18

Comparison of Timber Consumption in U.S. and China

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1. Introduction

Timber consumption is now a global concern from environmental protection and sustainable development prospective in the past decades. The nature of the environmental stress depends upon the quality and level of difference in the trends and patterns of natural resources consumption across countries (Parikh *et al.*,1991).

Forest resources supply timber, but that is not forest's only function. People are more concerned with its other functions like air-cleaning, and slowing down climate change. So the timber supply function is no longer the first choice of forest resource. Therefore, the large amount of timber consumption arose the claim that timber production is destroying the forests of the world, countries which consume large amount of timber are the focus of the controversy, especially the big countries such as China and U.S. As a matter of fact, there are different patterns of timber production and consumption in different countries because of different preference of using timber. So it is better to make a deep insight to the phenomena rather than believe the claims simply. On the other hand, China imports logs and processes them then exports large amount of forest products to the world. The processing brings more contamination to China as a longterm sacrifice as well as the contribution to the world. It is kind of "Smile Curve with two ends out" as Japan does in forest sector.

Though the possession quantity per capita is above world level, US is still a net timber import country. Given the strong consumption drive, imagine how much area of forest needs to be logged to meet such a huge demand. According to some statistics from forest service (James, 2007), the population of US increased by 52.70% from 194 million to 296 million during 1965-2005, meanwhile, the consumption of timber increased by 58.89% from 377 million m^3 to 599 million m^3. The dependence on import timber of US increased from 2% in 1991, up to 9% in 1996. This increased to 16% in 2002, and it is predicted to be 19% in 2050 if the current policy remains (State Forestry Administration, 2008). It is true that the timber consumption is dependent on population and consumption per capita, while the consumption per capita is a comprehensive factor and it changes over time because of the variation of the recycling rate, technical change, as well as people's disposable income.. What are the factors affecting timber consumption according to evidence from the past? Are there any policies affecting timber consumption in U.S. or not, when it comes to the sub-prime loan crisis on the housing sector? This brings out the need to examine the factors affecting the consumption of different products from the evidence of history data. Such an exercise is important to know what are the variables or policy instruments imposing impacts to different products.

On China side, due to the vast application of timber in industries like furniture, paper and pulp, housing construction and decoration, there are a great number of factors affecting timber consumption. For example, population, industry demand, and international trade. The research on this issue is important to know what are the variables or policy instruments imposing impacts to timber products.

2. Forest resources in China and U.S.

According to the seventh national forest resource survey (State Forestry Administration, 2004-2008), the forest area in mainland of China is 193.33 million ha, the forest coverage is 20.36% of total territory, the forest stock in terms of forest is 133.63 million m^3. the area of natural forest is 119.69 million ha with the forest stock of 11402 million m^3, the plantation area is 61.69 million ha with volume of 1961 million m^3， which rank the first place in the world. Because of the relatively young age structure of the plantation, China still needs large amount of timber from outside. On the other hand, China, a country with 19 percent population of the world has about 5 percent forest of the world, consumes about 25 percent industrial wood of the world. It is not easy for China to be self-sufficient in timber in a short run, but in a long run, the plantation will be the back up for China to be domestic-sufficient in forest sector.

While according to the forest facts (USDA, 2009), the forest area in U.S. is 303.93 million ha, the forest coverage is about 33% while the forest stock is 26393 million m^3. Forestry issues are of considerable significance to the United States, which has 5 percent of the world population and consumes 27 percent of the world's industrial wood products. Although domestic timber inventory is only 8 percent of the world total, 76 percent of U.S. consumption of industrial wood comes from domestic supplies.

Fig.1 gives the comparison of U.S. and China in population and forest resources, which shows the contrast of U.S. and China in forest resource. With almost the same territory with China, U.S. is more abundant in forest resource.

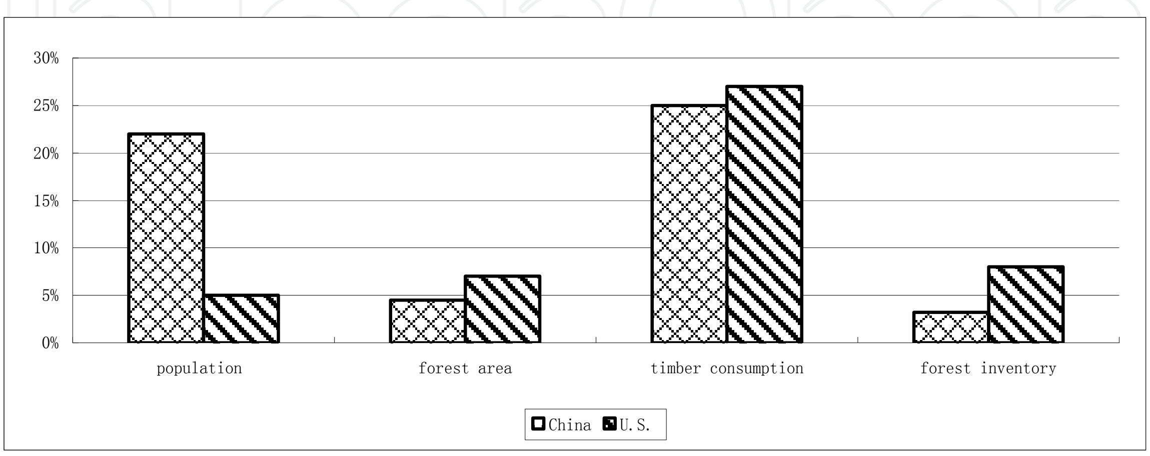


Fig. 1. Comparison of U.S. and China in social and forestry sector

2.1 Timber consumption in China and U.S.

In a global context, United States and China are both among the biggest timber consumers. The timber consumption per capita of U.S is 2.01 m^3 on average, almost 3.2 times of the average level in the world (State Forestry Administration, 2008). Because the large population, though the per capita level of China is relatively low about 0.24 m^3, China consumes lots of timber(see Fig. 2 and Fig. 3). Also the historical trends indicate that China's timber consumption is in rapid increase, while in the U.S. the consumption in the last two decades is in fluctuation mode, a bit increase compared with past.

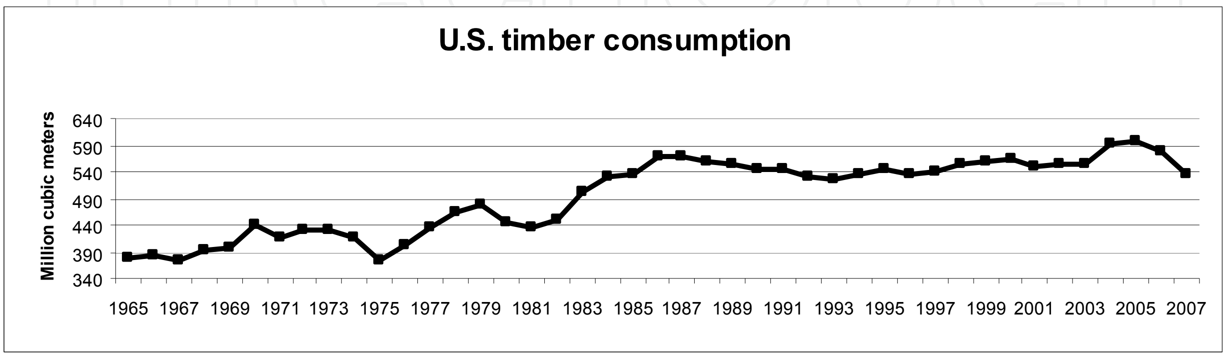


Fig. 2. U.S timber consumption

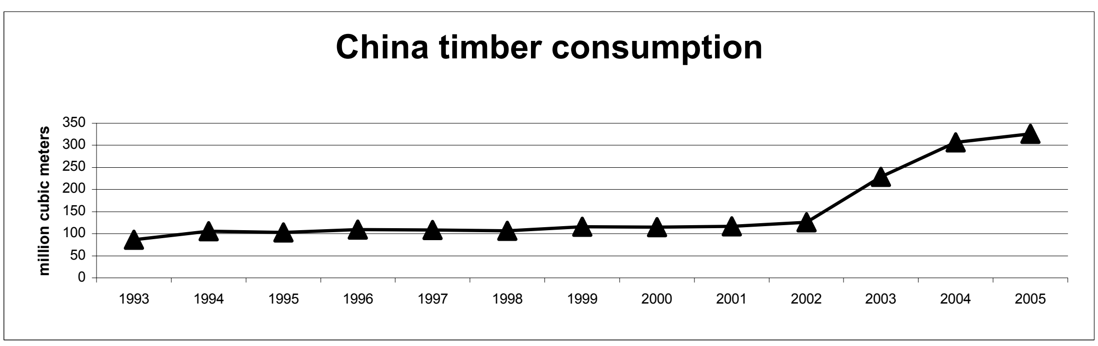


Fig. 3. China timber consumption

Furniture manufacturing, paper making and house construction are the three most timber-consuming industries in China. Furniture accounts for about one third of the total consumption. The rapid development of furniture industry enables China to be the No. 1 wood furniture export country since 2005. The quick increase of new house starts contribute to the timber consumption and log import increase. The average annual increase of timber consumption in newly-built house construction and interior decoration is over 20% since 2000. Paper making is on the rapid increase as well, the timber consumption by roundwood equivalent increase from 31million m^3 in 2000 to nearly 80 million m^3 in 2007.

Fig. 4 shows the dynamic share of the main industries in timber consumption in China.

New housing construction accounts for more than one third of U. S. softwood lumber and structural panels consumed about 10% volumes of other softwood and hardwood products, strengthened considerably in 2005, but declined soon after 2005. Housing starts of single family units led the increase and multi-family housing (see Fig.5). New housing and repair and remodeling drive the wood product demand, unfortunately it did not maintain the strong trend after 2005. However, investment in residential repair and remodeling rose to 226,359 million dollars, increasing by about 6.12% in 2006, while almost stabilized in 2007. The data collected by United States Census shows the average size of new single family home increase considerably. In the last 50 years, the size of new single-family home doubled.

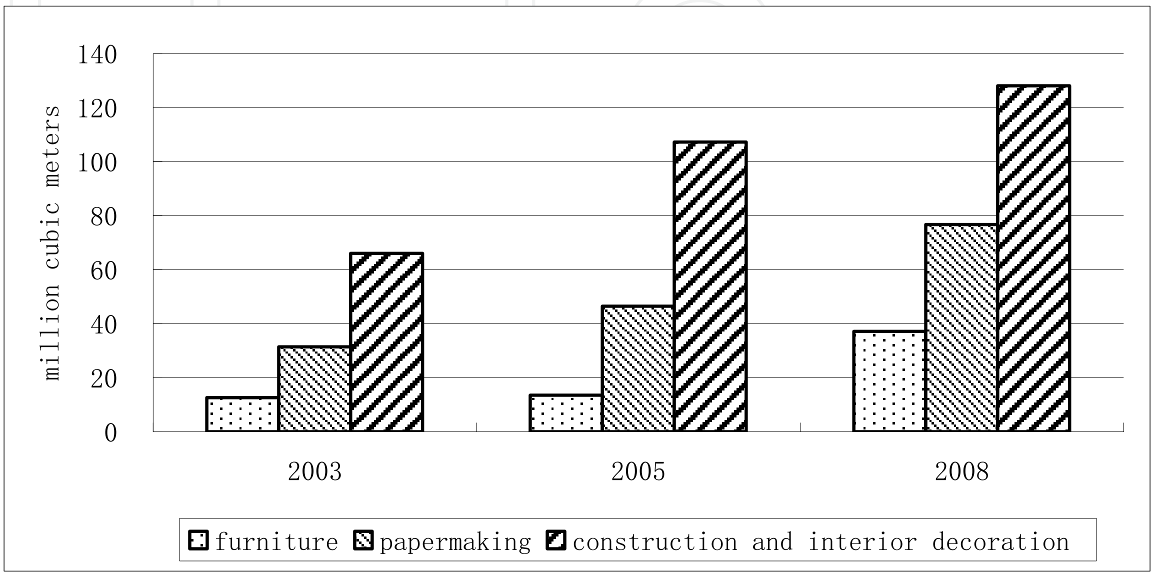
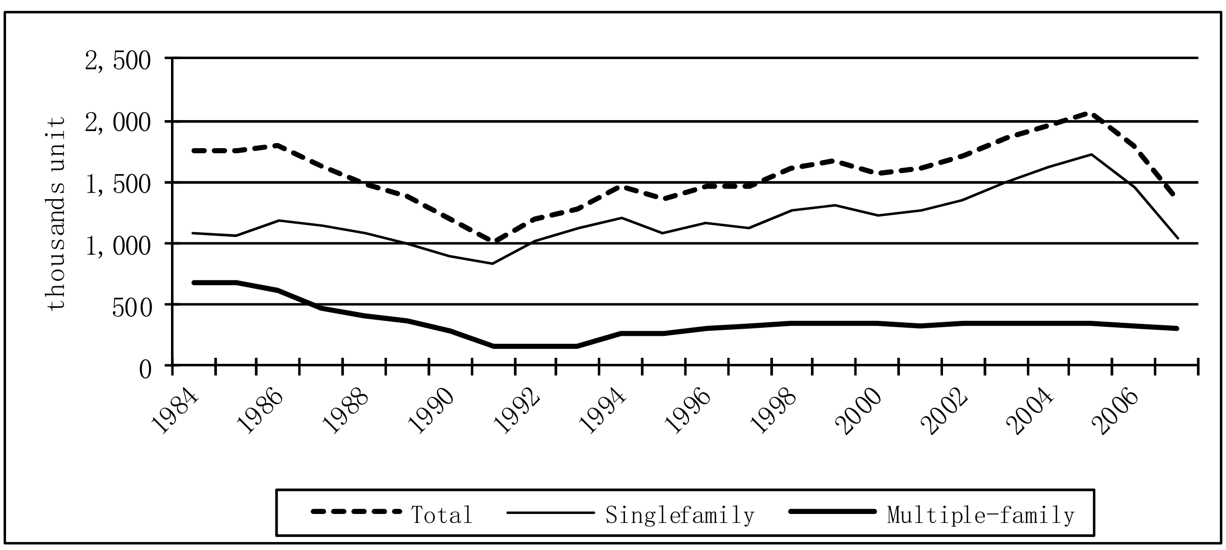


Fig. 4. Timber consumption of main wood related industries in China



Data source: U.S. Department of Agriculture

Fig. 5. Housing starts in U.S. by type 1984-2007

The timber consumption patterns are quite different in China and U.S. The former is more industry-oriented and the latter is more domestic construction related. The following work in section 3 and 4 will take a deep insight to the question what indeed are the factors affecting the timber consumption in both countries.

2.2 Previous research

In the literature, quantitative analysis and forecasting of forest product markets started from 1950s, based mostly on pure time-series analysis. Considerable improvements have been made in the theoretical issues of models, statistical estimation methods and the coverage of datasets. Some of previous studies tried to estimate the elasticity of different forest products like round-wood, pulpwood and newsprint. For a particular country or groups of countries (Hetemaki *et al*. 1992；Nebebe *et al*,1992) carried a study on Nirgeria and applied international consumption function to predict the demand and supply requirements (disaggregated product types) by using cross-section data of different countries, taking income and population as exogenous variables. Few studies (Rao, 1990; Rai, 1988) forecasted the demand of forest products in India using time series analysis. Although the above studies helped decision makers in estimating the demand for timber products, they ignored some of the important factors (population growth, economic condition, technical change, substitute materials) that affected the overall consumption and hence had limited utility in projecting the future requirements and the model result is hard to interpret (Samprit, 2000).

Few studies paid attention to variable selection and the interaction between variables. Since the initial set of independent variables is usually quite large selected subjectively and a number of coefficients will most likely have been estimated by Ordinary Least Squares methods (Forward, Backward or Stepwise approaches provided by most standard statistical programs). Although partial least squares regression (PLS) and principal component regression (PCR) provide good results, the problems still cannot be solved efficiently (Johan *et al*, 1998). More recently, several modified PCR and PLS methods have been proposed, for example a hierarchical PCA (HPCA), a consensus PCA (CPCA，a hierarchical PLS (HPLS) and a multi-block PLS (MBPLS) (Svante *et al*,1996).These methods divide the set of independent variables into multiple blocks according their physical context and try to explain the dependent variables from different dimensions, in order to solve regression by multi-block independent variables. However, these methods usually synthesize the information by extracting components from each block, then explain the dependent variables by components, but do not provide a variable selection in each block in advance. The initially selected independent variables differ in explanatory power and there may be severe collinearity existing in between. Therefore, other studies (e.g. (Wang Huiwen 2008, Lanhui Wang & Huiwen Wang, 2008) have proposed a solution which selects the main independent variables in each block, and then implement PLS regression on these variables. The present study attempts to apply this approach to timber sector in both countries and tries to find the statistical evidence between consumption of timber products and socioeconomic variables grouped into multiple blocks in order to see the difference in timber consumption pattern.

3. Methodology

3.1 The Schmidt orthogonal transformation and PLS method: Our theoretical basis

To begin, we introduce the Schmidt orthogonal transformation method to explore whether the Gauss_Markov assumption can be rejected if any group of independent variables were transformed by the Schmidt orthogonal transformation. After that, we present the PLS method.

3.1.1 The Schmidt orthogonal transformation and its reverse transformation

The proof of the following theorems is provided by Hao (2009).

Theorem 1: Any set of nonlinearly correlated vectors $x_1, x_2, \cdots, x_s$ can be transformed into a set of orthogonal vectors by a Schmidt transformation.

$$\begin{aligned} z_1 &= x_1 \\ z_2 &= x_2 - \frac{x_2' z_1}{z_1' z_1} z_1 \\ z_3 &= x_3 - \frac{x_3' z_1}{z_1' z_1} z_1 - \frac{x_3' z_2}{z_2' z_2} z_2 \\ &\cdots\cdots \\ z_s &= x_s - \sum_{k=1}^{s-1} \frac{x_s' z_k}{z_k' z_k} z_k \end{aligned} \tag{1}$$

Based on the theorem 1 and theorem 2, we prove the corollary 1 and get the reversal transformation of of Schmidt transformation.

Corollary1: For any variable set $x_1, x_2, \cdots, x_p$, with rank s where $s \le p$ the set $z_1, z_2, \cdots, z_p$ can be obtained. Of this set, there are s orthogonal vectors, while the remaining *p-s* vectors are zero vectors after the Schmidt transformation. For clarity and convenience in later discussion, we called z_j the Schmidt variable and the variables corresponding with z_j ,i.e., x_j are called variables related with z_j. There are two functions of a Schmidt orthogonal transformation: the first is an orthogonal decomposition of the information of the variable set and the second function is to exclude those variables not related with the Schmidt variables (these are the *p-s* vectors that changed into zero vectors).

Proof: Inverse Proof . If corollary 1 is not true, for any variable set $x_1, x_2, \cdots, x_p$ let

$$\begin{aligned} z_1 &= x_1 \\ z_j &= x_j - \sum_{k=1}^{j-1} \frac{x_j' z_k}{z_k' z_k} z_k, \quad j = 2, \cdots, p \end{aligned} \tag{2}$$

If there is $s+1$ non-zero vectors, it is easy to prove that they are orthogonal in between, while since the rank of is s, here comes the contradiction. Therefore, the corollary 1 is proved.

Theorem 2: For any variable set $x_1, x_2, \cdots, x_p$ with rank s , where $s \le p$ after the Schmidt transformation, there is a non-zero orthogonal vector $Z = (z_1, z_2, \cdots, z_s)$. In general, we assume the variables related to $z_1, z_2, \cdots, z_s$ are the set $x_1, x_2, \cdots, x_s$, denoted as $X = (x_1, x_2, \cdots, x_s)$. As well, we define

$$r_{jk} = \frac{x_j' z_k}{z_k' z_k}, \quad j = 2, \cdots s \ ; \ k = 1, \cdots, s-1$$

i.e. the transformation matrix of X and Z is R.

$$\tilde{R} = \begin{pmatrix} 1 & r_{21} & r_{31} & \cdots & r_{s1} \\ 0 & 1 & r_{32} & \cdots & r_{s2} \\ 0 & 0 & 1 & \cdots & r_{s3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & 1 \end{pmatrix}_{s\times s}$$

The reversal transformation of Schmidt transformation is as follows:

$$Z = X\tilde{R}^{-1} \quad (3)$$

Prove: neglect those zero variable vectors after Schmidt transformation $x_{s+1}, x_{s+2}, \cdots, x_p$, the matrix form of Schmidt transformation is:

$$(z_1, z_2, \cdots, z_s) = (x_1, x_2, \cdots, x_s) - (z_1, z_2, \cdots, z_s)\begin{bmatrix} 0 & r_{21} & \cdots & r_{s1} \\ 0 & 0 & \cdots & r_{s2} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 0 \end{bmatrix} \quad (4)$$

From (4), it can be deduced that

$$(z_1, z_2, \cdots, z_s)\begin{bmatrix} 1 & r_{21} & \cdots & r_{s1} \\ 0 & 1 & \cdots & r_{s2} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} = (x_1, x_2, \cdots, x_s) \quad (5)$$

Obviously, $\tilde{R}$ is a reversible matrix. Therefore the conclusion of theorem 2 can be obtained

According to theorem 2, if carrying out regression on y Schmidt variables $Z = (z_1, z_2, \cdots, z_s)$, the model will be:

$$\hat{Y} = Z\hat{\beta} \quad (6)$$

Then if reverse the model to the regression y on $X = (x_1, x_2, \cdots, x_s)$, it will be

$$\hat{Y} = X\tilde{R}^{-1}\hat{\beta} \quad (7)$$

3.1.2 The Schmidt orthogonal transformation and the Gauss-Markov condition in OLS

In classical multiple linear regression, y is denoted as the dependent variable and $x_1, x_2, \cdots, x_p$ as the set of independent variables and the regression model is

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p + \varepsilon \quad (8)$$

We take the variables transformed by the Schmidt transformation as our independent variables and then regress y on this set. It is easily proven that in model (8), if we regress y on $z_1, z_2, \cdots, z_s$, the Gauss-Markov condition can be satisfied.

From this discussion, the parameter test and model evaluation method can be applied directly in the regression of y on $z_1, z_2, \cdots, z_s$.

3.1.3 Introduction of PLS regression method

Assume there is one dependent variable denoted as y_1 and p independent variables denoted as $\{x_1, x_2, \cdots, x_p\}$ for a set of n observations, which provides us with the two following matrices: $X = [x_1, x_2, \cdots, x_p]_{n\times p}$ and $Y = [y_1]_{n\times 1}$. PLS extracts the component t_1 from X, i.e., t_1 is a linear combination of $x_1, x_2, \cdots, x_p$. Two requirements should be met during extraction:

1. t_1 should carry as much as possible the variance information on variation of each matrix;
2. the correlation of t_1 and y_1 should be maximum.

These two requirements state that t_1 should represent most the information of matrix X, while t_1 should possess the greatest power of explanation towards y.

After the first component is extracted, PLS will implement the regression of X on t_1 and the regression of Y on t_1. If the regression model has reached a satisfactory level of precision, the algorism terminates. Otherwise, the residuals, after the extraction of X and Y, are regressed on t_1 for a second time. This step is repeated until a required level of precision is reached. If there are m components, i.e., $t_1, t_2, \cdots, t_m$ extracted from X, then y_1 is regressed on these m components. The model is then expressed in terms of y_1 and $x_1, x_2 \cdots x_p$.

3.2 PLS regression of multi-block variables based on the Schmidt transformation

Given the theory introduced in the last section, we now present the PLS regression method of multi-block variables, based on the Schmidt transformation.

We begin by standardizing the variables and denote the standardized dependent variables as y and the independent variables as x_{ij}, $i = 1,2 \cdots m,$, where m is the number of independent variables in the set and $j = 1,2 \ldots p_i$, is the number of variables in set i. The specific steps are given as follows:

Step 1. Regress y on each variable x_{1j} ($j = 1,2 \ldots p_i$,) in set 1, we choose (Or the algorithm chooses) the Schmidt variable with largest t-value into the model. Assume $z_{11} = x_{11}$, then carry out the Schmidt orthogonal transformation of the other with z_{11} and let :

$$z_{1j}^2 = x_{1j} - \frac{x'_{1j} z_{11}}{z'_{11} z_{11}} z_{11}, \ j = 2,3,\cdots,p_1 \tag{9}$$

Step 2. Carry out a bi-variate regression of y on $z_{11}$and z_{1j}^2, $j = 2,\cdots,p_1$, choose the Schmidt variable with the largest t-value into the model . Let the related variable with z_{12} be x_{12}.

Step 3. Let

$$z_{1j}^3 = x_{1j} - \frac{x'_{1j} z_{11}}{z'_{11} z_{11}} z_{11} - \frac{x'_{1j} z_{12}}{z'_{12} z_{12}} z_{12}, \ j = 3,4,\cdots,p_1 \tag{10}$$

Do a tri-variate regression of y on z_{11}, z_{12} and $z_{1j}^3, j = 3,4 \cdots p_1$ and select the Schmidt variable with the largest t-value for introduction into the model.

Step 4. Repeat steps 1 to 3, until no more variables outside the model can pass the t test. Then the first subset of regressions s_1 can be obtained, i.e., those variables related to the Schmidt variables such as z_{11}, z_{12}). s_1 is called the first main variable subset of the first block of variables

Step 5. For subset i ，repeat steps 1 to 4 and make a variable selection for each block of variables. Then the final main subset can be obtained as $s = s_1 \cup s_2 \cup \cdots \cup s_m$.

Step 6. mplement PLS regression of y on the variables included in s, then the regression model is as follows：

$$\hat{y}_i = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \cdots + \hat{\beta}_k x_k \tag{11}$$

Step 7. Reverse the set of standardized data into the original their original scale. Then the final result can be obtained.

4. Dataset and result

Table 1 and table 2 give the variables for each country. The data used here is time series data, for U.S 1965-2007; for china 1993-2005 because the dataset is incomplete when compared with U.S side and the two countries have different national forest survey timing. The independent variables are grouped into three blocks related with macro economy, industry and international trade which are the main factors affecting timber demand and supply.

Block	Independent variables included	Symbol and unit
s_1 Macro-economy	GDP per capita	x_{11} , billion in 1996 dollars
	Population	x_{12} , million persons
	Personal disposable income	x_{13} , billion in 1996 dollars
s_2 Industry	Expenditure on housing maintenance	x_{21} , billion in 1996 dollars
	Expenditure on new housing	x_{22}, billion in 1996 dollars
	construction	x_{23}, percentage
	Mortgage rate	x_{24} , unit
	Housing stars	x_{25} , square feet
	One family house average size	x_{26} , square feet
	Multi-family house average size	x_{27} , percentage
	industry index	
s_3 International Trade	Exchange rate with Yuan	x_{31} , ratio
	Exchange rate with Euro	x_{32} , ratio
	Exchange rate with Canadian dollar	x_{33} , ratio (before 1999, European Currency Unit is used)

Table 1. Independent variables for US timber consumption

By using the method proposed above (Lanhui,Wang&Huiwen,Wang, 2008), following the detailed steps, the main factors affecting the U.S. and China were captured. For U.S timber sector, the factors affecting timber consumption are: GDP per capita(x_{11}), population (x_{12}), expenditure in house maintenance (x_{21}), among them, population is the most powerful drive. The results are shown as follows:

U.S.:
$$\hat{y} = 2013.48 + +19.06x_{11} + 1029.5x_{12} + 42.18x_{21} \tag{12}$$

China:
$$\hat{y} = 1356.76 + 0.21x_{13} + 2.15x_{23} \tag{13}$$

Block	Independent variables included	Symbol and unit
s_1 Macro-economy	GDP	x_{11} , billion in 1990 RMB
	Output of manufacturing industry	x_{12} , million Yuan in 1990 RMB
	Output of construction industry	x_{13} ,million Yuan in 1990 RMB
	Out put of secondary industry	x_{14} ,million Yuan in 1990 RMB
	Personal disposable income	x_{15} ,Yuan/year
s_2 Industry	Paper and paper board Production	x_{21} , million tons
	Floor area for new housing	x_{22} , million square meter
	Wood panel production	x_{23} , million cubic meters
s_3 International Trade	Exchange rate with US dollar	x_{31} , ratio
	Exchange rate with Euro	x_{32} , ratio (before 1999, European Currency Unit is used)

Table 2. Independent variables for China timber consumption

The fitting charts can be seen in Fig.6 .

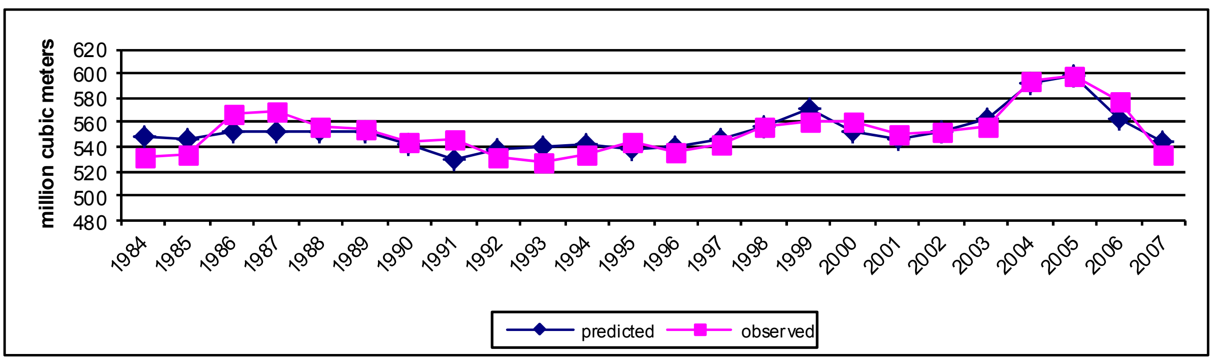


Fig. 6. Fitting chart of U.S timber consumption

For China , the determinants are output value of manufacturing industry (x_{12}) and paper and paper board production (x_{21}) and they have a positive effect on timber consumption. The fitting chart can be seen in Fig.7.

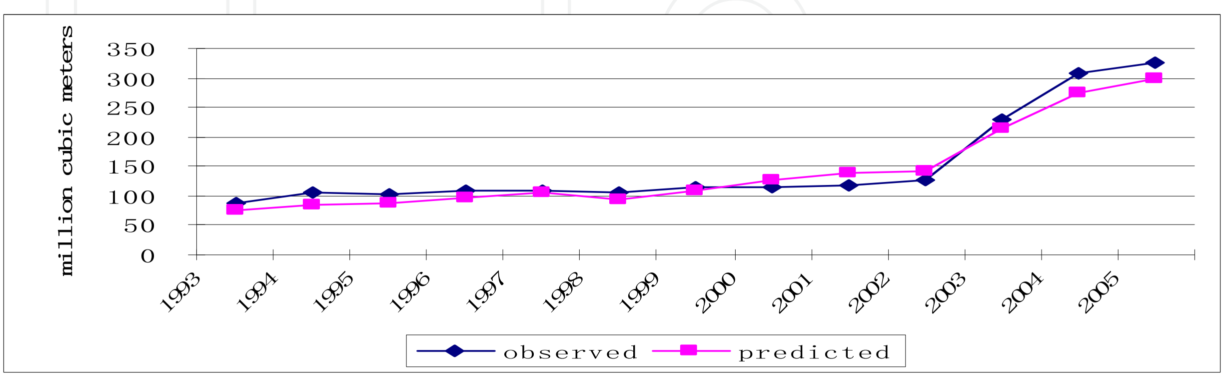


Fig. 7. Fitting chart of China timber consumption

5re the main factors affecting timber demand and supply.bundant in forest resource. The results show different timber consumption pattern in U.S. and China. China is more industry driven but U.S. is more housing construction driven. Different driving forces explain the different consumption patterns in the two countries. Furthermore, it is foreseeable that the long term the factors affecting timber consumption will not change the increase trend abruptly so the timber consumption patterns will continue for a relative long period respectively in the long run in both countries. Given the growing environment concerns, China will confront more difficult timber trade situation to satisfy her own increasing domestic demand. U.S. will be mostly self-sufficient in timber supply.

5. Discussion

China is more industry-oriented in timber consumption and the main factors are from processing-industry. While U.S. is mainly domestic consumption-oriented, the drives come from the GDP and population and housing sector. The result coincides with the "China-factory phenomena" in many timber-related industries. U.S. is more economy and population oriented in timber industries. This multi-block PLS method is effective for selecting the important variables. In a large dataset, the variable selection based method-Multiple Block Partial Least Squares is a good choice.

From the view point of forest resource, the different consumption patterns propose different prospective for both countries. China is a country lack of forest resources; while U.S. has abundant forests to support its domestic-consumption, though U.S. relies on import to satisfy its demand to some extent in order to meet the environmental concerns. The gap between production and consumption of China to a large degree was filled by the international trade. In view of the security of timber resources and promotion of environmental consciousness, many countries tightened or are trying to tighten the timber trade policy. For example, Russia increased its log export tariff to 80% since January 2010, this policy affects many countries in the world especially its neighboring country China, whose nearly 70% log import is from Russia. It is hard for China to source the timber overseas . So the fast growth plantation is a feasible choice. So far it seems underperforming in terms of quantity and quality, it doesn't follow the original ambitious goal about 13 million ha by 2015 with supply capability of 130 million m^3(China report, 2002). Compared with U.S, China's timber industry needs to enlarge the forest investment to guarantee sustainable timber supply. The pressure of forest resource in both countries are quite different. On the U.S. side, it can rely on its own forest resource for timber and environmental system in a long run. The feasible way for China is to follow the steps of U.S. to be self-sufficient and environmentally-friendly consumption mode in the future.

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This book is dedicated to global perspectives on sustainable forest management. It focuses on a need to move away from purely protective management of forests to innovative approaches for multiple use and management of forest resources. The book is divided into two sections; the first section, with thirteen chapters deals with the forest management aspects while the second section, with five chapters is dedicated to forest utilization. This book will fill the existing gaps in the knowledge about emerging perspectives on sustainable forest management. It will be an interesting and helpful resource to managers, specialists and students in the field of forestry and natural resources management.

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