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Supply and demand functions for global wood markets: Specification and plausibility testing of econometric models within the global forest sector

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ABSTRACT

Forests cover about one-third of the land surface on Earth. Currently, < 7.5% of this forest area is defined as planted forest. Removals from planted forests are shown to be responsible for about 45% of the global industrial roundwood production. It is therefore of great importance to study how the production of roundwood from planted forests could potentially influence the production of roundwood from natural forests and the global wood markets in general.

The objective of this study is to describe and specify the functioning and interdependencies of global wood markets and implement wood removals from different types of forests, such as planted or natural. In this study we use an econometric approach to analyze how global markets affect the amount of wood supply, demand and trade.

According to our results and with regard to roundwood supply, only removals from planted forest respond significantly positive to changes in the roundwood prices. The supply of all other roundwood products seems to be nearly inelastic. Regarding wood product demand, all products under consideration show significantly negative responses to changes in product prices.

To test the plausibility of our estimations, we implemented the computed elasticities in an economic partial equilibrium model. The results suggest that the nearly inelastic wood supply improves model simulations as the results better replicate historical data compared to the original model version.

1. Introduction

Forests cover about one-third of the land surface on earth. < 7.5% of the forest area is planted forest, which is defined as "… *predominantly composed of trees established through planting and/or deliberate seeding.*" (FAO, 2015). However, planted forests are responsible for about 45% of the global roundwood production (FAO, 2015 and Jürgensen et al., 2014). Planted forests have developed dynamically over the last decades. Since 1990, the area of planted forests increased about 64%, while the global forest area decreased about 3% (FAO, 2015). During the same period, the global demand for industrial roundwood increased by about 37% (consumption of industrial roundwood by FAO, 2017). Since the production of roundwood from planted forests is a relevant factor in the supply of wood, it is necessary to attain knowledge about the relationships between the quantity of roundwood harvested from planted forests, on the one hand, and the economic factors influencing it, on the other hand.

At present, there are only few studies which discuss market interactions of wood removals from planted forests. Carle and Holmgren (2008) provide a detailed outlook for the potential area and volume of planted forests using surveys and a deterministic model. Cubbage et al. (2014) estimate investment returns for timber plantation species via dynamic investment appraisal methods. Buongiorno and Zhu (2014) use a partial equilibrium model to discuss effects of shifts in wood supply caused by changes in planted forests. The present study follows this field of investigation and aims to provide further knowledge about economic effects on the quantity harvested from planted forests. However, markets were always determined by interdependencies between supply, demand and trade. Thus, the other objective of the present study is to determine global wood market functions, while simultanously characterizing the market behavior of roundwood harvested from planted and natural forests. To achieve this objective, an econometric approach is used to analyze the way in which market equilibria affect the amount of wood supplied, demanded and traded. Existing literature, explicitly covering all aspects of wood markets are rare. Two exceptions are Kangas and Baudin (2003) dealing with market analysis in European countries, or McKillop (1983), aiming at the improvement of global trade modeling. However, none of these

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studies consider different forest types for timber production. In contrast to the above mentioned and the present study, existing econometric studies, which base on a similar methodology, often concentrate on dependencies in partial aspects of wood markets, e.g., Turner et al. (2006) analyze the effect of prices on supply; Michinaka et al. (2011) estimate determinants on the demand side of global wood markets, and Turner and Buongiorno (2004) concentrate on relationships in imports. Even though the level of detail can increase within such isolated analyses, the interactions with other aspects of markets cannot fully be taken into account. The present study addresses the latter issue by considering possible market interactions. With this comprehensive approach we intend to enhance the plausibility of econometric estimation results with reference to supply, demand and trade elasticities. To prove the plausibility of econometric estimations we use a global economic partial equilibrium model which uses market elasticities to calculate the interactions between all segments of the wood market.

The study is organized as follows: First, data and methods are explained. Thereafter, the results are tested and validated using a global economic partial equilibrium model. Finally, a discussion and conclusion summarizes this study.

2. Methodology and data

2.1. Methodology

A simple but frequently approved way to analyze wood markets is to estimate the relationship between quantities and prices via Ordinary Least Squares (OLS). This method can be applied in cross country, time series or panel data. For global wood markets, data for the individual country level as well as time series information can be obtained. In such a panel, information about observed variables could vary across time or country level. This effect, called unobserved heterogeneity, can lead to inefficient and biased OLS estimators. Different methods can be used to avoid unobserved heterogeneity, e.g., Fixed Effects or Random Effects (Wooldrigde, 2010).

Fixed Effect Models (FE) try to explain heterogeneity across country levels by addressing individual specific constants. In general there are several approaches to estimating Fixed Effects, e.g.: The Within Estimator, the Least Square Dummy Variable Estimator (LSDV), or a First-Difference Model (FD). The Within Estimator and the LSDV Estimator differ in the theoretical approach but give practically the same results (Baltagi, 2008).

Eqs. (1) and (2) describe the Within Estimator and the First-Difference Model, with y as dependent and x as independent variables, β as coefficient and e as error term which covers minor influences. The vector which covers the individual data scale is illustrated with i, the time series in the data with t and country means with $\widetilde{y}_i = \frac{1}{T}\sum y_{it}$; $\widetilde{x}_i = \frac{1}{T}\sum x_{it}$; $\widetilde{e}_i = \frac{1}{T}\sum e_{it}$ (T = number of periods). Both methods eliminate the intercept, but they only achieve the same estimation results when panels with two periods are considered (Baltagi, 2008).

$$\text{Within Estimator:} y_{it} - \widetilde{y}_i = \beta(x_{it} - \widetilde{x}_i) + e_{it} - \widetilde{e}_i \tag{1}$$

$$\text{First} - \text{Difference: } y_{it} - y_{it-1} = \beta(x_{it} - x_{it-1}) + e_{it} - e_{it-1} \tag{2}$$

The decision which model should be preferred depends on a variety of factors. However, one important factor could be the presence of time-variant effects like non-stationarity (Wooldrigde, 2010). Time-variant effects, to some degree, can be handled by taking growth instead of total values. For this reason, in cases where non-stationarity appears, we use the FD instead of the Within Estimator.

The Random Effects method (RE) assumes that heterogeneity varies randomly across country levels. RE can be estimated via Feasible General Least Squares (FGLS) (Greene, 2007).

A Breusch-Pagan Test is conducted to test for the existence of unobserved heterogeneity (Breusch and Pagan, 1979), the null hypothesis is homoscedasticity. A Maddala-Wu Unit-Root test is conducted to investigate the existence of non-stationarity (Maddala and Wu, 1999), the null hypothesis is non-stationarity. Moreover, we use the Hausman test to determine whether or not unobserved effects were country specific (Hausman, 1978), in our cases the null hypothesis is that the RE model gives the best fit.

Additionally, we applied an analysis which increases the level of detail in estimations through a differentiation between time and income groups (Buongiorno, 2015). Three time periods and two income levels were selected. The time limits were chosen to cover effects caused by the collapse of the Soviet Union, and those which were caused by financial crises after 2007. Therefore, regarding the time horizons, three relatively symmetric periods were chosen: 1992 to 1998, 1999 to 2006 and 2007 to 2014. Because it is likely that the income level of a country influences domestic wood markets, we split the list of countries into high income and low income groups by the world's average GDP per capita (World Bank, 2017a, 2017b).

Price elasticities are parameters to describe the behavior of markets. However, such parameters have to be tested for their plausibility before relying on these econometric results. In the present study tests on plausibility were conducted with a method which can simultaneously deal with demand, supply, trade and its interactions: an economic global forest products equilibrium model. In literature, there are several models which fit in such procedure. Most models were built in partial equilibrium frameworks and depend mainly on input specifications, which define market reactions (Romer, 2012). In contrast, coefficients in the form of market elasticities play a major role in such models: *"… econometric methods may provide the necessary quantitative information for large-scale numerical models…"* (Toppinen and Kuuluvainen, 2010, p 5). Some examples of these numerical models are the Global Forest Trade Model (GFTM, Jonsson et al., 2015), the European Forest Institute-Global Trade Model (EFI-GTM, Kallio et al., 2004) or the Global Forest Products Model (GFPM, Buongiorno et al., 2003). Based on those model frameworks, it is possible to simulate the behavior of wood markets caused by international developments as, e.g., described for the GFPM: *"The GFPM is designed mainly as a policy analysis tool, to project the general future trends in quantities and prices at different stages of transformation, under different scenarios."* (Buongiorno et al., 2003, p 39).

In order to test our econometric estimation results, the present study uses a modified and extended version of the original GFPM as global partial equilibrium model. The GFPM, as originally described by Buongiorno et al. (2003), was chosen due to its open source character and its structure, which bases on FAOSTAT (FAO, 2017) data (Fig. 1).

Unlike in many other studies, the present study does not apply the GFPM to forecast market developments for policy analysis. We use the inherent model structure to plausibilize the wide range of market functions estimated below. For this purpose, the original GFPM had to be modified in order to match all aspects of markets considered in the study. In particular, the modifications target a separation of coniferous and non-coniferous industrial roundwood and sawnwood as described in Schier et al. (2018). Additionally, three types of industrial roundwood removals were implemented: industrial roundwood removals from primary,[1] secondary[2] and planted[3] forests. A similar approach was already undertaken by Buongiorno and Zhu (2014), where planted forests were implemented through exogenous shifts in the supply of wood in seven world regions. However, timber and forest type

[1] Primary forests are defined as "naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed." (FAO, 2015)

[2] For secondary forests we used the FAO definition for "Other naturally regenerated forest": "Naturally regenerated forest where there are clearly visible indications of human activities." (FAO, 2015)

[3] For planted forests we used the FAO definition: "Planted forests are composed of trees established through planting and/or through deliberate seeding of native or introduced species. "(FAO, 2015)