African Journal of Environmental Economics and Management Vol. 1 (5), pp. 153-166, December, 2013. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Market and welfare economic impacts of sustainable forest management practices: An empirical analysis of timber market in Peninsular Malaysia

AS Abdul-Rahim[1]*, HO Mohd-Shahwahid[1], S. Mad-Nasir[2] and AG Awang-Noor[3]

[1]Faculty of Economics and Management, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.
[2]Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.
[3]Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

Accepted 13 April, 2013

The main objective of this study is to analyze the impact of sustainable forest management (SFM) practices on the timber market in Peninsular Malaysia. A partial equilibrium model was applied in this study covering domestic timber market namely supply and domestic demand of timber. It was analyzed by using a system of equations approach. All data were compiled from published sources of Malaysian Government publications namely from the Department of Statistics and Annual Report of the Forestry Department of Peninsular Malaysia. All of the data are annual time series basis from 1970 to 2008. Impact analysis was conducted based on three scenarios that arise from SFM practices (that is (1) reduced by 24% in harvested area, (2) increased by 74% in external cost of timber harvesting and (3) increased by 47% in the cost of internalization the externalities). These scenarios will be incorporated in the timber market model. Results show that changing from the conventional logging (CL) practices to SFM practices reduce the equilibrium quantity of timber and increase the price level. The welfare economic impacts of SFM provide empirical evidence that there is a loss in welfare economic impacts on the timber industry in Peninsular Malaysia. However, an increase in the domestic price of timber would help to compensate for the loss volume of timber. The state government and any related agencies should be able to use these results as a reference to come out with good mechanisms in strengthening the effectiveness of SFM policy. Hence, they should be able to assist domestic timber industry by supporting them to fetch various potential incentives such as price premium, carbon credit and market access for timber produced from sustainably managed forest.

Key words: Consumer surplus, producer surplus, equilibrium price, equilibrium quantity.

INTRODUCTION

According to Kumari (1995), when we are discussing about sustainable forest management (SFM), it should cover all mechanisms of allocation and not focused on market only. However, there are many situations and resources which are not and cannot be allocated by market mechanism. For example, many cultures, including indigenous people, use non-market mechanism for resource allocation. This does not mean that their resource allocation is not at optimal level. Similarly, with regards to carbon sequestration, nationally or globally would enjoy the benefit of clear atmosphere received from the carbon storage which cannot traded in the market. However, nowadays, there is a term known as carbon credit created by economists assigning values on carbon for trading in the market.

In Malaysia, Kumari (1995, 1996) conducted a study of total economics valuation (TEV) approach in the context of conventional logging (CL) and SFM practices. The

*Corresponding author. E-mail: abrahim@econ.upm.edu.my. Tel: +6019-2090970. Fax: +603-89486188.

Table 1. Forest of goods and services valuation under CL and SFM practices.

Goods/Services	Method/variable analysis	Location	Value estimated (RM/ha)		Source
			CL	SFM	
Total social benefits[a]	TEV	Malaysia	627	1,118	
Total global benefits[b]	TEV	Peninsular Malaysia	8,389	9,146	Kumari, 1996
Carbon Storage	TEV	Peninsular Malaysia	8,049	8,677	
Water	Cost of water treatment	Peninsular Malaysia	704	1,477	Mohd Shahwahid et al., 1999
Timber and non-timber	Cost-benefit (NPV)	Sarawak	9100	9905	Dagang et al., 2005
Watershed protection	NPV	Peninsular Malaysia	1,019	1,060	Mohd Rusli, 2002
Forested catchment	NPV	Peninsular Malaysia	1,006.1	740.7	Mohd Rusli, 2002

[a]Hydrological, rattan, bamboo, recreation, domestic water and fish; [b]Endanger species and carbon stock.

TEV involves use value, non-use value, direct use value, indirect use value, option value, existence value and quasi-option value. In general, Editorial (2007) mentioned that the concept of SFM in the context of economics is the study of the socially optimal allocation of scarce resources. This means the economics study is not limited to the study of markets, marketed resources, market signals of scarcity, and market mechanisms of resource allocation but it also includes the study of all resources, marketed and non-marketed; all categories (Aboriginal, ecological, environmental, legal, social and market) of resource scarcity signals; all mechanisms, including market, social, legal, and political, of resource allocation; and intra and inter-generational equity as part of social optimality.

Table 1 indicates several goods and services with respect to the economic value estimated from the two types of forest management practices namely conventional logging (CL) and reduced impact logging (RIL) practices where RIL is also represent the implementation of SFM practices. Both CL and RIL deal with the impacts of the forest management practices on goods and service of the forest multiple functions through economic analysis. Economic analysis is referring to the social effects or externality effects that might occurred due to timber harvesting operations. For example, some of these include hydrological, rattan, bamboo, recreation, domestic water, fish, endanger species and carbon storage. The full valuation of forest goods and services would yield surpluses for countries to invest in and achieve SFM.

Owing to the externality effects, SFM policy is in favor to provide greater positive externality effects compared to CL practices. For example, in Table 1, Kumari (1996) found that at national benefit, the total social benefits under CL and SFM are RM627/ha and RM1,118/ha respectively. This has also increased the global benefits from RM8,389/ha to RM9,146/ha under CL and SFM respectively. In addition, Mohd Shahwahid et al. (1999) revealed that the cost of treating the water is lower under SFM practices with less externality effects.

This study will not only analyze the determinant of Peninsular Malaysia timber market, but also internalise the externality effects in the systems analysis. For example, to minimizing the externality effects from timber harvesting operations, the additional activities and procurement are really needed. This will lead to increase in the operational cost. A study by Abdul Rahim et al. (2009b) revealed that the operational cost has increased by 47% due to additional activities that may minimise the externality effects. In addition, the incremental cost of treating water due to timber harvesting will also incurporate in this analysis. This is because it could consider as externality effects as the third party namely water treatment plant has to bear higher cost in treating the water resulting from timber harvesting. One recent study by Abdul-Rahim and Mohd-Shahwahid (2010) showed that the cost of water treatment has increased by 74% due to timber harvesting activities. This is crucial issues need to be analyze and discuss because if there is a significant distortion in the market, government intervention is one of the solution to easy the problem.

To make it clear, timber market in this study is also known as log market. Most of previous studies on timber market analysis typically deal with the prices, supply and demand in domestic and international market. However, to the best of authors' knowledge, none of the study analyzes timber market that internalizes the value of price and quantity as the value that already incorporated the externality effects. For example, a current domestic timber prices in Peninsular Malaysia is just determined by the market driven. It is expected that by internalizing the externalities, the price is potentially higher than the current prices. Hence, government intervention is really needed to correct the distortion. In this context, this present study will provide some output of analysis that could be used by the government for policy decision making. Therefore, the optimum level of output and price at externality level will be quantified because the net benefit is maximized when it takes into account the negative externality effects as well (Tietenberg, 2003).

In a view of Malaysian case, Malaysian Government has given its priority to manage the forest with sustainable manner which refer to SFM practices. In recognition to the need of strengthening SFM, Malaysia has undertaken a critical step to reduce the annual coupe or AAC in the country (Woon and Tong, 2004). Consequently, the AAC has been reduced from 52,250 ha per annum for Peninsular Malaysia during the Sixth Malaysia Plan (1991 to 1995) to 46,040 ha per annum during the Seventh Malaysia Plan (1995 to 2000). This reduction continues during the Eight Malaysia Plan (2001 to 2005) and Ninth Malaysia Plan (2006 to 2010) to 42,870 ha and 36,940 ha respectively. Looking at the actual number of timber that has been extracted, it is shown that the total volume of timber extracted is lower than the AAC approved during Eight Malaysia Plan at 37,326 ha instead of 42,870 ha. Furthermore, on the marketing front, the supply of Malaysian timber has been declining; mainly due to the Malaysian commitment to SFM practices (Jamal and Mohd Shahwahid, 1996; Tan et al., 2003).

This planned reduction in logging rate helps to ensure the extraction of forest resource is in line with the sustainable capacity of the forests. A downward trend in available supply which referred to AAC has put considerable pressures to the local production of timber as well as other wood products. As mentioned by Lim et al. (2002), the declined in timber production was mainly due to the reduction of annual coupes resulting from the Rio Convention and Malaysia's need to achieve ITTO objectives 2000 and international certification standard in attaining SFM. Therefore, if all of these conditions are followed successfully, it would further reduce the supply for domestic consumption. It will be even more worrying, when the accessible forestland in Malaysia is slowly given a way to agriculture especially in oil palm, new satellite towns and other forms of land use, creating a conflict between agriculture production and forest management (Ahmad Fauzi, 2005).

Beside the AAC has been reduced, the stringent criteria of SFM on harvesting operation has affected the timber volume that can be extracted from forests. Consequently, Malaysian timber supply has been continuously diminished. For example, timber production from Peninsular Malaysia natural forests has been decreasing steadily. According to Forestry Department of Peninsular Malaysia (2008), the statistic shows that timber production decreased from 12.8 million m^3 in 1990 to 4.0 million m^3 in 2008.

Most of the studies conducted either locally or abroad revealed that there is incremental cost in operating SFM other than the reduction in timber production (Schwarzbauer and Rametsteiner, 2001; Ahmad Fauzi et al., 2002; Linden and Uusivuori, 2002; Woon and Tong, 2004; Abdul Rahim and Mohd Shahwahid, 2009a). All of these possible changes are directly related on harvesting regulations and additional guidelines on timber harvesting activities. Hence, this will reduce the volume of timber which can be extracted from forest as well as incurred higher cost. In other words, in the short run, it may reduce potential harvesting volumes and producers may have to bear higher cost in implementing SFM. However, in the long run, this may support a sustainable level of production that will exceed of what would be possible in later years if environmentally harvesting systems were to be continued (Thang, 2007). Beside the issues of operation cost and timber production, several other elements in SFM that potentially give direct impact to the timber market are also identified; such as price premium and market access. With regard to the economic reasons, timber producers must acknowledge that there are some economic advantages to participate in SFM.

With the above issues rose relating to the Malaysian timber industry, it is paramount that the market is to be understood in term of the relationship of its major parameters. It has become essential to know the various impacts of SFM practices on timber market in Peninsular Malaysia. This is where we have to come out with several scenarios of SFM practices and carry out simulations analysis for examining the market and welfare economic impacts.

METHODOLOGY AND DATA

While there are different issues in forest sector policies analysis, the analytical framework is quite similar. The common approach is to develop a forest sector model and to simulate the impacts of the policy on the timber and product markets for domestic or international markets. A typical model building involves the estimation of output consumption, price and trade of the timber products. The impacts of the policies were evaluated by comparing the simulated results for with and without policy scenarios.

Studies on forest related policies such as Kallio et al. (1986), Menurung (1995), Schwarzbauer and Rametsteiner (2001), Barbier et al. (1995), Ismariah (2001), Mohd Shahwahid (1993, 1995), Mad Nasir and Mohd Shawahid (1995) and Ahmad Fauzi (2005) have used such framework. A review on their analytical framework is useful, as this study will address most likely similar policy questions relating to certain policy approach. However, this paper differs as it takes into account the SFM policy by incorporating with several scenarios of SFM practices namely (1) reduced by 24% in harvested area, (2) increased by 74% in external cost of timber harvesting and (3) increased by 47% in the cost of internalization the externalities. In other words, the current input cost of timber harvesting operation has to incorporate together with the cost that is related to the externalities. This is where most of the prior studies have ignored the externality effects in their econometric modeling.

Overview of the model structure

The underlying objectives of this study as discussed earlier focused on the internalization of externality effects on the analysis of timber market in Peninsular Malaysia. Figure 1, illustrates the flow of the economic impact analysis with respect to the objectives of study and the analysis approach. In this study, there are two major steps of impact analysis. The first step is to estimate the Peninsular Malaysia timber market model. The second step is to analyze the market and welfare economic impacts by incorporating several scenarios under SFM practices. In sum, both analyses are important to investigate the impact of the implementation of SFM practices on the timber industry.

The logic of the economic analysis is rather simple. If the forested area is manage according to the SFM practices, it will

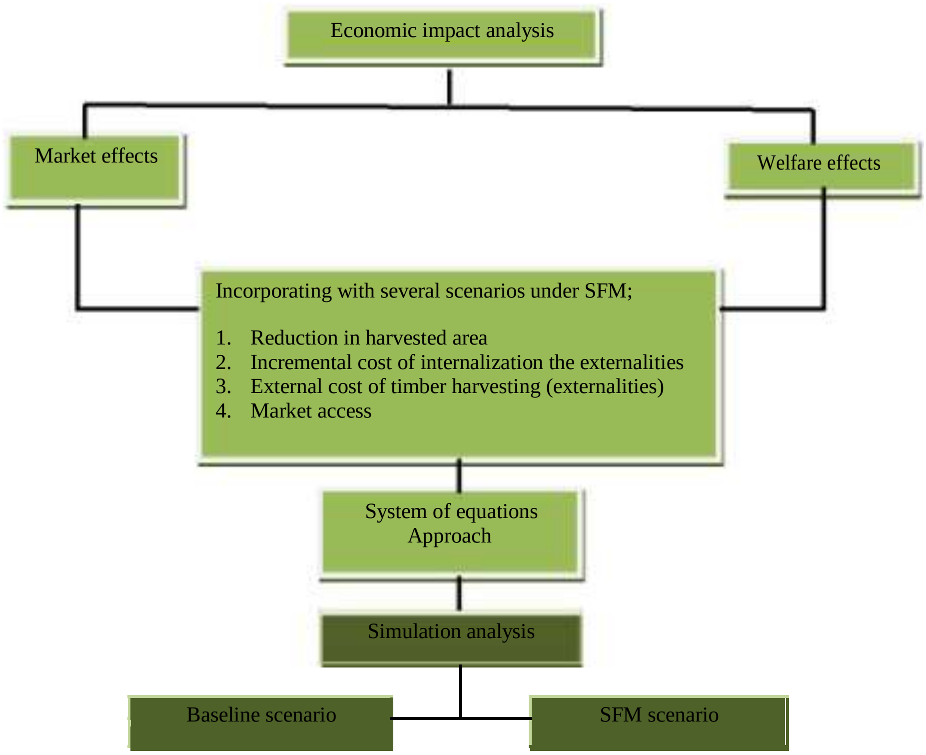


Figure 1. Economic impact analysis schematic diagram.

Figure 2. Schematic diagram of timber supply.

affect several economic elements such as harvested area, operational costs, price and market. Changes in these elements influence the economics of timber supply and demand. The model analyzes the impact of these shifts in timber supply and demand on key variable such as the production and consumption of timber market. Several impacts under SFM scenarios are simulated by linking them into Peninsular Malaysia timber market model.

Peninsular Malaysia timber market model

This study adopted and modified the model developed by Kumar (1981, 1983), Kinus (1992), Mohd Shahwahid (1993, 1995), Mad Nasir and Mohd Shahwahid (1995), Ismariah (2002), Ahmad Fauzi (2005) and Abdul Rahim and Mohd Shahwahid (2009a). Timber that comes from natural forests will be analyzed in this study.

The schematic diagram (Figure 2) not only shows the flow of production of timber but also insist on developing the model. There are timber supply, domestic demand and export demand in the diagram.

However, import demand export demand was not considered in this study. This is because Malaysia is not fully relying on imported timber particularly for Peninsular Malaysia and its export of timber has been banned since 1990s. The detailed justifications will be explained in the next section.

Supply of timber from natural forest

The timber supply from natural forest is given by the equation:

$\ln TS_t = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 \ln AH_t + \alpha_3 \ln IC_t + \alpha_4 \ln TS_{t-1} + \varepsilon_t$ (1)

where:

TS_t = Supply of natural forest timber

P_t = Price of timber

AH_t = Harvested area in natural forest

IC_t = Total salaries and wages paid in logging industry

TS_{t-1} = Lag supply of timber supply by one year

t = Years

ε_t = Error term

ln = natural logarithm

Equation 1 estimates the total supply of timber from natural forest, which should be positively related to the natural forest timber prices and harvested area in natural forest. TS_t is the supply of natural forest timber as endogenous or dependent variable; P_t is the price of natural forest timber, which is an important variable in determining the quantity of natural forest timber supply; AH_t is the natural forested area open for harvesting; IC_t is total salaries and wages paid in logging industry represents to the production cost;

TS_{t-1} is previous year natural forest timber supply, which have influenced the natural forest timber supply.

Incorporation the cost of internalization the externalities and external cost

Input cost under the scenario of SFM = input cost + cost of Internalization the externalities (2)

Input cost under the scenario of SFM = input cost + external cost of timber harvesting (3)

Equations 2 and 3 explain the situation where the timber market model is incorporated with the cost of internalization the externalities and external cost. Incorporation those elements are crucial, otherwise it can lead to market failure. Market failure associated with the externality effects resulting from timber harvesting activities in forest. Without taking into account the externality effects, the timber production from natural forest could be considered as being managed without sustainably produced. In other words, it cannot achieve the optimum level of quantity and price of timber. Most of previous studies especially studies using econometric modeling had ignored the external cost in their research. Therefore, this study tries to incorporate with that element so that the research outcome could represent the optimal level estimation of quantity and price in timber market.

Demand of timber from timber processing mills

$\ln DD^*_t = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 \ln IPI_t + \alpha_3 \ln WMP_t + \alpha_4 \ln DD_{t-1} + \varepsilon_t$ (4)

where;

DD^*_t = Domestic demand for timber

P_t = Domestic price for timber

IPI_t = Industrial production index

WMP_t = World import price of timber

DD_{t-1} = Lag of domestic demand for timber for by one year

t = Years

ε_t = Error term

ln = natural logarithm

Equation 4 describes the estimated total domestic demand for timber from natural forests. It suggests that the lower the price offer, the higher the volume of forest timber demanded domestically. On the other hand, the higher world import price of timbers would encourage further consumption of domestic timbers. Similarly, the higher industrial production index (IPI) would promote timber processing mills (that is sawmills, plywood and veneer mills) to demand more domestic timbers.

Instead of using Malaysian income, IPI will be used in this study because the timber demand is considered as intermediate goods. IPI is also used to measure the economic growth of the timber-based manufacturing industries and it should therefore be positively related to the timber demand. When there is a growth in timber processing mills, demand for timbers would rise but domestic demand would have to compete with other substitute such import of timber. Hence, we used world import price of timber (WMP) which represents substitute good. It suggests that the higher the WMP, the higher the volume of domestic demand of timbers. $\ln DD^*_t$ is the dependent variable for domestic demand for timber, which is influenced by the domestic price of timber (P_t), industrial production index (IPI_t), world import price of timber (WMP_t) and the previous year's domestic demand of timber (DD_{t-1}).

Closing identities (total supply of timber)

The above timber market model has two main equations. To close the system, an identity equating timber availability with domestic demand of forest timbers is postulated as follows:

$TS_t = DD_t$ (5)

To analyze the timber market model, this study estimates timber supply and demand for domestic market. Then, re-estimate the supply and demand simultaneously followed by simulation analysis of several scenarios under the SFM practices. The domestic supply and domestic demand equations will be estimated by system of equations approach.

From Equation 5, a partial equilibrium of quantity and price of timber can be generated.

The details calculation can be seen in Appendix A. In addition, the producer and consumer's surplus that represents welfare economic impacts are also being quantified.

Welfare economic impact analysis

The effects on the timber sector from several scenarios under SFM

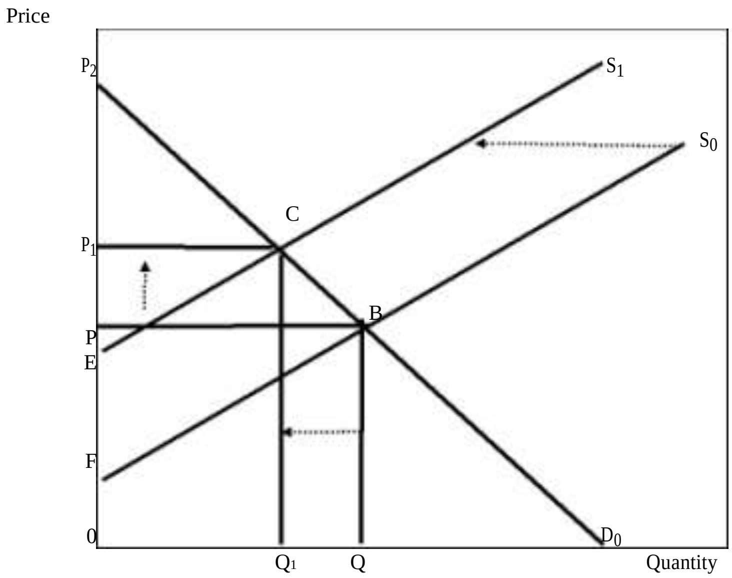


Figure 3. Change in consumer and producer surplus from shift of timber supply in domestic market.

practices namely reduction in harvested area, incremental cost of internalization the externalities and external cost of timber harvesting operations can be explained by the changes in the aggregate consumer and producer's surplus. Consider the timber market in Figure 3, the market demand curve for timber is simply the horizontal summation (that is, summation n along the quantity axis) of the demand curves of each individual timber processing mills (sawmills, veneer and plywood mills).

The aggregate price value of a given quantity of timber will be equal to the area under the market demand curve and the height of the market demand curve is equal to the price value of each unit of timber. For example, the total value of Q units of timber is equal the area OP_2BQ. But, if the commodity could be purchased at price P, the total cost of Q units to the consumer would be only the area OPBQ.

Since the total cost would be less than the total value to the consumer, timber processing mills would realize a net gain referred to as consumer's surplus equal to the difference area PP_2B. Similarly, the market supply curve for timber is the horizontal summation of the supply curve for all mills in the industry. The height of the supply curve for timber is equal to the opportunity cost of each unit of timber, since the height of a firm's supply curve indicates the price value of the marginal opportunity cost of each unit of the commodity.

The price paid for inputs by the industry reflects the opportunity cost of the last unit purchased. The area under the market supply curve for timber will therefore be equal to the total opportunity cost of the inputs used by the industry to produce timber. Then, the difference between the total revenue received by an industry and the area under the market supply curve for timber is equal to the total producer's surplus received by the timber supplies in that industry. In summary, the aggregate consumer's surplus is equal to the area under the market demand curve and above the market price line, area PP_2B. In turn, aggregate producer's surplus is equal to the area above the market supply curve and below the price line, area PBF.

The price value of the benefits and costs resulting from the shift of the supply curve for timber in the domestic market can be calculated using the concepts of consumers and producer's surplus discussed previously. As illustrated in Figure 3, the reduction in available cut and increases in cost of internalization the externalities and external cost of timber harvest would reduce timber supply.

The supply curve before the policy is labeled S_0, and the total consumer and producer's surplus is equal to the area FBP_2. Hence, the supply curve shifted to S_1, and the total consumers and producer's surplus is equal to the area ECP_2. Therefore, the shift in the supply curve for timber from S_0 to S_1 would result in a decrease in total consumers' and producers' surplus equal to the area BCEF.

The total sum of the consumer and the producer surplus is the social surplus. At this level, the value of consumer and the producer surplus were represented the value after taking into account several scenarios under SFM practices.

Evaluating the time series properties

It has become a standard practice to begin the analysis by examining the time series properties of the data. Any time series data can be thought of as being generated by a stochastic or random prices and a concrete set of data. A stochastic process is said to be stationary if its mean and variance over time and the value of covariance between two time periods depends only on the distance or lag between the two time periods and not on the actual time at which the covariance is computed. With these particular characteristics, shocks to a stationary time series would be; over time, the effect of the shocks will dissipate and the series will revert to its long run mean level. Consequently, long-term forecasts of a stationary series will converge to unconditional mean of the series. In contrast, a non-stationary series process has a permanent component. Its mean variance is time independent. For a non-stationary series, there is no long-run mean to which the series returns.

We start the analysis by examining the time series properties of the data used in the supply and demand equations. However, depending on the power unit root tests, deferent tests might yield different results which eventually lead to certain degree of uncertainty in the analysis of level relationships. Therefore, this

Table 2. Results of timber market.

Supply function			
$\Delta \ln TS = -1.7281 + 0.1497\Delta \ln P - 0.0828\Delta \ln IC + 0.2076\Delta \ln AH + 0.9531\Delta \ln TS_{t-1}$			
(0.05)*	(0.07)*	(0.00)***	(0.00)***
$R^2 = 0.93$	Adj. $R^2 = 0.92$	DW = 1.93	Ramsey RESET Test = (0.33)
Heteroscedasticity Test = (0.63)		Wald Test = (0.00)***	
Demand function			
$\Delta \ln DD = 4.2010 - 0.3687\Delta \ln P + 0.2792\Delta \ln IPI + 0.3216\Delta \ln WMP + 0.6758\Delta \ln DD_{t-1}$			
(0.05)*	(0.20)	(0.12)	(0.00)***
$R^2 = 0.73$	Adj. $R^2 = 0.69$	DW = 1.88	Ramsey RESET Test = (0.61)
Heteroscedasticity Test = (0.73);		Wald Test = (0.00)***	

study utilize two different unit root testing procedures in examining the stationary properties of the data to provide a robust test result on the information of the order of integration of the data used. The use of alternative unit root testing procedures is very important in dealing with anomalies that arise when the data are not very informative about whether or not there is a unit root. These two unit root tests used are the non-stationary test of Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) unit root test.

Data description

The data used in this analysis is time series data. With regards to the time series data analysis, this study intends to evaluate the empirical performance of SFM practices in Peninsular Malaysia domestic market using annual data from 1970 to 2008. Published data on all variables in this study were available from the Forestry Department of Peninsular Malaysia, Department of Statistics, Malaysia and Ministry of Plantation Industries and Commodities, Malaysia.

EMPIRICAL RESULTS

Econometric analysis is capable of providing a quantitative analysis of the actual economic phenomenon based on the concurrent development of theory and observation, related by an appropriate method of inference (Gujarati, 2003). Since this analysis uses time series data, it is necessary to find out whether the data are stationary or otherwise. For this reason, unit root test has been conducted using the ADF and PP unit root test.

Unit root test on time series data

It is necessary to test the order of integration of each variable in a model. This is to determine how many times the variables need to differently produce a stationary series. It is essential to note that testing for stationary condition for a single variable is very similar to testing whether a linear combination of variable cointegration to form a stationary and equilibrium relationship (Harris, 1995).

Since the unit root test results are sensitive to different values of the autoregressive lag lengths, the selection rule of the truncation lag parameter is crucial in determining the order of integration of the data. In this study, the optimal lag length of the ADF test is chosen based on automatic selection by Schwartz information criterion (SIC), while Newey-West Bandwidth criterion is used for the optimal lag length selection in the PP test to ensure the errors are white noise. All the unit root tests are carried out using E-views 6.0 software.

All the variables are non-stationary in levels. Thus, we cannot reject the null hypotheses of a unit root in both the ADF and PP tests. On the other hand, all series appear to be stationary after first differencing that is I (1). This result is consistent for both ADF and PP tests used in this study. Therefore, higher order of differencing is not required to make the data into stationary process. The results imply that there is I (1) variables in the Peninsular Malaysia data, and no existence of I (2) variable.

There is a concrete support for the existence of a unit root stationary at I (1) by ADF and PP unit root tests in Peninsular Malaysia. The result of I (2) is automatically do not need to carry out because all the variables are integrated at I (1). If, there are not integrated at I (0) and I (1), then it is necessary to analyze the unit root test at I (2) level.

Estimated coefficients of timber market

Table 2 provided the empirical result of the estimated equations. As mentioned earlier, the supply and demand models for the timber industry were estimated using the system of equations approach as endogenous variable exists in each of the equation. Based on the result of unit root tests, all parameters used in the model are stationary at first difference. Therefore, the data are not stationary at level form; it should be transformed to the first difference before importing those variables in the model. In general, the estimated equations in the model have reasonable goodness-of-fit. All of the variables coefficients in the model were as expected and consistent with the theory of supply and demand.

Based on the empirical result of timber supply function, the estimated coefficients of *P* and *IC* were statistically significant at the level of 10%. This means that, they are the significant determinants of timber supply. For P, the result suggested that for every 10% growth in average *P*, ceteris paribus, timber supply would increase by 1.5%. The significant coefficient of *P* verified the priori assumption that price is an incentive for timber production.

On the other hand, *IC* has a negative coefficient. Based on the estimation, a growth of 10% in *IC*, ceteris paribus, the timber supply would decrease by 0.8%. In other words, larger value in *IC* will then reduce the volume of timber produced. *AH* on the other hand appeared to be highly significant at the level of 1%. This is believed to be due to the direct impact of timber harvesting activities on timber supply. Thus, a 10% reduction in *AH* led to approximately 2% decrease in timber supply. This is where the Malaysian Government has taken a proactive action when the rate of AAC shows declination since early 1990s. This to a certain extent may pull down the timber supply to a sustainable level. This result is similar with the study conducted by Jamal and Mohd Shahwahid (1997) and Lim et al. (2002) which concluded that the Malaysian strategy to reduce AAC in the natural forest is in preparation towards SFM practices. For example, Jamal and Mohd Shahwahid (1997) mentioned that timber supply started declining from 1992 onwards due to the practice of sustainable forest management.

The estimates obtained for the domestic demand equation were as expected. The coefficients for own price and lagged one year dependent variable were significant at the level of 5% and one percent respectively. The own price elasticity is -0.389. This result confirmed the findings of previous studies (Mohd Shahwahid, 1995; Abdul Rahim; Mohd Shahwahid, 2009e) that the domestic demand and supply for timber price is inelastic. A 10% growth in the price of timber decreases the domestic demand for timber by 3.8%. Similarly, Daniels and Hyde (1986) reported that both supply and demand price were fairly inelastic and suggested that price changes will not result in dramatic harvest fluctuation. Conversely, the coefficients for substitute price and industrial production index were not significant. The industrial production index does not influence the demand for timber (Mohd Shahwahid, 1995). The insignificant result of the substitute price (that is, world import price) implied that the domestic timber market in Peninsular Malaysia do not really rely on imported timber.

In the case of Peninsular Malaysia, there was no export market for timber since early 1990s. According to FDPM (2005), Peninsular Malaysia has imposed a ban on timber export since the 1990s. This action was taken to give local timber processing mills priority in getting their raw materials and also to meet the domestic demand.

Any export has to be processed timber. In addition, Peninsular Malaysia has marginally imported timber from abroad. For example, in 2007, Peninsular Malaysia has imported 70,704 m^3 of timber or 1.6% out of the total supplied. Hence, the total quantity supplied and demanded can be solved within the domestic market as a large portion of these quantities were not from the foreign market.

This is a reasonable explanation for the exclusion of international timber market in the partial market equilibrium analysis. In other words, this study will focus on the impact of domestic market and economic welfare, for the case of Peninsular Malaysia.

Validation of timber market model

The overall fit of the equation between the explanatory variables and dependent variable could be explained by the value of R-square. This is an important criterion in evaluating the quality of regression. For example, the value of R-square obtained from the estimated supply equation is 0.93. This implied that 93% of the variation in timber supply can be explained by the explanatory variables in the model.

Other diagnostic tests that have been carried out for timber supply and demand equations were serial correlation of Durbin-Watson (DW) test, heteroscedasticity, Ramsey RESET test and Wald test (Table 2). The results of DW and Heteroscedasticity tests have shown no evidence of serial correlation and heteroscedasticity problems. The Ramsey RESET test has proven that the equation is stable and has no functional misspecification. The Wald test is important to test whether the estimated equations have a long run relationship between independent and all explanatory variables. The result showed that the model is cointegrated at the significant level of 1%. The root mean square error and Theil inequality test demonstrated that the deviation of simulated variables is quite close to the average size of the variable in the equation.

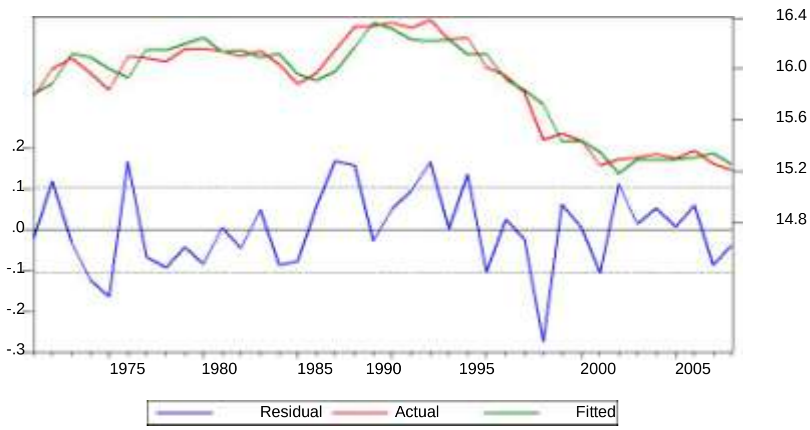
A historical simulation has been carried out in the sample throughout the period of this study. This is where the adequacy of the model in forecasting and policy analysis. The detailed tests and results were depicted in Table 3.

The root mean square error (RMSE) and Theil's inequality coefficient were found to be relatively small for timber supply (TS) and domestic demand (DD). This result suggested that the forecasting and policy analyses can be considered as accurate.

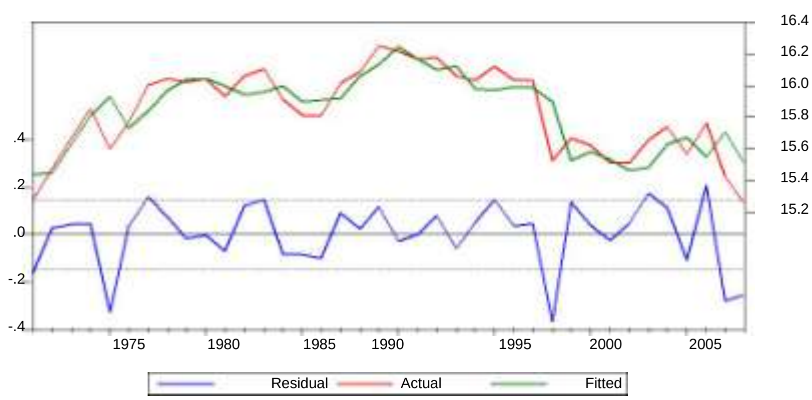
The value of bias proportion is equal to zero, indicating the non-existence of a systematic bias for TS and DD. Figure 4a and b showed the actual, fitted and residual graphs of the timber supply and demand equations. This result provides strong evidence that the equation is stable between the dependent and all independent variables.

Table 3. Historical simulation of timber model.

	TS	DD
Root mean square error	0.08	0.10
Theil's inequality coefficient	0.002	0.003
Bias proportion	0.000	0.000
Variance proportion	0.03	0.019
Covariance proportion	0.96	0.98



a



b

Figure 4. Simulation of timber supply and demand.

Results of price and quantity equilibrium

Table 4 presents the empirical results of the average simulated value calculated from the timber partial market equilibrium model for the period of 1995 to 2008. During this period and thereafter, the SFM/RIL has been implemented in the Malaysian forest management. Since this study examined the economic impact of SFM practices, this study will only averaged out the data for the period of 1995 to 2008 from the simulated output for further analysis. As mentioned earlier, the impact analysis comprised of three scenarios; (1) reduced by 24% in harvested area, (2) increased by 74% in external cost of timber harvesting, and (3) increased by 47% in the cost of internalization the externalities. The percentage of the reduction in harvested area was

Table 4. Average simulated values due to SFM practices.

Parameter		Equilibrium quantity (m^3)	Equilibrium price (RM/m^3)
Baseline scenario		6,655,871	514
Scenarios % changes under SFM practices	Reduced by 24% in harvested area	6,392,684	573
	Rise by 74% in external cost of timber harvesting	6,442,272	561
	Rise by 47% in the cost of internalization the externalities	6,506,564	546

adopted from the study conducted by Ahmad Fauzi et al. (2002). Whereas, the remaining two scenarios (that is, incremental cost of internalization the externalities and incremental cost of external cost of timber harvesting activities) were borrowed from the study conducted by Abdul Rahim et al. (2009) and Abdul Rahim and Mohd Shahwahid (2010) respectively. The incremental external cost of timber harvesting activities and the cost of internalization the externalities by minimizing damages from timber harvesting activities will result in optimum level of quantity and price level.

In this impact analysis, the equilibrium price was calculated from the estimation of timber market model, where the market equilibrium was set-up. By definition, the equilibrium price is the price at which the supply of timber equals the demand for timber (Equation 5). After substituting the equilibrium price into the supply or demand model, the equilibrium quantity was obtained. In other words, from the estimated coefficient, the equilibrium price and quantity of timber could be quantified. The detailed processes are available in Appendix A. The average timber market equilibrium point for price and quantity was RM514/m^3 and 6.65 millions m^3 respectively. This point corresponds with the baseline scenario.

The incorporation of the three impacts of SFM practices; (1) reduction in harvested area, (2) incremental external cost of timber harvesting activities and (3) incremental cost of internalization the externalities by minimizing forest damages from timber harvesting activities through simulation analysis, showed negative effect upon equilibrium quantity. On the other hand, the price of timber showed positive effect as it increased under the three impact scenarios from SFM practices. As shown in Table 4, the price of timber increased by 12, 9 and 6% to RM573/m^3, RM561/m^3 and RM546/m^3 respectively under the three scenarios of SFM practices. This reflected the domestic timber market in Peninsular Malaysia that potentially may fetch price premium averaging from 6 to 12% if the three potential impacts were imposed on timber producers. In other words, these simulated prices were the price of timber when best practice environmental resource management was adopted and when price distortion was remedied. This finding is consistent with the result obtained from the previous studies. Some authors claimed evidence that consumer in Europe and USA were willing to pay between 2 to 30% more for sustainably produced certified tropical timber (Baharuddin, 1995; Baharuddin and Simula, 1996; Simula and Baharuddin, 1996; Oliver, 2005). In addition, Kollert and Lagan (2007) carried out their study in selected forest management units (FMUs) in Sabah, Malaysia and found that Sabah timber achieved a price premium averaging from 2 to 56%.

Based on this empirical analysis, the advantage of complying with SFM practices in Peninsular Malaysia is the increase of domestic price of timber, averaging from 6 to 12%. This is where Malaysian Government intervention is needed to ensure that the advantages of price premium in the domestic market can be realized; particularly, the timber produced from sustainably managed forest. As seen in Table 4, the equilibrium quantity of timber has decreased by 4, 3 and 2% to 6.39 m^3, 6.44 m^3 and 6.51 m^3 respectively under the three scenarios of SFM practices. This finding is consistent with the study conducted by Schwarzbauer and Rametsteiner (2001) which revealed that the timber production will decrease in the long run due to SFM practices. This implied that the domestic timber processing mills might rationalize their consumption of timber as raw material from natural forest by being more efficient processors. Those who could not upgrade or switch towards the more efficient production practices may have to close down, while those who can may expand their production base. In addition, Woon (2001) revealed that the total number of timber processing mills (that is, sawmills, plywood and veneer mills) were expected to be drastically reduced due to SFM practices. The result of this study provides an empirical evidence of the implication under SFM scenarios on timber market in Peninsular Malaysia. The percentage of decreases in equilibrium quantity of timber in the long run provided an explanation that the Malaysian timber production was managed not only for present needs but also for the benefits of the future generation as well. Furthermore, the timber harvesting technique in SFM practices that gave

Table 5. Average welfare impacts due to SFM practices.

Item		Producer surplus	Consumer surplus	Total Social benefits
Baseline scenario		88,225	118,224,286	118,312,541
Scenarios % changes under SFM practices	Reduced by 24% in harvested area	67,347	118,122,972	118,190,319
	Rise by 74% in external cost of timber harvesting	68,364	118,143,237	118,211,601
	Rise by 47% in the cost of internalization the externalities	75,799	118,168,669	118,244,468

priority in curbing externality effects and logging damages enhanced the process of regeneration of timber tree in the next cutting cycle. In this context, Thang (2007) revealed that the Malaysian timber production would increase in the long run due to the implementation of SFM.

Results of welfare economic impacts

Based on the simulated value calculated earlier as given in Table 4, the average annual estimated values of welfare economic impacts were further calculated (Table 5). The similar scenarios as what in the market impact analysis were adopted and simulated in this welfare economic impacts analysis. The simulation results showed that the calculated value of producer surplus and consumer surplus changes when incorporating the three scenarios under SFM practices. The detail process can be seen in Appendix B.

Under scenario one, where HA reduced by 24%, the producer surplus reduced from RM88,255, under the baseline case to RM67,347. Similarly, the consumer surplus also decreases from RM118.22 million, under the baseline scenario, to RM118.12 million. Under scenario two, where external cost of timber harvesting increased by 74%, the producer surplus reduced from RM88,255, under the baseline case, to RM68,364. Similarly, the consumer surplus also decreased from RM118.22 million, under the baseline scenario, to RM118.14 million. Under scenarios three, where the cost of internalization the externalities went up by 47%, the producer surplus reduced from RM88,255, under the baseline case, to RM75,799. Similarly, the consumer surplus also decreases from RM118.22 million, under the baseline scenario, to RM118.17 million.

This result indicated that the variation in the *HA* is the main cause of reduction in the calculated value of the producer and consumer surplus. This is because the elasticity of *HA* was relatively higher than the other policy variables. This situation would bring towards loss in the economic welfare on timber market in Peninsular Malaysia. The economic welfare in this study referred to the calculated value of total social benefit, which is the summation of the value of producer and consumer surplus. Hence, this finding implied that when the timber industry complies with the SFM practices, the economic welfare of the stakeholders in the timber sector will decline.

As noted by Wells and Wall (2005), there is an element of trade-offs between environmental protection and timber from forests. However, with SFM practices, the source of timber supply from natural forest could be sustained and the externality effects from timber harvesting activities could be minimized. Otherwise, the regeneration of timber from the natural forests would be affected. In general, the nation would also lose the valuable non-timber forest products (NTFPs) and environmental services that could potentially generate income for the society and government in the future. In addition, Kotwal et al. (2008) claimed that SFM practices could enhanced the growing stock of timber and forest productivity of timber and non-timber forest produce.

CONCLUSIONS

The above findings showed that such *HA* and *IC* behaviors may have significant impact on the future equilibrium price and quantity process, which in turn affects the welfare of producers and stakeholders in the timber-based industry. On the supply side, the results showed that compliance with SFM practices will reduce the supply of timber to a sustainable level. However, the level of price was pushed up in the partial equilibrium process. Hence, the equilibrium price and quantity of timber have increased and decreased respectively, representing the optimum level in internalizing the externalities from timber harvesting activities.

For the case of Peninsular Malaysia, the simulation showed that the market and welfare economic impacts arising from SFM practices were small. Based on those scenarios, a decrease in harvested levels were likely to affect the market and economic welfare more than an increase in input costs (direct and indirect) owing to SFM practices. This result is similar with the study conducted by Schwarzbauer and Rametsteiner (2001). They found that any decrease in harvested levels gave an immense impact on forest products market than any increase in the operational costs due to SFM practices.

The simulation results of partial market equilibrium presented above revealed that producers could potentially fetch price premium in the domestic timber market in Peninsular Malaysia. In this context, one should expect that timber producers will choose to comply with the SFM practices if the price is an incentive. Therefore, the price premium is required to offset the foregone value of two elements considered in this study; (1) incremental cost of internalization the externalities by minimizing the environmental damage from timber harvesting activities, and (2) external cost of timber harvesting operations which refers to cost of water treatment. Ignoring the externalities would lead to market failure or distortion in equilibrium price and quantity. In this context, government intervention is needed to alter the distortion of market equilibrium.

This is due to the timber prices used in the timber market does not reflect the price of environmental resources. Government could built-in the mechanism of forest taxation rates which are in line with changes to market timber prices. In this context, Majawat (2010) mentioned that there is a need to place monetary value to environmental services.

The policy variables used in Peninsular Malaysia timber market model (that is *HA* and *IC)* were significant and inelastic. Exogenous shocks in those policy variables would have small impact on the equilibrium price and quantity of timber, and eventually impact on the economic welfare of timber industry. The result indicated that stakeholders in timber industry experienced a small reduction in economic welfare due to SFM practices. However, if the government could impose some good mechanisms, this could offset their losses. As a result, this could encourage more stakeholders in the timber industry to comply with SFM policy and minimized the externality effects from timber harvesting activities. This could be materialized when timber producers include the external cost of externalities in their total operational costs, or known as full economic costs.

Future research direction

Based on this study, several elements of limitations are captured. The potential future research directions are as follows:

(1) The extension of this study should be carried out in order to identify the total economic impact of SFM practices to the rest of the economic sectors. In this context, the common method that has typically been used is an input-output model. The coefficients estimated in the econometric model could be used in the input-output (I-O) model to measure the total economic impact for the whole economy. In addition, the I-O model is also capable to take into account the importance of inter-dependencies that exists between sectors in an economy. Then, the direct and indirect impacts of SFM practices could be highlighted.

(2) This study only analyzes the economic impact of SFM practices on timber market as it gave direct impact to the timber harvesting activities. However, it would be wise for decision makers to further conduct the economic impact analysis of SFM practices on timber-based industries such as sawntimber, plywood, pulp and paper, veneer and moulding. This could be done through individual analysis which analyzes the types of timber-based industries by using econometric model. Alternatively, this could be analyzed by using a system dynamic (SD) approach. This approach is very comprehensive. It covers forest sector aspects from timber up to paper consumption, which is the main strength of this approach compared to other approaches in the econometric models with less scope but more detail.

(3) In this study, the timber market analysis for SFM practices refers to the timber that were produced from natural forests. For the extension of this study, timber produced from the forest plantation establishment is also needed to be taken into account in the analysis. This is because forest plantations plays an important role in supplying timber to the timber processing mills and ease the pressure of natural forest which related to the timber production. Therefore, new timber market model for timber produced from forest plantation need to be developed.

(4) In the context of SFM, future research on integration of all aspects related to sustainably managed forests such as environment, economic and social is vital as the result of the integration approach of these aspects would be more compatible. Hence, future work needs to focus on developing sufficient approaches and methodologies for better integration approach.

(5) Only the stakeholders in the timber industry for the welfare economic impact analysis due to SFM practices were being evaluated in this study.

Hence, the gain and loss of the economic welfare is limited to the stakeholders in the timber industry. In fact, SFM practices affect other stakeholders (that is, society) as well apart from the stakeholders in the timber industry. In this respect, new research should be carried out in measuring the welfare economic impact of SFM practices on other stakeholders that are believed to be related to the forests particularly on the NTFPs and environmental services.

Thus, the welfare economic impact of SFM practices could be evaluated comprehensively and a better picture of the total gains or losses pertaining to the SFM practices could be drawn.

REFERENCES

Abdul Rahim AS, Mohd Shahwahid HO (2009a). Short run and long run effects of sustainable forest management practices on West Malaysian log supply: An ARDL approach. J. Trop. For. Sci. 22(4): 369-376.

Abdul Rahim AS, Mohd Shahwahid HO (2010). External cost of water treatment under two regimes of timber harvesting: A case study in Kelantan. Proceedings of the 9th International Annual Symposium on Sustainability Science and Management pp.217-221.

Abdul Rahim AS, Mohd Shahwahid HO, Zariyawati MA (2009b). A comparison analysis of logging cost between conventional and reduce impact logging practices. Int. J. Econ. Manage., 3(2): 354-366.

Ahmad Fauzi P (2005). The Economic Impact of Sawntimber Export Levy Removal on the Peninsular Malaysia's Economy. Unpublished PhD Thesis, Universiti Putra Malaysia.

Barbier EB, Bocksteal N, Burgess JC, Strand I (1995). The linkages between the timber trade and the tropical deforestation–Indonesia. World Econ. 18(3):411-422.

Editorial (2007). Economic perspectives and analyses of multiple forest values and sustainable forest management. Forest Pol. Econ. 9:733-740.

Forestry Department of Peninsular Malaysia (2008). Statistics on forestry in Peninsular Malaysia. Forestry Department of Peninsular Malaysia, Malaysia.

Gujarati DN (2003). Basic Econometrics, 4th ed. McGraw-Hill Book Company, New York.

Harris RID (1995). Using cointegration analysis in econometric modeling, Prentice Hall, Great Britain.

Ismariah A (2001). Economic of carbon emission and squestration in the Malaysian forest sector. Unpublished PhD Thesis, University of Washington.

Jamal O, Mohd Shahwahid HO (1996). Sustainable forest management in Malaysia: Issues and perspectives. Paper presented at the Fourth MIER Econometrics Conference, 14-15 October, 1996, Kuala Lumpur.

Kallio M, Propoi A, Seppala R (1986). A model for the forest sector. TIMS Stud. Manage. Sci. 21:89-112.

Kinus M (1992). Econometric analysis of supply and demand for log and sawntimber in Sabah, Unpublished Master Thesis, Faculty of Economics and Management, University Putra Malaysia.

Kumar Raj (1981). Regional forecasting of demand for Malaysia wood products. Malay. For. 44(1):1-11.

Kumar Raj (1983). A quantitative analysis of the elasticity of export and home demand of key Malaysian wood products. Kaj. Ekon. Malay. 17(1):35-45.

Kumari K (1995). An environmental and economic assessment of forest management options: a case study of Malaysia, Environment Department Working Paper 026 World Bank, Washington DC.

Kumari K (1996). Sustainable forest management: myth or reality? Exploring the prospects for Malaysia. Ambio. 25(7):459-467.

Lim HF, Norini H, Woon WC, Krisnhnapillay B (2002). The socio-economics aspects of pancy Rrivate forest plantation in Peninsular Malaysia. Forest Research Institute Malaysia. Consultancy report commissioned by small scale fast growing forest plantation programmes. p.137.

Linden M, Uusivuori J (2002). Econometric analysis of forest conservation: the Finish experience. Environ. Dev. Econ., 7: 281-297.

Mad Nasir S, Mohd Shahwahid, HO (1995). A market model of Peninsular Malaysian sawntimber industry. Pertanika J. Soc. Sci. Hum. 3(1):47-53.

Menurung EGT (1995). Economic impacts of the log ban policy on the development of the forest products industries of Indonesia. Unpublished PhD Thesis, University of Wisconsin, Madison.

Mohd Rusli Y (2002). Economic impacts of logging intensities in the Muda-Pedu forested catchment, Kedah, Malaysia, Unpublished Master Thesis, Faculty of Economics and Management, University Putra Malaysia.

Mohd Shahwahid HO (1993). Modeling the West Malaysian Log Market, in Malaysian Agriculture Commodity Forecasting and Policy Modeling, Centre to Agriculture Policy Studies pp.69-81.

Mohd Shahwahid HO (1995). Forest conservation and its effects on Peninsular Malaysia log supply. ASEAN Econ. Bull. 11(3):320-334.

Mohd Shahwahid HO, Awang Noor AG, Abdul Rahim N, Zulkifli Y, Ruzani U (1999). Trade-offs among competing uses of a Malaysian forested catchments. Environ. Dev. Econ. 4(3):279-311.

Schwarzbauer P, Rametsteiner E (2001). The impact of SFM-certification on forest product markets in Western Europe – an analysis using a forest sector simulation model. Forestry Pol. Econ., 2: 241-256.

Tanc YE, Razak MAA, Rajan S (2003). Promoting the use of timber construction. Pp. 355–361 in Lee, S.S. et al. (Eds.) Proceedings of the Conference on Forestry and Forest Products Research (CFFPR 2003) "Forestry for Society". 6-8 October 2003, Kuala Lumpur Malaysia.

Thang HC (2007). An outlook of the Malaysian forestry sector in 2020. Unpublished Report, Forestry Department of Peninsular Malaysia (FDPM). p.89.

Tietenberg T (2003). Environmental and natural resource economics. Sixth Edition. Addison Wesley, USA.

Woon WC, Tong PS (2004). Sustaining the Malaysian wood-based industries. Pp. 411–418 in Lee, S.S. et al. (Eds.) Proceedings of the Conference on Forestry and Forest Products Research (CFFPR 2004) "Forestry for Society", 6-8 October 2004, Kuala Lumpur Malaysia.

APPENDIX A. Market equilibrium process

Domestic markets

In order to obtain the equilibrium condition, we have to equate the supply and demand equations as can be seen in Equation 6. As there is only domestic market in the Peninsular Malaysia timber market model, only domestic supply and domestic demand for timber were required to obtain the market equilibrium. Then, we are able to calculate the equilibrium price. To find the equilibrium quantity, we can substitute the equilibrium price into either the supply or demand equation. Equation A.1 was derived from the estimated result of Equation 1 and 4. Note that the value of α_1 *lnP* and α_0 were the summation of coefficient of price and intercept that have been estimated in Equation 1 and 4 respectively. The rest of the coefficients correspond to the parameters in the model.

$$\alpha_1 \ln P = \alpha_0 - \alpha_2 \ln AH + \alpha_3 \ln IC + \alpha_4 \ln IPI + \alpha_5 \ln WMP - \alpha_6 \ln TS_{t-1} + \alpha_7 \ln DD_{t-1} \quad (A.1)$$

In order to solve *lnP,* we have to divide the estimated coefficient in Equation A.1 with α_1

$$\ln P = \frac{\alpha_0}{\alpha_1} - \frac{\alpha_2}{\alpha_1} \ln AH + \frac{\alpha_3}{\alpha_1} \ln IC + \frac{\alpha_4}{\alpha_1} \ln IPI + \frac{\alpha_5}{\alpha_1} \ln WMP - \frac{\alpha_6}{\alpha_1} \ln TS_{t-1} + \frac{\alpha_7}{\alpha_1} \ln DD_{t-1} \quad (A.2)$$

By substituting all of the parameters used in Equation A.2 with the average data of time series, then we will be able to find the equilibrium price for Peninsular Malaysia's timber market. To find the equilibrium quantity, we substitute the equilibrium price into either Equation A.3 or A.4.

$$\ln TS = \alpha_0 + \alpha_1 \ln P - \alpha_2 \ln IC + \alpha_3 \ln AH + \alpha_4 \ln TS_{t-1} \quad (A.3)$$

$$\ln DD = \alpha_0 - \alpha_1 \ln P + \alpha_2 \ln IPI + \alpha_3 \ln MP + \alpha_4 \ln DD_{t-1} \quad (A.4)$$

Note that the calculated value of equilibrium price and quantity are in natural logarithm form. Hence, we have to convert the equilibrium price and quantity to a real value.

APPENDIX B. Welfare economic impact process

Using partial equilibrium consumer surplus (CS) and producer surplus (PS) concepts, it is possible to analyze the economic gains and losses in the domestic economy from the implementation of SFM practices. CS refers to the area above the equilibrium price line but below the demand curve (Figure 3). It represents the difference between the amounts that consumers are willing to pay for a given quantity. PS refers to the area below the equilibrium price line but above the supply curve (Figure 3). It represents the difference between the total revenue received by producers for producing a given quantity. It is typical for economist to measure CS and PS in order to assess the impacts on consumers and producers of given policies.

In this study, we used integral calculus to find the areas of CS and PS that we adopted from Hess (2002). From Equation 6, we could further find CS and PS. To find CS we need to subtract the total expenditures of consumers (P_0*Q_0) from the area under the demand curve up to the quantity transacted (Figure 3). According to Hess (2002), if the calculation is integrated with respect to the quantity variable, the Marshallian formulation must be used.

$$\text{CS = area } PP_2B = \int_0^{Q_0} d^{-1}(Q)dQ - (P_0 * Q_0) \quad (B.1)$$

Alternatively, we could find CS by integrating with respect to the price variable.

$$\text{CS = area } FP_2B = \int_{P_0}^{P_2} d(P)dP \quad (B.2)$$

Here the interval of interest is along the price axis from the equilibrium price P_0 to the maximum demand price of P_2.

On the other hand, to find PS we need to subtract from the total revenues received, (P_0*Q_0), the area under the supply curve up to the quantity transacted Q_0.

$$PS = \text{area } FP_0B = (P_0 * Q_0) - \int_0^{Q_0} s^{-1}(Q)dQ \qquad \text{(B.3)}$$

Alternatively, we could find PS directly by integrating with respect to the price variable.

$$PS = \text{area } FP_0B = \int_F^{P_0} s(P)dP \qquad \text{(B.4)}$$

Here the interval of interest is along the price axis from the minimum supply price of *F* up to the market equilibrium price of P_0.