volume in Japan, by application.
Source: Forestry Agency, 2012

Softwood species comprises more than 80% of the total domestic log harvest level in recent years, whereas the ratio of hardwood logs has declined substantially to less than 20% (around 2 million cubic meters) from its peak of over 40% (almost 20 million cubic meters) in the 1970s (Figure 2-6). Hardwood logs have been exclusively used for chip production, with over 90% going into chip mills in recent years, while a large part of softwood logs have been used for lumber production and a limited amount for plywood and chips.

Softwood log harvest volume declined from its 1960 peak of around 35 million cubic meters to its lowest level of 12 million cubic meters in 2002. This is mainly because a large part of softwood plantation forests was immature and unable to supply large volume of wood as cheaply and efficiently as imported wood (MAFF, 2003). It is only since 2003 that the volume of softwood logs harvested started to increase.

Detailed by species, *sugi* has been the dominant species with the highest share of around 40% of domestic softwood supply in volume, followed by *hinoki* and Japanese larch both with around 10% to 15%. All of these species have been used largely in lumber manufacture, with increasing amount of *sugi* and Japanese larch used in plywood industry in recent years. Although Japanese red pine had been widely used in Japanese traditional post and beam houses especially for beams, it does not have much share in recent years due to a sharp decline in the resource from the pine wilt disease, which began to spread nationwide since the 1970s.

It should be noted that almost all domestically produced logs have been consumed in Japan while the volume of export has been quite small. As of 2011, the volume of logs exported was 1,538 thousand cubic meters, comprising only 0.8% of domestically produced logs.

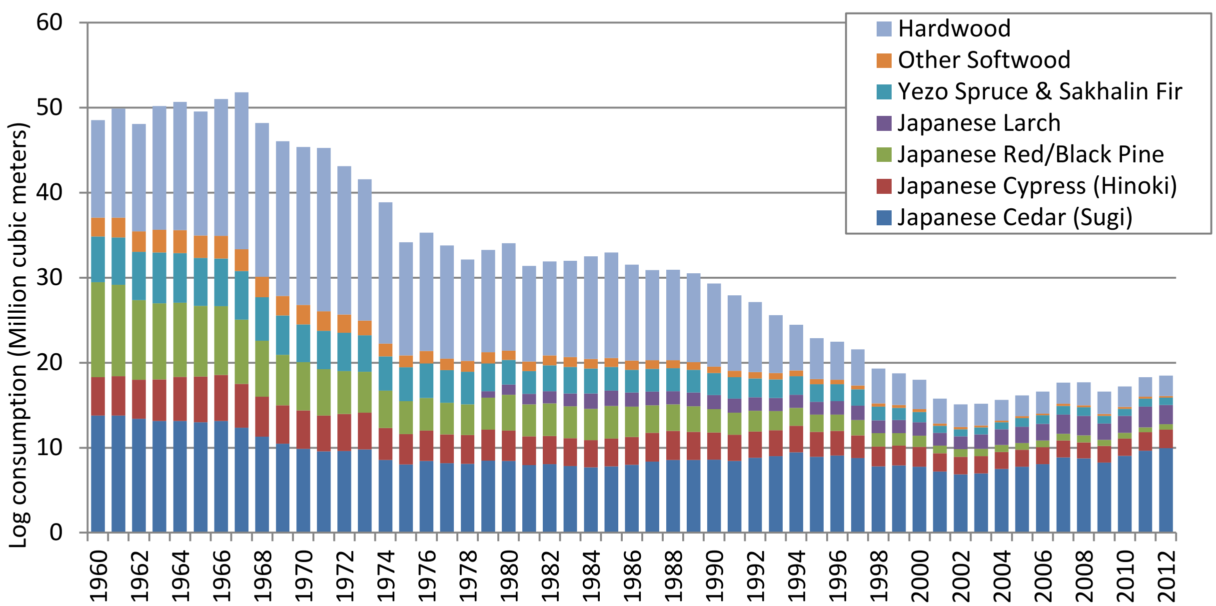

Figure 2-6. Log consumption volume in Japan, by species.
Source: MAFF, 2007-2012

Japan's Wood Import

The volume of Japan's log import has been in decline since the end of the 1970s, although Japan's total import value of wood products increased until the middle of 1990s. This is mainly due to a shift from log exports to value-added products exports in exporting countries (MAFF, 2003).

Main source countries of imported logs in recent years have been the U.S., Canada, and Russia, with the market share of 40%, 29% and 16% respectively as of 2012 (Figure 2-7). Log imports from the U.S. have greatly decreased since 1990, whereas those from Canada have been gradually increasing during the most recent decade. While Russia had long been the largest source of softwood logs into Japan following the U.S. share declined, the volume of log imports from Russia plunged after they introduced an export tariff rate of 20% in 2007 and increased it to 25% in 2008. The share of Malaysian logs in Japan also has substantially decreased since the 1990s as they reduced their domestic timber harvest volume in order to protect their domestic forest resources and achieve sustainable forest management goals (MAFF, 1991).

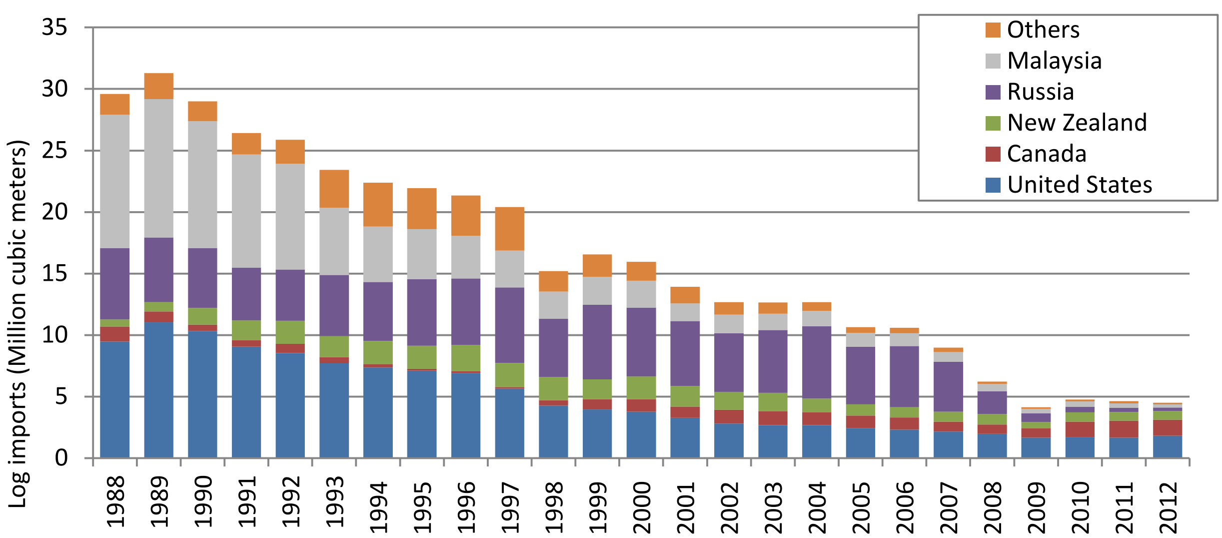

Figure 2-7. Japan's imports of log (HS 4403), by source country.
Source: MOF, 2012

With respect to species distribution, Douglas-fir has long been the dominant species among softwood logs, comprising two thirds of total softwood log imports in 2012 (Figure 2-8). Douglas-fir logs have been sourced mostly from the U.S., and since1999 partly from Canada. While pine and larch had been major imported log species into Japan in the 1990s and the early 2000s, imports of these species dropped substantially after the imposition of higher export tariff on logs by Russia, which accounted for about half of pine log imports and almost all of larch log imports. Similarly, import of hemlock logs has greatly declined as the U.S. introduced restrictions on log exports from federal and state lands since the early 1990s, and currently comprises only a few percent of total log imports (MAFF, 2001).

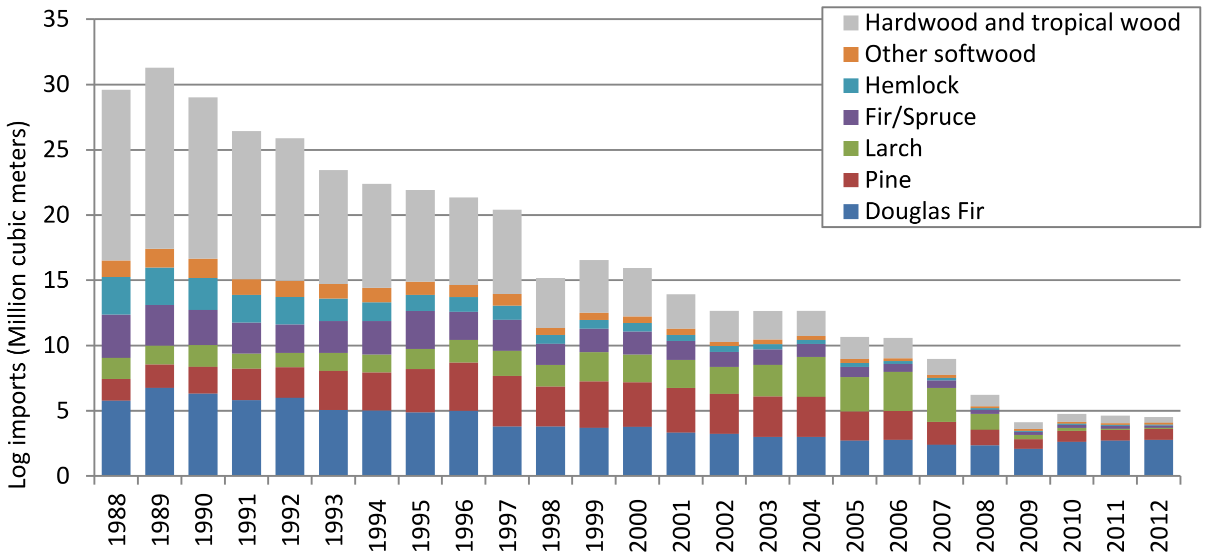

Figure 2-8. Japan's imports of log (HS 4403), by species.
Source: MOF, 2012

Japan's lumber imports recorded its highest volume in 1997, and has been in decline since then, although the extent of the decline is modest compared to that of log imports. Prior to the middle of the 1990s, Canada and the U.S. were the two major lumber source countries to the Japanese market, representing around 70% of total lumber imports (Figure 2-9). Both countries, especially the U.S., have lost their market share since the middle of the 1990s when Japan started to import substantial volumes of lumber from European countries, mainly from Scandinavian countries, which increased the share from merely 2% in 1993 to 37% in 2012. Over the same period, the proportion of lumber import from Canada and the U.S. has dropped from 52% to 35% and 22% to 6% respectively. After the U.S. lost its share in Japanese lumber market, Russia has been the third largest supplier of lumber to Japan, with the proportion of imports over 10% since 2004.

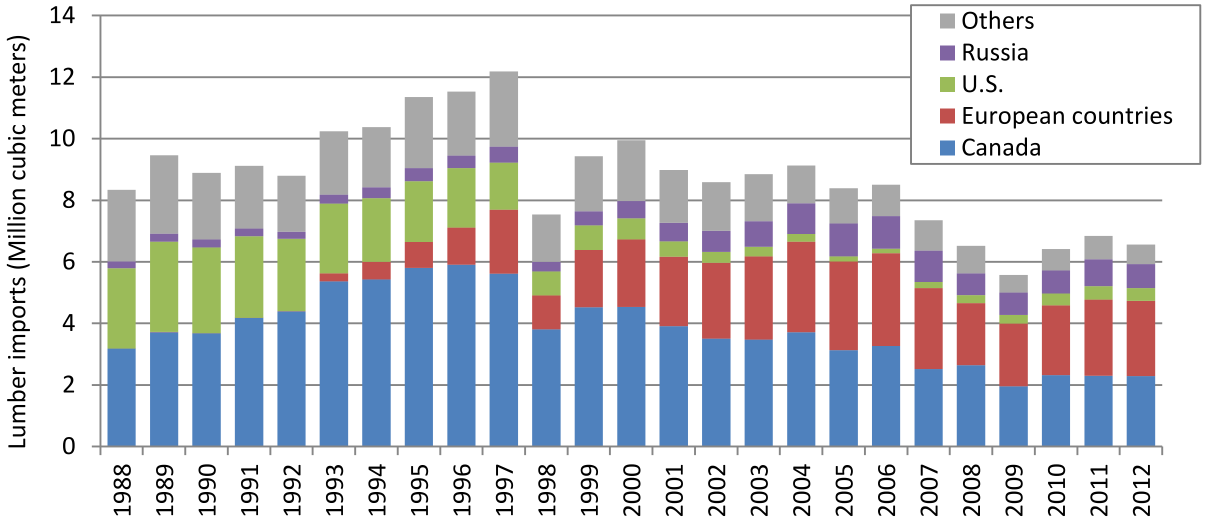

Figure 2-9. Japan's imports of lumber (HS 4407), by source country.
Source: MOF, 2012

Change in source countries of lumber has affected the species composition of lumber imports. The share of Douglas-fir and hemlock lumbers, which have been sourced from the U.S. and Canada and were the major lumber species imported to Japan before the 1990s, decreased over the years, whereas the volume of fir, spruce, and pine has increased as the share of European lumber has increased (Figure 2-10).

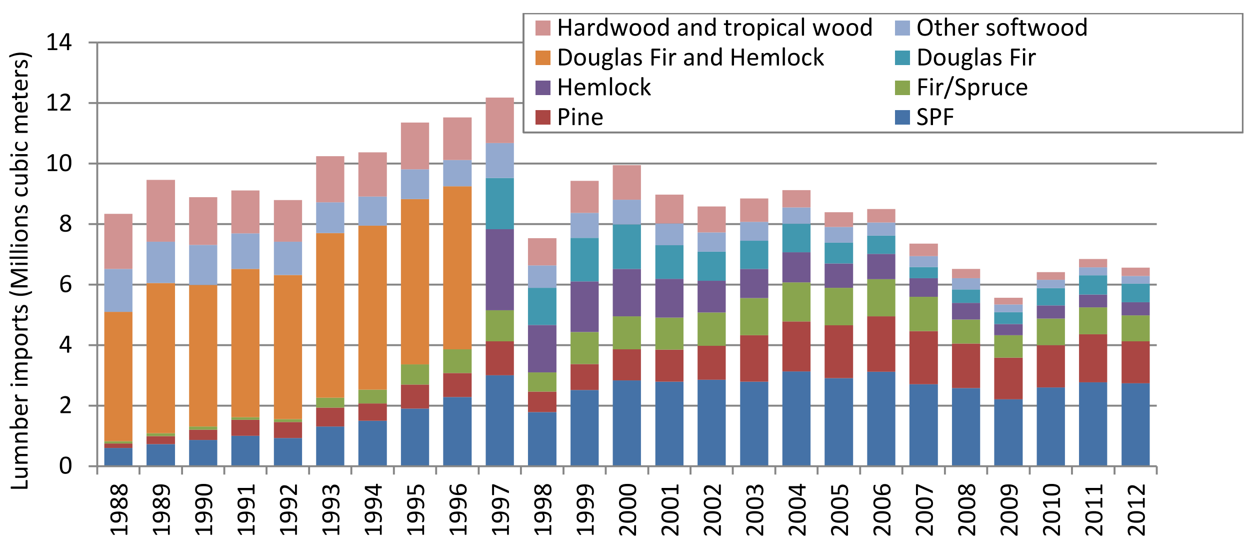

Figure 2-10. Japan's imports of lumber (HS 4407), by species.
Source: MOF, 2012

Competition between Domestic Wood and Imported Wood

Although competitive relationship between domestic and imported wood at species level is not directly observable, wood use in several sectors gives us a hint on how they are competing in practical uses.

Domestic and imported softwood logs are mainly consumed in lumber mills. The volume of log consumption by Japanese sawmills indicates that there had been more imported logs used than domestic logs from 1970 through 2000. Less imported logs and more domestic logs have been used in sawmills since 2002 (Figure 2-11). The reliance on domestic logs by sawmills have been enhanced as log imports have experienced a steady decline. Since 2009, the proportion of imported wood on a total log consumption by sawmills have been less than one third, indicating that most domestic sawmills in Japan have switched their raw materials inputs to domestic logs.

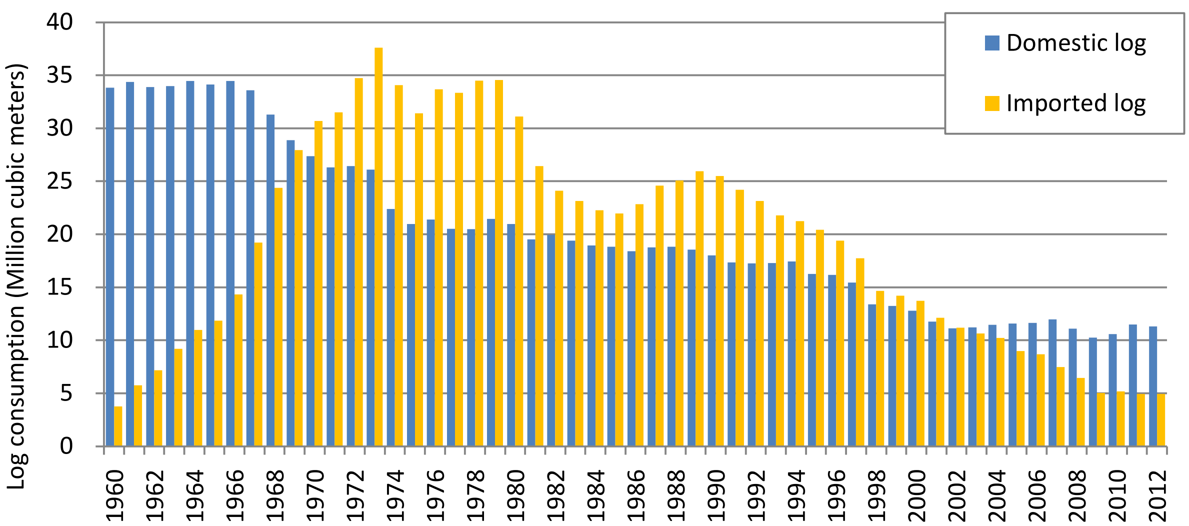

Figure 2-11. Volume of logs consumed by sawmills in Japan, by origin.
Source: MAFF, 2007-2012

For lumber, housing is estimated to be its largest demand sector in Japan, with approximately 80% of the lumber used in housing construction. In 2005, MAFF estimated the proportion of domestic wood use in traditional wooden housing (Table 2-1). The estimation indicated that the ratio of domestic wood use in post and beam houses was 31%. By parts, the ratio of domestic wood use was especially low in beams, whereas more than half of posts used domestic wood.

Table 2-1. Estimated ratio of domestic wood use in post and beam houses.

	Ratio		Total wood use (million m^3: in log-equivalent volume)
	Domestic wood	Imported wood	
Posts	54%	46%	3.7
Sills	28%	72%	1.6
Beams	5%	95%	6.5
Non-structural lumber	36%	64%	9.6
Fixtures & Trims	56%	44%	1.6
Total	31%	68%	23.0

Source: MAFF, 2007

Recent Japanese Forestry Policy

Except for the period of high economic growth when the government promoted wood imports to meet increasing wood demand, the Japanese government has focused exclusively on growing its domestic forestry and wood processing industries through a myriad of subsidy programs and regulatory frameworks including tax advantages and financial supports (Eastin et al., 2002). Despite the enormous support by the governmental budget, the domestic forestry had been plagued by inefficiency due to several structural problems, including a large proportion of its plantation forest resources as immature, a large number of small-scale forest owners, an undeveloped forest road network, and an increasing wage of workers. The combination of these problems has increased the production costs for domestic wood, making domestic wood less competitive against cheaper imported wood products (MAFF, 2010). Replaced by imported wood, domestic wood suffered continuous price decline, leading to further aggravation of the profitability of the domestic forestry.

It is against this background that the Forestry Basic Act was amended to the Forest and Forestry Basic Act in 2001, which introduced the new concept of multifunctional roles of forests. These functions included water conservation and carbon storage, as well as wood production on which the old act focused primarily. Under the concepts of promoting and sustaining multifunctional roles of forests, further efforts were put forth by the government to promote thinning operations in plantation forests, where owners were reluctant to conduct any forest management activities due to ever-decreasing domestic wood prices. Thus, the level of forest maintenance activities remained relatively high even in disadvantaged areas where profitability was expected to be negative (MAFF, 2010). In the meantime, MAFF started working on promoting internationally competitive large-scale sawmills promoting the use of local woods in these regional sawmills through several subsidy programs named the “New Distribution System” and the “New Production System.” Although the results of the programs were partly successful, the effect on increasing demand for domestic wood was limited (MAFF, 2011a).

The years since 2009 have seen several significant changes and reforms in governmental policy regarding the forestry and wood processing industries in Japan. In the general election of August 2009, the Democratic Party of Japan (DPJ) won the majority of seats in the lower house of the Diet, leading to a change in government from the Liberal Democratic Party (LDP) government which had been in power since 1955. One of the biggest issues the new DPJ government had to tackle was the economy recovery of the country. The country had been suffering from a sluggish economy for the past two decades and a high unemployment rate of over 5% after the 2008 global financial crisis. Thus, in October 2009, the DPJ government, which received wide support from labor unions in the election, developed the "Urgent Employment Measures," in which much emphasis was put on creating jobs in "the green industry". Forestry was regarded as one of the prospective sectors.

In response to this, MAFF developed the "Forest and Forestry Revitalization Plan" in December 2009, as a comprehensive strategy to revitalize the domestic forestry and wood processing industry over the next 10 years. The Revitalization Plan described its purpose as "to convert Japan's society from a "concrete society" into a "wood society" which would fully utilize the forest resource to contribute to employment and a better environment," and set the goal of achieving a 50% self-sufficiency rate in 10 years. It appeared that the Revitalization Plan was created on the basis of the "Forest and Rural Areas Revitalization Plan" which DPJ developed two years prior to the 2009 election, given the fact that the latter plan also set a goal of increasing self-sufficiency over 50% in 10 years and shared several similar measures to achieve the goal.

The major components of the Revitalization Plan include: 1) reforming the forest planning system, 2) developing a system to ensure sustainable forest management, 3) accelerating the development of the forest road networks, 4) developing and training forest management contractors, 5) developing an efficient processing/distribution system for domestic wood products, 6) expanding the domestic demand for wood products and biomass, and 7) developing and training forestry technicians and coordinators.

In March 2010, MAFF set up several study groups comprised of people from academia, industry, and the government in order to better implement each component of the Revitalization Plan. After discussing the detailed measures for eight months, the study groups prepared a final report on the direction of reform in November 2010, pointing out that "past policies on forest and forestry have focused primarily on establishment of forest resources, and (the government has) provided subsidies on wide range of forest management activities, such as thinning, without having concrete visions for sustainable forest management and frameworks necessary for the implementation of the visions," and, in order to achieve the self-sufficiency of 50% in 10 years, the "following measures should be implemented: 1) establishing a proper system to ensure proper forest management, 2) establishing low-cost operation systems nationwide, 3) developing forest management contractors and forestry technicians 4) streamlining processing and distribution systems of domestic wood and expanding the use of domestic wood" (MAFF, 2010).

In response to the final report, MAFF revised the Forest Act in April 2011 in order to introduce the new Forest Management Plan system to promote coordination and consolidation of forestry practices among groups of small forest owners, introduced a new subsidy program named "Forest Management and Environmental Conservation Direct Support System" by which costs of forest management, such as thinning, and forest road construction are substantially supported, and developed the new "Forest and Forestry Basic Plan" in July 2011 so that the targeted domestic wood supply comprise 50% of expected total wood demand in 2020 (Table 2-2). Additionally, a number of governmental subsidy programs were implemented in the wood processing sector since 2011 in order to realize the Revitalization Plan.

Table 2-2. Goal of domestic wood supply and outlook for total wood demand.

(Unit: million cubic meters)

	Domestic Wood Supply			**Total Wood Demand**		
	2009	**2015**	**2020**	**2009**	**2015**	**2020**
Lumber use	11	14	19	26	27	30
Pulp and Chip use	5	9	15	29	36	37
Plywood use	2	4	5	8	8	9
Others	1	1	1	2	2	2
Total	**18**	**28**	**39**	**65**	**72**	**78**
Self-sufficiency		**-**		**28%**	**39%**	**50%**

Source: MAFF, 2011b

It should be noted that, based on the minutes of the study groups issued by MAFF (2010-2011), the study groups focused much of the discussion on how to increase the supply of domestic wood and to utilize them in domestic mills, and paid little attention to the competitive relationship between domestic and imported wood. It seemed throughout the whole discussion that domestic and imported wood were presumed to be substitutes and any increase in domestic wood supply would inevitably replace the demand for imported wood. In spite of the substantial potential impacts on Japan's wood import as well as on source countries the Revitalization Plan might have, any analysis on these issue have not been officially conducted. In addition, while such potential impacts of the policy on trade activities could be analyzed with trade models, the assumption behind the models that the domestic and imported wood are perfectly substitutes has not yet examined as well.

3. Study Hypothesis

In this study, it is hypothesized that the domestic and imported wood markets are integrated in Japan. If both woods compete in a single Japanese market, then the law of one price, the necessary condition for substitution between imported and domestic wood to occur, must hold.

In the following section, a cointegration model was employed to test the integration of markets. After discussing the results and the implications of the tests, an analysis of Japan's forestry policy measures on the effect on the Japanese wood market was made.

4. Literature Review

A number of previous studies have examined market integration of forest products in North America and Europe. The concept of market integration was already discussed in the previous section. Many studies used cointegration analysis to test for market integration and whether the LOP holds in a variety of wood products markets.

U.S. and Canada

In the U.S. and Canada, cointegration analysis has been used to examine markets for softwood lumber (Jung and Doroodian, 1994; Murray and Wear, 1998; Nanang, 2000; Yin and Baek, 2005), timber (Nagubadi et al., 2001; Yin et al., 2002), log and lumber (Stevens and Brook, 2003; Yin and Xu, 2003), stumpage (Prestemon and Holmes 2000, Daniel 2011), and pulp and paper (Buongiorno and Uusivuori, 1992; Alavalapati et al., 1997). These studies generally examined the extent of integration in regional wood product markets in the U.S. and Canada and discussed the appropriateness of assuming spatial equilibrium in modeling markets and international trade of wood products. The results are mixed; some studies confirmed the LOP held nationwide and concluded there existed a single national market for the product, whereas others found regional markets were not integrated but instead there existed several segmented markets within the country.

Some other studies have focused on the existence of the LOP with respect to the softwood lumber trade dispute between the U.S. and Canada. Shahi et al. (2006) found the LOP did not existed in the combination of the U.S. and Canadian regional SPF markets but some of the regional markets of homogeneous products were cointegrated. On the other hand, Baek (2006) found that the North American softwood lumber markets were integrated, with the U.S. price significantly affecting Canadian lumber prices. Shook et al. (2009) also confirmed a cointegrating relationship among the price of North American softwood lumber species, but failed to conclude that those species were perfect substitutes based on their finding that the cointegration among the price series was likely to be caused by common demand-side factors, such as construction activity.

Europe

Cointegration analysis has also been applied extensively to study market integration of wood products in European countries. Studies on market integration in Europe are well summarized by Toppinen and Kuuluvainen (2010). As they pointed out, there have been a number of studies, especially in Scandinavian countries, on integration of regional log markets (e.g. Rii, 1996; Thorsen, 1998; Toppinen and Toivoinen, 1998; Toivonen et al., 2002; Mutanen and Toppinen, 2007). There studies generally indicated that prices of log markets were cointegrated and that markets in northern Europe roughly form single market.

Cointegration tests have also been used to analyze the markets of other wood products, such as imported softwood lumber (Hanninen, 1998; Mutanen, 2006) and newsprint (Hanninen et al., 1997), as well as the inter-market relationships between domestic, imported, and exported products of the same commodity (Nyrud, 2002; Stordal and Nyrud, 2003). The results of these studies were mixed and dependent on the region studied: for example, while Mutanen (2006) found that the German sawnwood import market was well integrated, Hanninen (1998) concluded that violation of the LOP among softwood lumber imported to the United Kingdom suggested imperfect competition models should be used in explaining and forecasting UK imports.

Japan

To date, little work has been done on the integration of wood product markets in Japan. Yukutake et al. (2008) studied the existence of the law of one price for logs and lumber of several tree species including both domestic and imported wood in Japanese market by performing cointegration tests on monthly data from 1974 to 2001. They found through their analysis that some of the price series were cointegrated and markets of *sugi* and hemlock could be regarded as integrated, whereas *hinoki* connected to none of the other markets.

5. Method

Theoretical Framework

Following other studies, market integration has been tested using cointegration analysis in this study. Several methods have been established to conduct the cointegration test. The most widely used techniques include the Engle-Granger residual-based test (Engle and Granger, 1987) and the Johansen's maximum-likelihood-based test (Johansen, 1995). According to the cointegration theory, a ($N \times 1$) vector time series,

$\boldsymbol{x_t}$, is said to be cointegrated if each of the elements of $\boldsymbol{x_t}$ is nonstationary with a unit root, or $I(1)$, individually, but that some linear combination of the series, $\boldsymbol{a'x_t}$, is stationary, or $I(0)$, for some nonzero ($N \times 1$) vector $\boldsymbol{a}$ (Engle and Granger, 1987). Consequently a test of the null hypothesis that $z_t = \boldsymbol{a'x_t}$ is (I) is equivalent to a test of null hypothesis that $\boldsymbol{x_t}$ is not cointegrated for a specific value $\boldsymbol{a}$**.** If the null hypothesis is rejected, it is concluded that z_t is stationary, or that $\boldsymbol{x_t}$, is cointegrated.

In the context of this study, cointegration implies that while the price series of various softwood sawlog[1] and lumber species, $\boldsymbol{x_t}$, may behave like random walks, over the long run they tend to drift in similar fashion, causing a linear combination of them, $\boldsymbol{a'x_t}$, to reduce to a stationary process.

In the next two sections, methods to examine the cointegrating relationship between price series are described. Firstly, the time-series properties of the data are scrutinized by using unit root tests in order to find the nonstationarity in each price series. Once nonstationarity of price series is confirmed by the unit root test, then the Johansen's multivariate cointegration test is implemented in order to find cointegrating relationships among several nonstationary price series.

Testing for Stationarity in the Individual Price Series

The cointegration method presupposes that the series to be tested are nonstationary unit root processes: a price series is stationary when the mean, variance, and covariance of the series are constant over time and nonstationary when they are not. Hence a unit root test must be conducted prior to a cointegration estimation to determine whether each price series is stationary or nonstationary. If a price series is stationary, it should be excluded from the cointegration estimation. Many unit root tests have been suggested to test stationarity properties. In this study, the Dickey-Fuller unit test is employed (Dickey and Fuller, 1979).

Consider the first-order autoregressive process, or AR(1).

$$p_t = \mu + \rho p_{t-1} + \varepsilon_t$$

where μ and ρ are parameters; p_{t-1} is the first lag of variable p_t, and ε_t is the residual. p_t is a stationary series if $|\rho| < 1$; a shock to the series would eventually result in a convergence back to a steady state. When $\rho = 1$, p_t is considered to be random walk with drift μ; any shock to the series will have permanent effects and the variance increases with time. The null hypothesis H_0: $\rho = 1$ is tested against the one-sided

[1] Sawlog is referred here as logs used for lumber production

alternative Ha: ρ < 1. The test is carried out by estimating an equation with p_{t-1} subtracted from both sides of the equation:

$$p_t - p_{t-1} = \mu + (\rho - 1)p_{t-1} + \varepsilon_t$$

$$\Delta p_t = \mu + \gamma p_{t-1} + \varepsilon_t$$

where $\gamma = \rho - 1$. The null and alternative may be written as H_0: γ = 0 and Ha: | γ | < 0. The test statistics is the ratio of γ to its standard error. The test is conducted under the null hypothesis of a unit root. If the calculated ratio is significantly different from zero, then the hull hypothesis is rejected. The critical values calculated by Dickey and Fuller are used to determine the significance of γ.

There are two important considerations when testing for a unit root. One thing is whether to include a constant term, a constant and a time trend, or neither in the test equation. Including irrelevant regressor reduces the power of the test to reject the null hypothesis of a unit root. Another aspect is the choice of lag length to eliminate the possible correlation in the error terms. In order to consider these two aspects, unit root tests are conducted using the augmented Dickey-Fuller (ADF) unit root test, which allows for adding correlation at higher order.

The ADF test is conducted by adding lagged difference terms of the dependent variable to the right-hand side of the test regression:

$$\Delta p_t = \mu + \gamma p_{t-1} + \sum_{i=1}^{m} \delta_i \, \Delta p_{t-i} + \Phi D_t + \varepsilon_t$$

where μ is a constant, Φ the coefficient on a time trend D_t, *m* the number of lags required to remove correlation in the error terms (lag order), Δp_{t-i} the first-difference operator, and ε_t a stationary error term. The null hypothesis is the same as that for the DF test. Limit distributions of the estimated parameters are similar to those for the DF test. The number of lags to include in the equation is determined using the Akaike information criterion (AIC) with a maximum lag length of 12 months.

Johansen's Multivariate Cointegration test

Once nonstationarity of series is confirmed by the ADF test, Johansen's multivariate cointegration test is implemented in order to test the market integration. Although the Engle-Granger (1987) cointegration test has been used for cointegration analysis in many early works, it has been criticized on the grounds that it is a two-step process, and the cointegration is confined to pairwise comparisons which require that one of the two variables be designated as exogenous (Nagubadi st al., 2001). Also the use of the cointegration method of Engle-Granger for testing the LOP using pairwise comparisons may suffer from simultaneous equation bias if more than two price series are modeled, since the prices are determined simultaneously under the assumption of the LOP. Moreover, the number of cointegration vectors may be more than one but it is not possible to determine more than one vector in the Engle-Granger method (Nanang, 2000).

In contrast to the Engle-Granger test, Johansen's maximum likelihood procedure for cointegration tests identifies cointegrating relationships in a multivariate system. This procedure does not require that one of the variables be designated as exogenous in a pairwise testing. In Johansen's methodology for the multivariate cointegration test, the basic statistical model is an unrestricted *p*-dimensional vector autoregressive (VAR) model of lag order *k*, as given:

$$y_t = A_1 y_{t-1} + \cdots + A_k y_{t-k} + \mu \ + \ \Phi d_t + \varepsilon_t$$

Where y_t is a $(p \times 1)$ vector that denotes the tth observation on a set of p variables in levels, μ is a $(p \times 1)$ vector of intercept terms, $\Pi_1, \ldots, \Pi_k$ are $(p \times p)$ matrices of parameters, d_t represents a matrix of non-stochastic variables like seasonal dummies, Φ is a $(p \times 1)$ vector of coefficients for the non-stochastic variables and ε_t is a $(p \times 1)$vector of normally, independently and identically distributed (NIID) disturbance terms with zero mean and variance-covariance matrix, $\varepsilon_t \varepsilon_t' = \Omega$. The k-th order VAR in levels in the above equation can be reparametarized and reformulated (Johansen 1995) as an error correction form as follows:

$$\Delta y_t = \mu \ + \Pi y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \, \Delta y_{t-i} + \Phi d_t + \varepsilon_t$$

where $\Pi = \sum_{i=1}^{k} \mathrm{A}_i - I$, $\Gamma_i = -\sum_{j=i+1}^{k} \mathrm{A}_j$, Δ is the first difference operator, Δy_t is a $(p \times 1)$ vector of variables integrated of zero order, i.e., *I*(0), in the system, Π and Γ_i are coefficient matrices, and the other symbols are the same as defined in the previous equation. The Γ_i describes the short run dynamics of the system and Π is the matrix of the long-run coefficients. The rank of the long-run matrix, $\Pi = \alpha\beta'$, determines the number of cointegrating vectors in the system. The information about the long-run dynamics of the system is embedded in the matrix beta, and the short-run effects of disequilibria are measured by the matrix α. The columns of the matrix β are the cointegration vectors representing the stationary linear combination of variables y_t. The respective columns of matrix α give the weights with which the error correction terms enter each equation, indicating the speed of adjustment to equilibrium. The lag lengths (k) in VAR models were determined by the Schwarz information criterion (SIC).

The likelihood ratio test devised by Johansen (1988) measures the number of cointegration vectors in the data. This test, also called a trace test, is used to test the rank of the cointegrating matrix, and is given by,

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}_i)$$

where *T* is the number of observations, $\hat{\lambda}_i$ are the estimated eigenvalues obtained from the estimated Π matrix, and *r* is the rank indicating the number of cointegration vectors. The rank, r, of matrix Π determines the number of cointegration vectors in the system of variables. The number of cointegration vectors can be thought of as representing that an economic system imposes on the movement of the variables in the VAR model in the long-run (Dickey et al., 1991).

If there are *p* variables in the system, full market integration requires a rank of *p-1* (Goodwin and Grennes, 1994). If the rank matrix Π is less than *p-1*, the hypothesis of full market integration is rejected, In this case, the degree of market integration is said to be lower and the law of one price does not hold in all *p* variables simultaneously.

6. Data Description and Preliminary Analysis

The data for the study consisted of monthly prices of sawlog and lumber for domestic and imported wood for the period of January1985 to December 2012. The price information for these items was obtained from the Wood Supply and Demand Report for 1985-2010 and Timber Price Survey for 2011-2012, both issued by MAFF[2], except for the prices for European whitewood glue-lam which was obtained from the *Nikkan Mokuzai Shinbun* (Japan Forest Product Journal)[3].

Domestic wood was defined here as grown and harvested in Japan, while imported wood as grown and harvested overseas and imported to Japan as sawlog or lumber. Lumber domestically processed from

---

[2] In the MAFF's statistics, sawlog price is the delivered price at sawmills and lumber price is the wholesale price. Price for sawlogs were originally collected from sawmills in several selected prefectures in which about 80% of the nation's total consumption of logs are consumed. Prices of lumber were originally collected from privately and cooperatively managed wood markets and wood wholesalers in 10 prefectures which have a large distribution volume of lumber within the prefectures. Both price series are aggregated at the prefectural level by taking the simple average of the prices in the prefecture, and then again aggregated to represent the price at national level by taking the weighted average of prefectural prices based on the prefecture's share of wood for each wood product in a particular base year. In the case of the Wood Supply and Demand Report between 2006 and 2010, for example, 2005 was chosen as the base year.

[3] Unlike other price series in the MAFF statistics, prices for whitewood glulam from the *Nikkan Mokuzai Shinbun* were not aggregated spatially but represent a single market in the Tokyo area.

imported sawlog was also categorized as imported wood. Since single price data representing each item, such as aggregate domestic lumber price or aggregate imported sawlog price, were not available in the MAFF's statistics, price series at the tree species level by origin were used for the following analysis.

Items included in the analysis were basically identified on the basis of the domestic consumption level over the study period, but the availability of data in the MAFF's statistics database confined the item selection. For sawlog price series, *sugi* (Japanese cedar), *hinoki* (Japanese cypress), and Japanese larch were chosen as domestic wood species, while Douglas-fir, hemlock (both from North America), Russian larch, Russian Yezo spruce (both from Russia) as imported wood species.

For lumber price series, *sugi* and *hinoki* were chosen as domestic species, and Douglas-fir, hemlock, and Russian Yezo spruce as imported species. In addition to these items, price series for kiln-dried (KD) lumber of *sugi* and *hinoki* as well as European whitewood glulam were included in the lumber price analysis for the time period of January 1998 to December 2012.

Properties for each item are summarized in Table 6-1. It should be noted that price series of logs and lumbers of Douglas-fir and Hemlock are categorized as originating from North America, meaning that they are from either the U.S. or Canada, and there is no distinction from which country those wood come from in the MAFF's statistics database. All price series includes the consumption tax and are reported in Japanese yen per cubic meters[4]. The following analysis was carried out using the price series in logarithm transformation.

Issue on Structural Change in the Data

Structural change is an important issue in time-series analysis and affects all the inferential procedures associated with unit roots and cointegration tests (Maddala and Kim, 1998). If there is a break in the deterministic trend, then unit root tests could lead to a false conclusion that there is a unit root, when in fact there is not (Perron, 1989). Thus existence of structural change should be considered in testing stationarity as well as cointegration of time series data.

In this study, effect of a potential structural change on the conclusion on market integration was examined by dividing price data at a certain time point. Potential structural changes were determined by looking at the shape of price charts and examining corresponding historical events. For sawlog price series, North

[4] Price series for European whitewood was originally recorded per piece. For convenience, they were converted to price per cubic meter by multiplying by a coefficient of 30.234.

American sawlogs (Douglas-fir and hemlock) were suspected to have experienced a structural change around 1992, which correspond with the federal timber harvest reductions in the Pacific Northwest in the U.S. This structural change could be supported by the study by Baek (2006) in which he found that price series of the U.S. and Canadian lumber experienced structural shifts in 1992 due to the restriction on federal timber harvests.

For lumber price series, almost all price series seemed to have experienced a structural change between 1997 and 1998, which could correspond with the huge drop in domestic housing starts in 1997 in Japan against the backdrop of economic downturn possibly caused by the Asian financial crisis as well as the introduction of the higher consumption tax rate (from 3% to 5%) in Japan. This period is also the time when European whitewood began to record increasing imports to Japan and to replace North American lumber in Japanese wood market.

Given these historical facts and derived assumptions, price data for both sawlog and lumber were divided into two periods according to the breakpoint estimated above. Since the interests on the competitive relationship between domestic and imported wood in this study are of recent one, rather than the one in the former period, price series for the period after 1992 for sawlog and the one after 1998 for lumber were analyzed, in addition to the data for the entire period of 1985 to 2012 for both sawlog and lumber[5].

[5] Although there was a huge change in Japan's import of Russian wood after 2007, when Russia introduced higher export tax on roundwood, the potential break caused by this event was not considered in this study. This is because sample size for the period of analysis, 2007 through 2012, was considered too small to be tested statistically.

Table 6-1. Data description for sawlog and lumber price series.

Sawlog

Origin and Species	**Grade**	**Dimension (Height× Width × Length)**	**Abbr.**	**Sampling period**
North America				
Douglas-fir	#3	30- cm × 6.0- m	S_DF	1985.1 – 2012.12
Hemlock	#3	30- cm × 6.0- m	S_HEM	1985.1 – 2012.12
Domestic				
Japanese cypress	Mix	14-22 cm × 3.65-4.0 m	S_JC	1985.1 – 2012.12
Japanese larch	Mix	14-28 cm × 3.65-4.0 m	S_JL	1985.1 – 2012.12
Japanese red cedar	Mix	14-22 cm × 3.65-4.0 m	S_JRC	1985.1 – 2012.12
Russia				
Russian larch*	Mix / for plywood	20- cm × 4.0- m / 20-28 cm × 3.8- m	S_RL	1985.1 – 2012.12
Russian Yezo spruce	Mix	20-28 cm × 3.8- m	S_RYS	1985.1 – 2012.12

Lumber

Origin and Species	**Grade**	**Dimension (Height× Width × Length)**	**Abbr.**	**Sample period**
North America				
Douglas-fir	2nd	Hirakaku, 10.5-12 cm × 24.0 cm × 3.65-4.0 m	L_DF	1985.1 – 2012.12
Hemlock*	2nd	Square, 10.5 cm × 10.5 cm × 3.0 m	L_HEM	1985.1 – 2012.12
Domestic				
Japanese cypress	2nd	Square, 10.5 cm × 10.5 cm × 3.0 m	L_JC	1985.1 – 2012.12
Japanese cypress (KD)	2nd	Square, 10.5 cm × 10.5 cm × 3.0 m	L_JCKD	1998.1 – 2012.12
Japanese red cedar	2nd	Square, 10.5 cm × 10.5 cm × 3.0 m	L_JRC	1985.1 – 2012.12
Japanese red cedar (KD)	2nd	Square, 10.5 cm × 10.5 cm × 3.0 m	L_JRCKD	1998.1 – 2012.12
Russia				
Russian Yezo spruce	1st	Board, 1.3-1.5 cm × 15.0 cm × 3.65-4.0 m	L_RYS	1985.1 – 2012.12
Europe				
Whitewood glulam	1st	Square, 10.5 cm × 10.5 cm × 3.0 m	L_WW	1998.1 – 2012.12

Source: MAFF, 2007-2011

*Note that, because of the data availability, price series of Russian larch sawlog is a combination of price data of Russian larch log for lumber production from 1985 to 2001 and that of Russian larch log for plywood production after 2002. Price series of hemlock lumber is also a combination of price series of hemlock square lumber from 1985 to 2006 and that of treated hemlock square lumber (the same dimension) multiplied by 0.87 (for adjustment) after 2007.

Price series of sawlog and lumber by tree species for the period of analysis are presented in Figure 6-1 and 6-2 respectively. These figures illustrate relatively different pattern of movement between price series of domestic wood species and those of imported wood species: price of domestic wood species, especially Japanese cypress, have declined over time, whereas imported wood species tend to fluctuate in a certain price range. Nevertheless, several simultaneous responses among price series, such as the one in 1987 and in 1996, indicate that linkages among price series may exist.

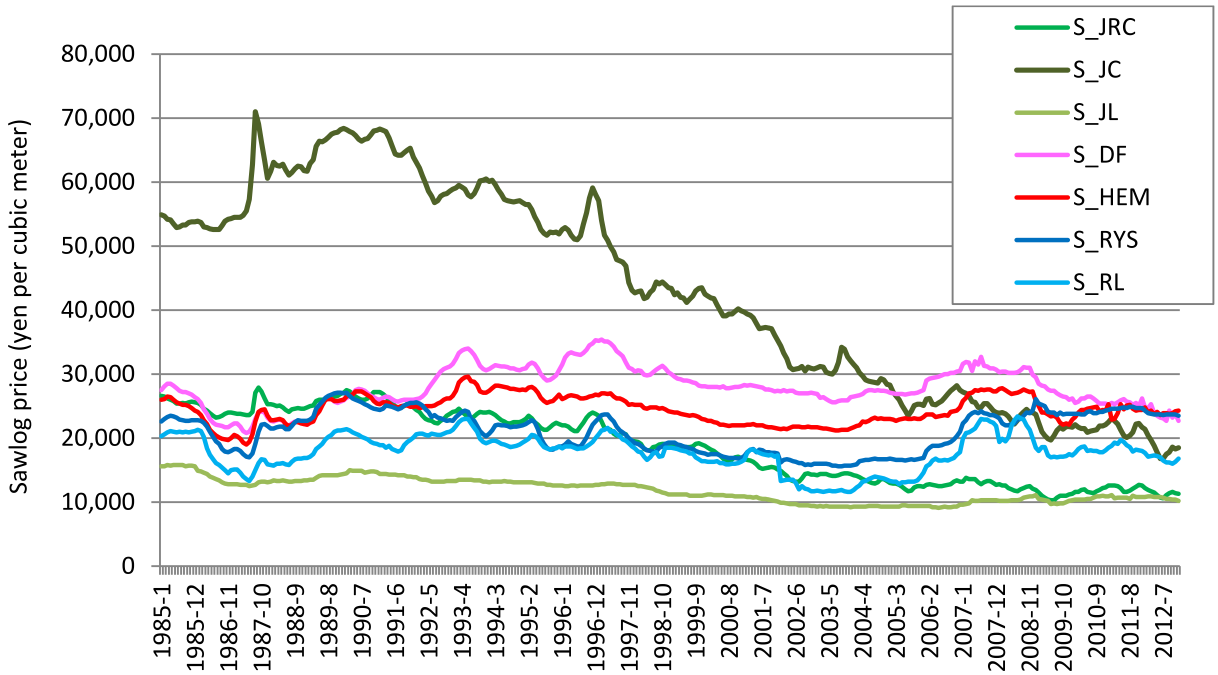

Figure 6-1. Sawlog prices in Japanese market, Jan. 1985 through Dec. 2012.
Source: MAFF, 1985-2012

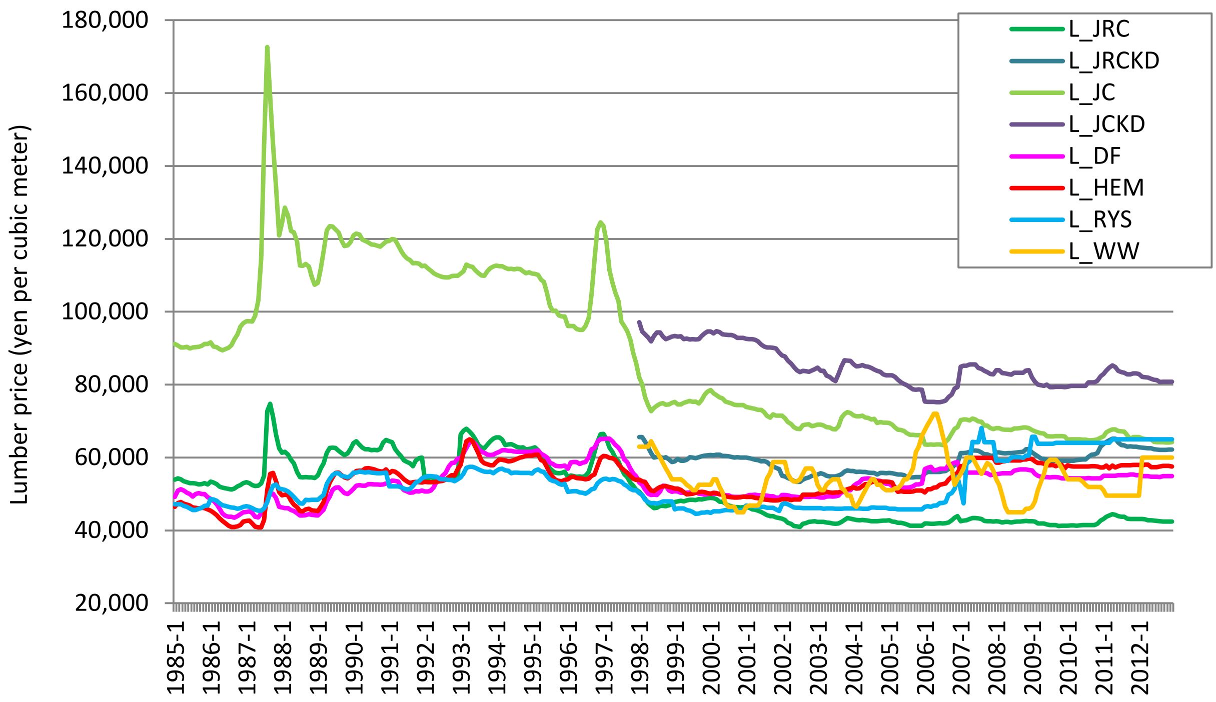

Figure 6-2. Lumber prices in Japanese market, Jan. 1985 through Dec. 2012
Source: MAFF, 1985-2012

Correlations

Correlation coefficients for products to be analyzed provide an index measure of market integration. Correlation coefficient values near 1.0 suggest that products are in the same market, whereas values near zero suggest products are in different markets, if price series of the products are stationary. Pearson's correlation coefficients for the price series for sawlog and lumber over time are calculated as a measure of interdependence, and reported in Table 6-2 through 6-5.

For sawlog prices for the entire period of 1985 to 2012 (Table 6-2), pairs of three domestic species showed strong correlation relationship with values higher than 0.8, suggesting that these domestic sawlog species could be in a same market. Pairs of imported sawlog prices of the same origin, sawlog prices from North America (Douglas-fir and hemlock) and those from Russia (Russian larch and Russian Yezo spruce), also showed relatively higher correlation values of 0.69 and 0.78, respectively, suggesting again that imported sawlog species of the same origin are more likely to be in a same market. The results on pairs of sawlog prices of different origin were more variable. Pairs of domestic and imported sawlog prices generally showed less or no correlation relationship, suggesting that those wood species could have different markets, except for pairs of Japanese larch and two Russian species with values above 0.5, whereas pairs of hemlock and Russian species had relatively high correlation.

A similar trend was observed for the recent subsample from 1992 to 2012 (Table 6-3), along with the fact that some additional pairs exhibited moderately higher correlation values, including price pairs of Doulas-fir and all the domestic species, Douglas-fir and Russian larch, and hemlock and Japanese larch.

Table 6-2. Correlation matrix of sawlog price, Jan. 1985 to Dec. 2012.

Correlation	S_DF	S_HEM	S_JC	S_JL	S_JRC	S_RL	S_RYS
S_DF	1.0000						
S_HEM	**0.6889**	1.0000					
S_JC	0.0289	0.1887	1.0000				
S_JL	-0.0427	0.3856	**0.8381**	1.0000			
S_JRC	-0.0125	0.2248	**0.9843**	**0.9015**	1.0000		
S_RL	0.4508	**0.7888**	0.2766	**0.5769**	0.3422	1.0000	
S_RYS	0.0099	**0.6088**	0.1291	**0.5239**	0.2142	**0.7796**	1.0000

Note that correlation values greater than 0.5 are bold for emphasis.

Table 6-3. Correlation matrix of sawlog price, Jan. 1992 to Dec. 2012.

Correlation	S_DF	S_HEM	S_JC	S_JL	S_JRC	S_RL	S_RYS
S_DF	1.0000						
S_HEM	**0.6915**	1.0000					
S_JC	**0.6537**	0.3713	1.0000				
S_JL	**0.5586**	**0.6806**	**0.7783**	1.0000			
S_JRC	**0.6579**	0.4630	**0.9849**	**0.8474**	1.0000		
S_RL	**0.5697**	**0.8171**	0.2856	**0.6721**	0.3729	1.0000	
S_RYS	0.1292	**0.6478**	-0.1386	0.4169	-0.0308	**0.7847**	1.0000

Note that correlation values greater than 0.5 are bold for emphasis.

For lumber prices for the entire period (Table 6-4), correlation relationships was generally similar with those observed for sawlog prices. Higher correlation values were observed among pairs of lumber prices of the same origin and less correlation among price pairs of domestic and imported lumber. The highest correlation existed between *hinoki* and *sugi* prices with correlation value of 0.96, followed by the price pair of Douglas-fir and hemlock with 0.86. These results suggested that *sugi* and *hinoki* as well as Douglas-fir and hemlock are most likely in a same market, respectively.

The recent subsample of lumber price data for 1998 to 2012 (Table 6-5), which included three additional items of kiln-dried *hinoki* lumber, kiln-dried *sugi* lumber, and European whitewood glulam, showed an interesting result. North American and Russian lumbers had relatively higher negative correlation with domestic species, except for kiln-dried (KD) *sugi* which had no correlation with other domestic lumber prices but moderate correlation with imported lumber prices. It was notable that the price for European whitewood glulam showed no correlation with any other prices included in the subsample, suggesting that whitewood might have a distinct market from other lumber products.

Table 6-4. Correlation matrix of lumber price, Jan. 1985 to Dec. 2012.

Correlation	L_DF	L_HEM	L_JC	L_JRC	L_RYSBD
L_DF	1.0000				
L_HEM	**0.8630**	1.0000			
L_JC	0.0200	0.0295	1.0000		
L_JRC	0.1612	0.1438	**0.9648**	1.0000	
L_RYSBD	**0.5145**	**0.7178**	-0.0673	-0.0185	1.0000

Note that correlation values greater than 0.5 are bold for emphasis.

Table 6-5. Correlation matrix of lumber price, Jan 1998 to Dec. 2012.

Correlation	L_DF	L_HEM	L_JC	L_JCKD	L_JRC	L_JRCKD	L_RYSBD	L_WW
L_DF	1.0000							
L_HEM	**0.8526**	1.0000						
L_JC	-0.6304	-0.5170	1.0000					
L_JCKD	-0.6621	-0.4733	**0.9398**	1.0000				
L_JRC	-0.4541	-0.3763	**0.8700**	**0.8853**	1.0000			
L_JRCKD	0.3740	**0.5935**	0.0900	0.2596	0.3844	1.0000		
L_RYSBD	**0.6929**	**0.8950**	-0.5847	-0.43700	-0.3873	**0.6468**	1.0000	
L_WW	0.1055	0.1511	0.2834	0.2395	0.2869	0.1749	-0.0571	1.0000

Note that correlation values greater than 0.5 are bold for emphasis.

7. Results

Unit Root Test

The results for the ADF test using price series of sawlog and lumber in logarithmic form for both the entire sample (1985 to 2012) and the subsample (1992 to 2012 for sawlog; 1998 to 2012 for lumber) are presented in Tables 7-1 and 7-2. Lag length and exogenous regressor in the test regression are also provided in the tables. Three specifications of the ADF test equation, including an exogenous constant, constant and trend, and neither, were examined for each price series. One specification was selected from the three possibilities based on the statistical significance of the exogenous variables in the test equation.

For sawlog price data in level form for the entire sample, the null hypothesis that a unit root exists could not be rejected for any of the variables at 5% level of significance (Table 7-1), although the test results for hemlock was very close to the significance level. Eventually, all sawlog price series tested were found to be nonstationary in levels. For the subsample data of sawlog price series in levels, almost all tree species had nonstationary data series but only *hinoki* exhibited stationarity in its data over the period of the analysis.

Table 7-1. Results of augmented Dickey-Fuller tests for the price series of sawlog in Japanese market.

	Entire sample: 1985-2012				Subsample: 1992-2012			
Species	c/t	ADF test statistics	P-value	Lags	c/t	ADF test statistics	P-value	Lags
S_DF	c	-1.961	0.304	9	c/t	-3.050	0.121	9
S_HEM	c	-2.821	0.056	7	c	-1.791	0.385	5
S_JC	c/t	-2.471	0.343	9	c/t	-4.153**	0.006	12
S_JL	-	-1.306	0.177	6	c	-1.736	0.412	7
S_JRC	c/t	-2.797	0.200	12	c/t	-2.915	0.159	12
S_RL	c	-2.667	0.089	2	c	-2.099	0.245	2
S_RYS	-	-1.838	0.362	9	c	-2.210	0.203	2

Note that asterisks denote the significant level at which the null hypothesis is rejected: * rejection at 5% level; ** rejection at 1% level. P-values are calculated based on critical values from MacKinnon (1991).

As shown in Table 7-2, unit root tests on lumber prices suggested that all the price series tested were nonstationary in levels at 5% level of significance for the period of the entire sample, but *hinoki* and European whitewood were stationary for the period of the subsample. Again it should be noted that some lumber price series, such as *sugi* in the entire sample and Douglas-fir in the subsample, were close to the significance level, suggesting that they might have properties similar to stationary price series.

Table 7-2. Results of augmented Dickey-Fuller tests for the price series of lumber in Japanese market.

	Entire sample: 1985-2012				Subsample: 1998-2012			
Species	c/t	ADF test statistics	P-value	Lags	c/t	ADF test statistics	P-value	Lags
L_DF	c	-2.272	0.182	3	c/t	-3.369	0.059	1
L_HEM	c	-2.586	0.097	5	c/t	-2.541	0.308	2
L_JC	c/t	-3.226	0.081	6	c	-2.991*	0.038	2
L_JCKD		---			c	-2.077	0.254	2
L_JRC	c/t	-3.336	0.062	1	c/t	-2.566	0.296	0
L_JRCKD		---			c	-2.095	0.247	4
L_RYSBD	-	0.928	0.906	0	c/t	-2.612	0.276	1
L_WW		---			c	-3.060*	0.032	3

Note that asterisks denote the significant level at which the null hypothesis is rejected: * rejection at 5% level; ** rejection at 1% level. P-values are calculated based on critical values from MacKinnon (1991).

The ADF tests on the first-differenced price series for all sawlog and lumber which were found to be nonstationary in levels rejected the null hypothesis of existence of unit roots at the 1% level of probability (results not shown). Thus, these price series were found to be nonstationary integrated of order one, $I(1)$, and were used for the subsequent analysis for cointegration, whereas the price series which were found to be stationary, such as price series of *hinoki* sawlog for the subsample period and those of *hinoki* and whitewood lumber for the subsample period, were not analyzed any further.

Johansen's Cointegration Test

Multivariate Cointegration Test

Cointegration tests to detect market integration were performed on the price series which were found to be $I(1)$, integrated of order one, in the unit root tests. If all the price series in each cointegration test were found to be cointegrated simultaneously, meaning that the law of one price hold among all the price series tested and that all the markets tested are fully integrated, the maximum number of cointegration vector could be found in the test result. Price series of sawlog and lumber which consisted of the cointegration tests for the entire sample and the subsample period as well as the corresponding maximum number of cointegrating vectors are presented as follows.

- Sawlog price series for the entire sample (1985-2012): price series of Douglas-fir, hemlock, *hinoki*, *sugi*, Japanese larch, Russian larch, and Russian Yezo spruce, with maximum number of cointegrating vector of 6.
- Sawlog price series for the subsample (1992-2012): price series of Douglas-fir, hemlock, *sugi*, Japanese larch, Russian larch, and Russian Yezo spruce, with maximum number of cointegrating vector of 5.
- Lumber price series for the entire sample (1985-2012): price series of Douglas-fir, hemlock, *hinoki*, *sugi*, and Russian Yezo spruce, with maximum number of cointegrating vector of 4.
- Lumber price series for the subsample (1998-2012): price series of Douglas-fir, hemlock, kiln-dried *hinoki*, *sugi*, kiln-dried *sugi*, and Russian Yezo spruce, with maximum number of cointegrating vector of 5.

Table 7-3 through 7-6 shows the results of cointegration tests. The test specification allowed for a linear deterministic trend in the data and an intercept in the cointegration equation.

For the sawlog market for both periods of the entire sample and the subsample, the null hypothesis of no cointegrating vector was not rejected at the 5% level of significance (Table 7-3 and 7-4). Thus the cointegration tests revealed that there was no cointegration vector or stationary linear combination in the sawlog market, suggesting that every price series were stochastic and moving randomly and independently regardless of the movement of other price series over both periods of the analysis.

Table 7-3. Results from Johansen's cointegration analysis for sawlog prices, Jan. 1985 to Dec. 2012.

Hypothesized No. of cointegrating vectors	Eigen value	Trace statistic	5% Critical value	P-value
$r = 0$	0.118	116.843	125.615	0.151
$r \leq 1$	0.068	74.715	95.754	0.554
$r \leq 2$	0.058	50.936	69.819	0.597
$r \leq 3$	0.045	30.793	47.856	0.678
$r \leq 4$	0.025	15.484	29.797	0.748
$r \leq 5$	0.016	7.007	15.495	0.577
$r \leq 6$	0.005	1.532	3.841	0.216

Table 7-4. Results from Johansen's cointegration analysis for sawlog prices, Jan. 1992 to Dec. 2012.

Hypothesized No. of cointegrating vectors	Eigen value	Trace statistic	5% Critical value	P-value
$r = 0$	0.117	84.458	95.754	0.232
$r \leq 1$	0.103	53.240	69.819	0.495
$r \leq 2$	0.053	25.909	47.856	0.892
$r \leq 3$	0.030	12.231	29.797	0.924
$r \leq 4$	0.017	4.619	15.495	0.848
$r \leq 5$	0.001	0.244	3.841	0.622

Result for the lumber market for the period of the entire sample also revealed that there was no cointegration relationship among the price series tested, indicating again that every price series are stochastic, each price series moving randomly independent of the other, over the period of the analysis (Table 7-5).

Table 7-5. Results from Johansen's cointegration analysis for lumber prices, Jan. 1985 to Dec. 2012.

Hypothesized No. of cointegrating vectors	Eigen value	Trace statistic	5% Critical value	P-value
$r = 0$	0.094	56.705	69.819	0.350
$r \leq 1$	0.041	23.623	47.856	0.950
$r \leq 2$	0.020	9.534	29.797	0.986
$r \leq 3$	0.006	2.714	15.495	0.978
$r \leq 4$	0.002	0.565	3.841	0.452

Contrary to the result for the entire sample, cointegration test on the subsample of lumber price series rejected the null hypothesis of no cointegrating vector against the alternative hypothesis of existence of one cointegrating vector at the 5% level of significance (Table 7-6). Although one cointegration relationship was found in the data tested, full market integration of lumber from 1998 to 2012 was not confirmed since the acceptance of full market integration requires evidence for six stationary linear combinations.

Table 7-6. Results from Johansen's cointegration analysis for lumber prices, Jan. 1998 to Dec. 2012.

Hypothesized No. of cointegrating vectors	Eigen value	Trace statistic	5% Critical value	P-value
$r = 0$	0.219	111.174*	95.754	0.003
$r \leq 1$	0.130	66.725	69.819	0.086
$r \leq 2$	0.112	41.654	47.856	0.169
$r \leq 3$	0.073	20.322	29.797	0.401
$r \leq 4$	0.033	6.739	15.495	0.608
$r \leq 5$	0.004	0.633	3.841	0.426

Note that asterisks denote the significant level at which the null hypothesis is rejected at 5% level. P-values are calculated based on critical values from MacKinnon-Haug-Michelis (1999).

Thus simultaneous multivariate cointegration tests showed that full market integration could not be accepted for any of price series samples of sawlog and lumber, but instead provided evidence that the law of one price could hold for a pair of price series of lumber for the sample period from 1998 to 2012.

Bivariate Cointegration Tests

To understand the price relationship between various pairs of price series separately, bivariate cointegration tests were also performed on the subsample of lumber prices where a cointegrating vector was found in multivariate test. This bivariate testing was conducted using the Johansen's cointegration test on pairs of price series

The results of the bivariate cointegration tests for lumber price series from 1998 to 2012 are presented in Table 7-7. One cointegrating vector was found in the pairs of Douglas-fir and hemlock, kiln-dried *hinoki*, and *sugi* respectively. The result that two cointegrating vectors were found in the pair of kiln-dried *sugi* and (non-kiln-dried) *sugi* indicated that the model was misspecified in terms of determining lag length or deterministic trend, or the price series in the model were stationary in levels, although both series were previously found to be nonstationary.

Table 7-7. Bivariate cointegration tests for lumber prices, Jan. 1998 to Dec. 2012.

			Eigenvalue	Trace statistic	5% Critical Value	P-value
L_DF	L_HEM	r = 0	0.109	22.758*	15.495	0.003
		r ≤ 1	0.011	1.911	3.841	0.167
	L_JCKD	r = 0	0.100	21.542*	15.495	0.005
		r ≤ 1	0.014	2.585	3.841	0.108
	L_JRC	r = 0	0.092	20.367*	15.495	0.009
		r ≤ 1	0.017	3.024	3.841	0.082
	L_JRCKD	r = 0	0.045	14.858	15.495	0.062
	L_RYSBD	r = 0	0.069	13.411	15.495	0.101
L_HEM	L_JCKD	r = 0	0.074	15.252	15.495	0.054
	L_JRC	r = 0	0.061	12.853	15.495	0.120
	L_JRCKD	r = 0	0.050	11.995	15.495	0.157
	L_RYSBD	r = 0	0.042	8.522	15.495	0.411
L_JCKD	L_JRC	r = 0	0.062	18.078*	15.495	0.020
		r ≤ 1	0.036	6.509*	3.841	0.011
	L_JRCKD	r = 0	0.061	12.708	15.495	0.126
	L_RYSBD	r = 0	0.037	7.456	15.495	0.525
L_JRC	L_JRCKD	r = 0	0.044	8.656	15.495	0.398
	L_RYSBD	r = 0	0.050	9.678	15.495	0.306
L_JRCKD	L_RYSBD	r = 0	0.051	9.802	15.495	0.296

As the price series of Douglas-fir and three species were cointegrated respectively, the hypothesis of the law of one price was tested. As the unconstrained constant allowing the price difference was included in the cointegration equation, this hypothesis tested was the weak version of the law of one price (Buongiorno and Uusivuori, 1992). In testing the hypothesis, restrictions were imposed on cointegrating vector β, i.e., the price coefficients in vector β to be of equal magnitude but of opposite signs ($\beta_1 = 1$ and $\beta_2 = -1$).

The test results presented in Table 7-8 indicate rejection of the null hypothesis for all pairs tested. Consequently the law of one price was rejected for all the price pairs tested.

Table 7-8. Test results for law of one price by price pairs with restriction.

Tested price pairs	H_0	LR test statistic (P-value)
L_DF and L_HEM	$\beta_{\mathrm{L\_DF}} = 1$ and $\beta_{\mathrm{L\_HEM}} = -1$	6.199* (0.0128)
L_DF and L_JCKD	$\beta_{\mathrm{L\_DF}} = 1$ and $\beta_{\mathrm{L\_JCKD}} = -1$	16.188* (0.0001)
L_DF and L_JRC	$\beta_{\mathrm{L\_DF}} = 1$ and $\beta_{\mathrm{L\_JRC}} = -1$	13.862* (0.0002)

8. Discussion

Since the hypothesis of market integration was rejected for almost all price pairs of sawlogs and lumbers in Japanese wood market, domestic and imported wood products tested for cointegration could not be considered as close substitutes for each other. This was true in spite of the length of period tested. Although three pairs of lumber prices were found to be cointegrated in the bivariate test using the subsample data, the results from the pairs of Douglas-fir and two domestic species, *hinoki* and *sugi* (KD), were doubtful given the fact that correlation values for both price pairs indicated that their correlation was negative. Eventually, only the pair of Douglas-fir lumber and hemlock lumber could be considered to be integrated for the period after 1998, although the law of one price was not confirmed to hold between these products.

The absence of market integration between domestic and imported wood, and even between different species of domestic wood, for both sawlog and lumber suggest that the products evaluated in this study could be differentiated by buyers and constitute segmented markets in Japan. This observation is further supported by the fact that specific wood species are used for specific end-use application in Japanese traditional post and beam housing construction. As indicated in the previous section, 95% of beams in post and beam houses that require high strength capacity are imported wood. Additionally, several anecdotal surveys on the precut post and beam industry in Japan support the fact that particular species of lumber are preferable for beam and sill applications where strength and humidity resistance are required respectively (e.g. Eastin et al., 2003).

Thus, the assumption that domestic and imported wood are perfectly substitutable in the analysis of any trade policy for forest products is not appropriate, and the use of models that assume perfect substitutability have limited value and may lead to results that may not be correct. It can be inferred from the study results that any change in the supply of products that are species specific, such as increase in the *sugi* log supply, is not likely to affect demand for and the price of products of other species, such as the price of Douglas-fir log, since these markets are not integrated. It is quite likely, however, that some wood species have complementary relationships given the fact that, as mentioned above, certain parts require specific physical and /or mechanical properties in post and beam housing construction. If this is the case, greater use of domestic wood could lead to an increase in the demand for imported wood. Similarly, if the demand for domestic wood is elastic enough, an increase in the supply of domestic wood could also lead to increase the demand for imported wood as well, although the converse could also be true. However, in the case where the demand for wood remains constant, it is likely that a substantial increase in the demand for domestic wood would necessarily result in a corresponding decrease in the demand for imported wood.

In the case of the existence of market differentiation among wood products in the Japanese market, one possible way to model the impact of the Revitalization Plan, or that of the increasing supply of domestic wood, on changes in the demand for domestic and imported wood as well as volume of wood products traded would be to estimate the Armington (1969) elasticity of substitution. The Armington elasticity has several features including that: 1) it is derived based on the assumption that domestic and imported goods are imperfect substitutes for each other, and 2) the model used to estimate the Armington elasticity is simple and applicable for both production and consumption (Gan, 2006). The Armington elasticity of substitution between domestic and imported wood products measures the percentage change in the ratio of quantities demanded for the foreign and domestically produced forest products for a 1% change in their relative price, reflecting the ease of substitution between the domestic and imported forest products (Gan, 2006). Earlier works on estimating the Armington elasticity for wood products include Gan (2006) who estimated the elasticities between US domestic and imported wood products and Sauquert et al. (2011) who worked on estimating the elasticities between domestic and imported wood products in France. In a similar way, it would be possible to derive the Armington elasticity of substitution between Japan's domestic and imported forest products, and thus, the impact of the Revitalization Plan could be assessed.

Limitations of the study

It is important to recognize that several limitations exist in this study that affect both the results observed in the statistical tests and the inferences derived from the results. First, the wood products analyzed in this study included only sawlogs and lumbers, whereas other wood products such as plywood and wood chips, were not included. This was because plywood products are hard to distinguish its origin since both domestic and imported wood could be used in the same product. As for chips, it was suspected that an efficient market does not exist since the largest demand sector for chips is the paper manufacturing industry which has oligopsony power in the chip market.

Next, the price series of each good used in the analysis is spatially aggregated at the national level, which could have made each price series lose some information on the market relationship of domestic and imported wood at the regional level: some wood products could be actually integrated in some regions.

The length and frequency of the price data might have also affected the test results, since the power of the cointegration test is affected by the number of data points. Although this study employed monthly data based on the notion by Shahi et al. (2006) that data for cointegration tests should be used at the same frequency at which it is being generated, data with different length and span may give different results. However, the inferences derived from quarterly or yearly data over a longer period of time was not included in the scope of this study where the more recent relationship between wood products was sought to be revealed.

Two final points are that, major imported lumber was not tested for integration since the data of European whitewood glulam exhibited stationarity and thus was inappropriate for the test for cointegration. Second, the sparse availability of data sources also limited the analysis on the relationship between domestic and imported wood, since time series data on prices of some important lumber species, such as SPF from Canada and redwood (pine) from European countries, were not available in MAFF's statistical database.

Implication for Japan's Policy Implementation

With the goal of increasing self-sufficiency the Japanese government aims to increase the domestic wood supply, but the potential results of the policy may not necessarily be beneficial for forest owners in Japan. If the supply of domestic wood was increased through lowering harvesting cost and streamlining log distribution as a result of the successful implementation of the Revitalization Plan, the prices of domestic wood would drop in a short run if enough corresponding demand for domestic wood was not generated. This is because, as the results indicated, that domestic wood is not likely to substitute for imported wood. In fact, a sudden drop in the price of domestic log caused by an increased supply was already observed in some regions of Japan at the beginning of FY 2012 when MAFF started the aforementioned new subsidy program to promote thinning of plantation forests. Hence, without any demand stimulation for domestic wood, a supply increase is likely to be associated with further price drops for domestic wood which already has experienced long-lasting price decline since the 1980s.

Several policy measures for the expansion of wood demand do exist in the context of the Revitalization Plan, although they are limited compared to the policy measures on the supply side. Those measures which could contribute to expanding the demand for domestic wood include 1) the promotion of wood use in public buildings based on the "Law Concerning the Promotion of the Use of Wood in Public Buildings" implemented in October 2010, which required central and local governments to promote wood use in public buildings, and 2) promotion of the use of wood biomass as renewable energy source under the Feed-in Tariff (FIT) Scheme for Renewable Energy that launched in 2012.

MAFF projected that 700 to 800 thousand cubic meters of wood would be used annually in public building constructions under the law, although the volume is merely equivalent to less than 10% of the expected increase in demand projected in the Revitalization Plan, which anticipated that the annual supply of domestic wood for lumber production would increase by 8 million cubic meters (from 11 million cubic meters in 2009 to 19 million cubic meters in 2020). Additionally, the wood material used for the public building construction is not limited to domestic wood (although to date more than 80% has been domestic wood), thus a greater volume of imported wood could be possible in the future.

The effect by the FIT scheme on the increased use of domestic wood is more uncertain. During the first year following the implementation of the FIT scheme in April 2012, only one project was approved to use wood (logs) for power generation. This is in contrast to an increasing amount of investment into solar power plants under the scheme. Although several new projects using domestic wood as renewable energy source are reported to be on the way (New Energy Foundation, 2012), the impacts of these new projects in increasing the demand for domestic wood still seems to be limited.

As mentioned above, the demand for imported wood may not necessarily be adversely affected by the Japan's policy of increasing the supply of domestic wood. Nevertheless, several issues have to be pointed out in this regard. First, Japanese housing starts have been decreasing and they are not expected to dramatically increase given that Japanese population is aging and shrinking. Since lumber demand is largely dependent on the housing industry, the declining trend of housing starts will reduce the demand for wood in Japan. Given the emphasis of the Revitalization Plan on doubling the supply of domestic wood by 2020, this will inevitably lead to a reduce demand for imported wood.

Second, as imports of logs have decreased, domestic sawmills and plywood mills have been switching their raw material inputs from imported to domestic logs. This trend is being strengthened by the governmental subsidy programs that support domestic sawmills and plywood mills to replace older processing equipment with newer, more efficient processing technology that can utilize the smaller diameter domestic logs. Thus, the share of imported logs used in domestic sawmills and plywood mills is likely to decline.

Third, Japanese macroeconomic policy could affect wood import. In the lower house election of December 2012, the LDP won a landslide victory and returned to power. The new Prime Minister Shinzo Abe, the leader of the LDP, has repeatedly insisted on achieving a target of 2% annual inflation to end the two decades of deflation during the election campaign, and eventually made the Central Bank introduce a 2% inflation target and further loosen monetary policy. These monetary-easing measures are likely to impact the exchange rate through depreciating yen. In fact, the yen has depreciated by about 20% against U.S. dollar over the four months since Abe was elected in December 2012. The exchange rate has historically had a large impact on the volume of wood imports, since a strong yen makes it possible for Japanese importers to import more foreign wood products at a lower price. Likewise, exports of wood products from the U.S. and Canada are known to be elastic with respect to the exchange rate (Bolkesjøa and Buongiorno, 2006). Thus, the depreciation of the yen as a result of Japan's change in monetary policy is likely to lead to a decrease in wood imports into Japan.

Lastly, and potentially most importantly, government subsidy programs targeted to preferably use domestic wood may distort the market relationships found in this study. In early 2013, MAFF announced its plan to introduce the "Wood Use Points Program" which aims to increase the supply and usage of domestic forest products by giving a considerable amount of points (300,000 points valued at 300,000 yen) which have monetary values to new home buyers who purchase homes built with a specified amount of local wood products. It is plausible to think that consumers would be urged to preferably use more domestic wood and less imported wood with such incentive. Although governmental subsidy programs usually last only for one year or a couple of years at the longest, the adverse impact of the Wood Use Points Program on the demand for imported wood could be tremendous.

9. Summary and Conclusions

This study examined the existence of cointegration relationship between domestic and imported wood using price series of sawlog and lumber in order to understand the competitive relationship between them in Japanese market. Using Johansen's multivariate cointegration tests, it was revealed that domestic wood market and imported wood market had no cointegrating relationships. Based on the findings, it was concluded that the market of domestic wood and that of imported wood are not closely connected through price arbitrage and that any price change of a wood product would not affect prices of other wood products directly. Thus, any policy measures focused on increasing domestic wood supply were expected to have little effect on the demand for imported wood market through price impacts. However, the inferences derived from the results depend only on the price movement for past several decades and does not necessarily reflect the rapidly changing situation of domestic wood industry including the advancement of wood processing technology and changes in consumer's needs against wood products. Further research on the competitive relationship between domestic and imported wood (e.g. the Armington elasticity of substitution) should allow for better understanding on the impact of Japan's policy measures.

Bibliography

Alavalapati, J.R., Adamowicz, W.L., Luckert, M.K., 1997. A Cointegration Analysis of Canadian Wood Pulp Prices. American journal of agricultural economics 79, 975–986.

Armington, P.S., 1969. A Theory of Demand for Products Distinguished by Place of Production. International Monetary Fund Staff Papers 16, 159-176.

Baek, J., 2006. Price Linkages in the North American Softwood Lumber Market. Canadian Journal of Forest Research 36, 1527–1535.

Baulch, B., 1997. Testing for Food Market Integration Revisited. Journal of Development Studies 33, 512–534.

Bolkesjø, T.F., Buongiorno, J., 2006. Short- and Long-Run Exchange Rate Effects on Forest Product Trade: Evidence from panel data. Journal of Forest Economics 11, 205–221.

Buongiorno, J., Uusivuori, J., 1992. The Law of One Price in the Trade of Forest Products: Co-integration Tests for U.S. Exports of Pulp and Paper. Forest Science 38, 539–553.

Cabinet Office, 1998-2013. National Accounts of Japan. Retrieved May 16, 2013, from http://www.esri.cao.go.jp/en/sna/menu.html.

Daniels, J.M., 2011. Stumpage Market Integration in Western National Forests, Research Paper, PNW-RP-586. US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Dickey, D.A., Fuller, W.A., 1979. Distribution of the Estimators for Autoregressive Time Series with a Unit Root. Journal of American Statistical Association 74, 427-431.

Dickey, D.A., Jansen, D.W., Thornton, D.L., 1991. A Primer on Cointegration with an Application to Money and Income. Federal Bank if St. Louis Review 73, 58-78.

Eastin, I.L., Boardman, P., Perez-Garcia, J., 2002. A Competitive Assessment of the Japanese Forestry and Forest Products Sectors. CINTRAFOR Working Paper 87.

Eastin, I.L., Roos, J., Tsournos, P., 2003. Niche Market Opportunities for Alaskan Forest Products in Japan. CINTRAFOR Working Paper 91.

Eastin, I.L., 2011. CINTRAFOR NEWS, Autumn 2011. Retrieved May 15, 2013, from http://www.cintrafor.org/publications/newsletter/C4news2011autumn.pdf.

Engle, R.F., Granger, C.W.J., 1987. Cointegration and Error Correction, Representation, Estimation and Testing. Econometrica 50, 251-276.

Forestry Agency, 2007. Forest Resource Survey 2007 (*in Japanese)*. Retrieved May 15, 2013, from http://www.rinya.maff.go.jp/j/keikaku/genkyou/index.html

Forestry Agency, 2012. Wood Supply and Demand Chart 2012 (*in Japanese)*. Retrieved May 15, 2013, from http://www.e-stat.go.jp/SG1/estat/List.do?bid=000001022382.

Gan, J., 2006. Substitutability between US Domestic and Imported Forest Products: The Armington Approach. Forest Science 52, 1-9.

Goodwin, B.K., Grennes, T.J., 1994. Real Interest Rate Equalization and the Integration of Financial Markets. Journal of International Money and Finance 13, 107-124.

Hanninen, R.H., 1998. The Law of One Price in United Kingdom Soft Sawnwood Imports--A Cointegration Approach. Forest Science 44, 17–23.

Hänninen, R., Toppinen, A., Ruuska, P., 1997. Testing Arbitrage in Newsprint Imports to United Kingdom and Germany. Canadian Journal of Forest Research 27, 1946–1952.

Johansen, S., 1988. Statistical Analysis of Cointegration Vectors. Journal of economic dynamics and control 12, 231–254.

Johansen, S., 1995. Likelihood-based Inference in Co-integrated Vector Autoregressive Models. Oxford University Press, New York. 267p.

Jung, C., Doroodian, K., 1994. The Law of One Price for U.S. Softwood Lumber: A Multivariate Cointegration Test. Forest Science 40, 595–600.

MacKinnon, J.G., 1990. Critical Values for Cointegration Tests. Department of Economics, University of California.

Maddala, G.S., Kim, I.M., 1998. Unit Roots, Cointegration, and Structural Change. Cambridge University Press.

MAFF, 1985-2012, Statistics Survey on Lumber. Retrieved May 15, 2013, from http://www.e-stat.go.jp/SG1/estat/GL02020101.do?method=extendTclass&refTarget=toukeihyo&listFormat=hierarchy&statCode=00500217&tstatCode=&tclass1=&tclass2=&tclass3=&tclass4=&tclass5=.

MAFF, 1991. Annual Report on Forest and Forestry, Fiscal Year 1991 (*in Japanese)*.

MAFF, 2001. Annual Report on Forest and Forestry, Fiscal Year 2001 (*in Japanese)*.

MAFF, 2003. Annual Report on Forest and Forestry, Fiscal Year 2003 (*in Japanese)*.

MAFF, 2007. Basic Strategy for Streamlining Wood Processing Industry and for Expanding the Use of Domestic Wood *(in Japanese)*. Retrieved May 15, 2013, from http://www.rinya.maff.go.jp/puresu/h19-2gatu/0207honbun.pdf.

MAFF, 2010. Annual Report on Forest and Forestry, Fiscal Year 2010 (*in Japanese)*.

MAFF, 2010-2011. Minutes of Study Groups for the Implementation of the Forest and Forestry Revitalization Plan (*in Japanese*). Retrieved May 15, 2013, from http://www.rinya.maff.go.jp/j/kikaku/saisei/

MAFF, 2011a. Annual Report on Forest and Forestry, Fiscal Year 2011 (*in Japanese)*.

MAFF, 2011b. Forest and Forestry Basic Plan *(in Japanese)*. Retrieved May 15, 2013, from http://www.rinya.maff.go.jp/j/kikaku/plan/pdf/kihonkeikakuhontai.pdf.

Ministry of Finance (MOF), 2012. Trade Statistics of Japan. Retrieved February 14, 2013, from http://www.customs.go.jp/toukei/info/tsdl_e.htm.

Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 2011. Housing Starts Statistics.

Murray, B.C., Wear, D.N., 1998. Federal Timber Restrictions and Interregional Arbitrage in U.S. Lumber. Land Economics 74, 76–91.

Mutanen, A., 2006. Estimating Substitution in Coniferous Sawnwood Imports into Germany. Journal of Forest Economics 12, 31–50.

Mutanen, A., Toppinen, A., 2007. Price Dynamics in the Russian–Finnish Roundwood Trade. Scandinavian Journal of Forest Research 22, 71–80.

Nagubadi, V., Munn, I., Tahai, A., 2001. Integration of Hardwood Stumpage Markets in the Southcentral United States. Journal of Forest Economics 7, 69-98.

Nanang, D.M., 2000. A Multivariate Cointegration Test of the Law of One Price for Canadian Softwood Lumber Markets. Forest Policy and Economics 1, 347–355.

New Energy Foundation, 2012. Japan is Making Progress in Introducing Wood Biomass Power Plant. Retrieved May 24, 2013, from http://www.asiabiomass.jp/topics/1210_03.html. (*in Japanese*)

Nyrud, A.Q., 2002. Integration in the Norwegian Pulpwood Market: Domestic Prices versus External Trade. Journal of Forest Economics 8, 213–225.

Perron, P., 1989. The Great Crash, the Oil Price Shock and the Unit Root Hypothesis. Econometrica 57, 1361-1401.

Prestemon, J.P., Holmes, T.P., 2000. Timber Price Dynamics Following a Natural catastrophe. American Journal of Agricultural Economics 82, 145–160.

Rii, J., 1996. Forecasting Danish Timber Prices with an Error Correction Model. Journal of Forest Economics 2, 257-271.

Sauquet, A., Lecocq, F., Delacote, P., Caurla, S., Barkaoui, A., Garcia, S., 2011. Estimating Armington Elasticities for Sawnwood and Application to the French Forest Sector Model. Resource and Energy Economics 33, 771–781.

Shahi, C., Kant, S., Yang, F., 2006. The Law of One Price in the North American Softwood Lumber Markets. Forest Science 52, 353–366.

Shook, S.R., Plesha, N., Nalle, D.J., 2009. Does Cointegration of Prices of North American Softwood Lumber Species Imply Nearly Perfectly Substitutable Products? Canadian Journal of Forest Research 39, 553–565.

Stevens, J.A., Brooks, D.J., 2003. Alaska Softwood Market Price Arbitrage, Research Paper, PNW-RP-556. US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Størdal, S., Nyrud, A.Q., 2003. Testing Roundwood Market Efficiency Using a Multivariate Cointegration Estimator. Forest Policy and Economics 5, 57–68.

Thorsen, B.J., 1998. Spatial Integration in the Nordic Timber Market: Long Run Equilibria and Short Run Dynamics. Scandinavian Journal of Forest Research 13, 488–498.

Toivonen, R., Toppinen, A., Tilli, T., 2002. Integration of Roundwood Markets in Austria, Finland and Sweden. Forest Policy and Economics 4, 33–42.

Toppinen, A., Kuuluvainen, J., 2010. Forest Sector Modeling in Europe—the State of the Art and Future Research Directions. Forest Policy and Economics 12, 2–8.

Toppinen, A., Toivonen, R., 1998. Roundwood Market Integration in Finland: a Multivariate Cointegration Analysis. Journal of Forest Economics 4, 241-266.

Yin, R., Baek, J., 2005. Is There a Single National Lumber Market in the United States? Forest Science 51, 155–164.

Yin, R., Newman, D.H., Siry, J., 2002. Testing for Market Integration among Southern Pine Regions. Journal of Forest Economics 8, 151–166.

Yin, R., Xu, J., 2003. Identifying the Inter-market Relationships of Forest Products in the Pacific Northwest with Cointegration and Causality Tests. Forest Policy and Economics 5, 305–315.

Yukutake, K., Yoshimoto, A., Shoji, I., 2008. Existence of Price Comovement and the Law of One Price for Japanese Timber Products. FORMATH 7, 253-269. (*in Japanese*)