Int. J. Production Economics 169 (2015) 99–109

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Factor substitution and procurement competition for forest resources in Sweden

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ARTICLE INFO

Article history:
Received 8 April 2014
Accepted 27 July 2015
Available online 3 August 2015

Keywords:
Translog cost function
Elasticity
Substitution
Forest industry
Heating industry

ABSTRACT

The utilisation of forest resources in the energy sector has been increasing, partly caused by economic policies introduced to reduce the emission of greenhouse gases. This in turn has led to an increase in the procurement competition between the forest industries and the energy sector. A translog cost function approach is used to analyse the factor substitution in the sawmill industry, the pulp and paper industry and the heating industry in Sweden over the period 1970–2008. The estimated parameters are used to calculate the Allen and Morishima elasticities of substitution as well as the price elasticities of input demand. The results indicate that it is easier for the heating industry to substitutes between by-products and logging residues than it is for the pulp and paper industry to substitute between by-products and roundwood. This suggests that the pulp and paper industry could suffer from an increase in the procurement competition. However, overall the substitutions elasticities estimated in our study are relatively low. This indicates that substitution possibilities could be rather limited due to rigidities in input prices. This result suggests that competition of forest resources also might be relatively limited.

1. Introduction

Forests provide a diverse set of services. It provides not only commercial products such as timber and biofuels, but also recreational services such as hunting and leisure. In addition, forests can mitigate carbon dioxide emission as carbon-sinks and provide natural habitat for wildlife and biological diversity. Thus, how we choose to utilise our forests is a complex issue where changes in one usage will affect the whole set of services through a web of interlinked relationships. In this paper we focus on the commercial aspect of forest resources, especially on the procurement competition for forest resources between energy and wood-based products (i.e., sawn wood, pulp and paper). The analysis is applied on Sweden which has a relatively large forest industry and a large share of bioenergy in its energy mix making it a relevant and interesting case study. For instance, the share of bioenergy in Sweden is approximately 22 per cent of the total energy production and 68 per cent of the fuel input consisted of forest fuel in the heating industry in 2010 (Swedish Energy Agency, 2012). This was mainly by-products from sawmills and smaller quantities of logging residues from the forestry (Statistics Sweden, 2010; Swedish Energy Agency, 2012).

Traditionally, forest resources have mainly been used in the forest industries, e.g. the pulp and paper industry and the sawmill industry. However, since the oil crises in the 1970s and the more recent awareness and attention to the effect of global warming, a growing number of policies aimed to reduce the emission of carbon dioxide have been introduced which either directly or indirectly stimulate an increasing utilisation of forest-based biofuels (Furtenback, 2009a). Fig. 1 illustrates the industry sectors in question and the flow of forest products between them relevant for the study. As a consequence the procurement competition for forest resources has increased and has been driven by the implementation of policy instruments and the substitution possibilities between different types of fuels in the energy sector. For instance, in the energy sector the primary mechanism to increase consumption of forest fuels is inter-fuel substitution rather than capital – energy substitution. High substitution elasticities in the heating sector indirectly increase subsequent substitution between fuels and will thus further intensify the procurement competition. Furthermore, the nature and extent of the inter-fuel substitution possibilities in the energy sector are important to the question of reducing carbon dioxide emission via the utilisation of bioenergy. Since the development of the future procurement competition is strongly connected to the substitution possibilities it is of interest to estimate and assess them for relevant industries and resources.

The purpose of this paper is to estimate substitution elasticities and analyse the procurement competition for forest resources between the sawmill industry, pulp and paper industry and the heating industry in Sweden. In order to assess the substitution possibilities for forest resources we estimate both Allen and Morishima elasticities of substitution by employing a translog cost function specification. This

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http://dx.doi.org/10.1016/j.ijpe.2015.07.029
0925-5273/

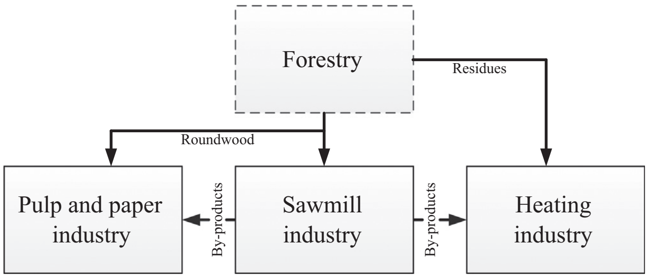

Fig. 1. The flow of forest products between industrial sectors.

approach, introduced by Christensen et al. (1973), has commonly been used to analyse characteristics of production structures in different industries. The data employed is annual time-series over the period 1970–2008.

2. Literature review

The translog cost functions is commonly used and there are several previous studies that employ the same methodological approach when analysing input substitution behaviour. For instance, Lundmark and Söderholm (2003) employ a translog cost function approach to estimate the Swedish own- and cross-price elasticities of wastepaper demand and examine structural changes in demand behaviour over time. Henriksson and Lundmark (2013) analyses altering energy demand patterns and energy factor substitution possibilities over time in the pulp and paper industry using a translog cost function. There are also related studies analysing the demand behaviour of sawmill, pulp and paper and heating industries using other methodological approaches. However, these previous studies do not focus on analysing the substitution between the feed-stock inputs that the included industries are competing for. There are few studies at a European level in general and in Sweden in particular that analyse this on a higher resolution. The related studies are summarised in Table 1 highlighting results relevant for this study.

There are relatively few studies on the input substitution behaviour for the sawmill industry. Nagubadi and Zhang (2006) analyse the Canadian sawmill and wood preservation industry between 1958 and 2003. They include labour (production and non-production), machinery and equipment (M&E), plants and structure (P&S), fuel, electricity and material in a translog cost function. Both Allen and Morishima substitution elasticities as well as the own-price and cross price elasticities of demand are reported. Their results indicate that substitution possibilities exist between production labour and M&E capital as well as between production labour and materials. In addition, they find complementary relationships between capital and energy, between non-production labour and P&S capital, and between materials and fuels. Geijer et al. (2011) constructs a model of the Swedish forest sector including four actors (forestry, pulp and paper industry, heating industry). The model employed consists of demand and supply functions in a general equilibrium setting and the data set includes annual time series observations and spans from 1966 to 2006. The inputs included for the sawmill industry are: timber, energy and labour; for the pulp and paper industry: pulpwood, energy and labour; and for the heating industry: wood fuel, oil and labour. The demand elasticities reported are the own-price elasticity for the respective industry's forest raw material input and the cross price elasticity for between the forest raw material inputs and energy and labour. Thus, neither the own-price elasticities for labour and energy nor all the cross price elasticities are given. In addition, the measures of substitution elasticities are not calculated in this study.

There are several studies of the Swedish pulp and paper industry that calculate the price elasticities of demand. Lundgren and Sjöström (1998) construct a dynamic factor demand model for the pulp industry and employ plant level data for the period 1972–1990. Short and long run demand elasticities are calculated for pulpwood, labour, electricity and capital. Brännlund and Lundgren (2007) develop an econometric partial equilibrium model for the Swedish industrial sector where the pulp and paper industry is included. The data set contains firm level data between 1991 and 2005. The objective of the study is to evaluate potential effects of an emission trading system on the Swedish industry sector. The inputs included in the pulp and paper industry is labour, capital, electricity and fuel. Demand elasticities are reported for each industry separately but only discussed on an aggregated level. Henriksson (2010) investigates the structural change in the pulp and paper industry by employing a flexible translog cost function. The data set consists of plant level data for the period 1974–2005. The inputs included are labour, electricity and capital. Demand elasticities for three sub-periods are reported. The study by Geijer et al. (2011) do, as mentioned previously also include some demand elasticities for the pulp and paper industry. None of these studies do however report the elasticities of substitution.

Previous studies of the input substitution in the heating industry have focused on the inter-fuel substitution. Brännlund and Kriström (2001) analyse the effects of changes in the taxation system on the heating industry. They estimate plant-specific production functions using a data set for the period 1989–1996. The inputs included are biofuels, fossil fuels (including oil, coal and natural gas), electricity and other fuels (including for example waste, peat and industrial hot water). Demand elasticities for four different plant sizes are reported. Brännlund and Lundgren (2004) analyse the inter-fuel substitution in heating plants. They employ a cost share linear logit model. The data set includes plant level observations for the period 1990–1996. The inputs included are wood fuel, non-gaseous fuel, gaseous fuel and other fuels (including for example waste, peat and industrial hot water). Both short and long run demand elasticities are reported. As for the sawmill industry and pulp and paper industry Geijer et al. (2011) do also report the previously mentioned demand elasticities for the heating industry. Neither in this case do any of the studies reviewed report substitution elasticities.

3. Model specification

The primary interest is to analyse the substitution possibilities between forest resources in the Swedish sawmill, pulp and paper and heating industries. In order to do this, own- and cross-price elasticities as well as Allen and Morishima elasticities of substitution are estimated.

Twice-differentiable sector-specific production functions are assumed to exist. If the relevant factor prices and output levels are exogenous determined, the duality theory implies that the production functions can uniquely be represented by a cost function. A variable cost function is specified in order to capture desired production characteristics of the different industries. If instead a total cost function approach is used, the implicit assumption is made that the industries are in a static equilibrium. This might be a poor assumption for industries with a capital structure that has a long life-span, making adjustments to demand changes costly. This is particular true for heavy industries such as the ones included in this study where capacities are planned and built on long-term forecasts. Moreover, an excess capacity might be maintained to meet sudden increases in demand. Together, this implies that the capital stock might be quasi-fixed and that the industries are not in a static equilibrium. As a consequence, estimates based on a total cost function could be inaccurate, suggesting that a restricted variable cost function is more suitable when estimating the production structure of the pulp and paper, sawmilling and heating industries. The variable cost function is