Cointegration analysis of wood and bioenergy markets in Austria

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Overview

Wood and woody biomass are important energy sources in Austria. In 2019, about 32% of the gross domestic energy consumption (1,450 PJ) have been produced from renewables, thereof 55.7% from biomass (258 PJ, see also Figure I) (BMK, 2020). The Austrian legislation - called "Erneuerbaren-Ausbau-Gesetz" (EAG) - aims to increase the power consumption from biomass by 3.6 PJ until 2030 (BMK, 2021). In 2018, nearly 60% of the total wood consumption were used for energy, including by-products from wood processing industries (Strimitzer et al., 2020). Hence, the competition for wood as raw material is likely to intensify. Thereby, the utilization of industrial by-products is incentivised with consequences on product, energy and raw material markets as well as price developments. In particular, wood chips and sawdust as by-products of the sawmill industry are produced in relatively large amounts (Kunttu et al., 2020) at suitable quality for material and energy applications. Their current main utilization pathways are shown in Figure II.

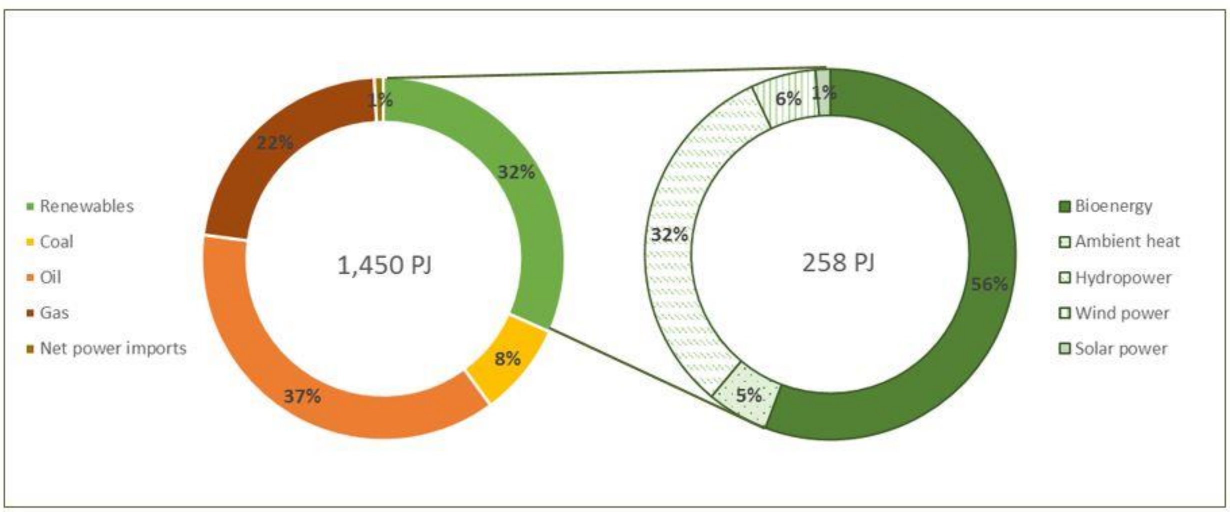

Figure I*: Austrian energy consumption by energy source in 2019 – 1,450 PJ in total (data source: BMK, 2020; own illustration)*

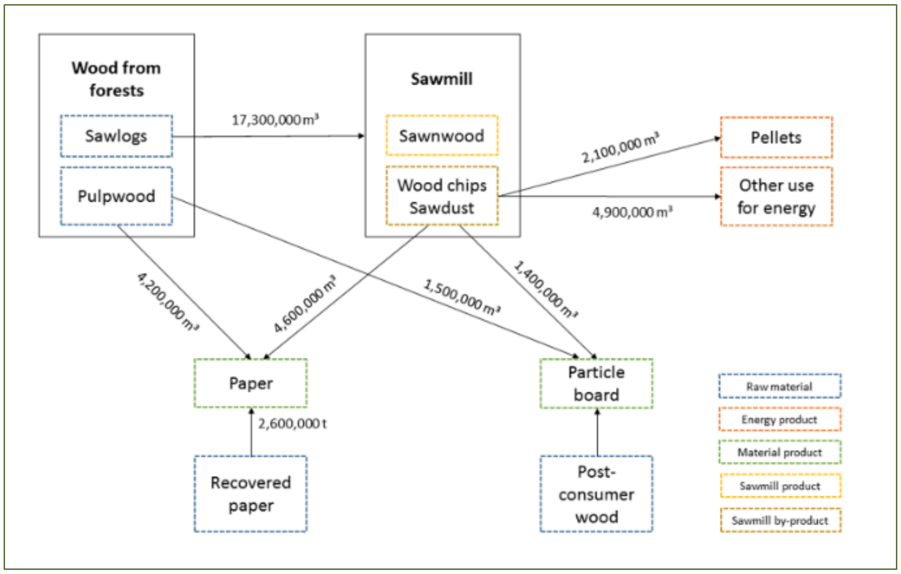

Figure II*: Wood utilization pathways in Austria with a focus on sawmill by-products. Data in m³ roundwood equivalent (data sources: Strimitzer et al., 2020; Austropapier, 2020; Association of the Austrian Wood Industries, 2020; own illustration)*

In recent years, sawmill by-product (SBP) prices have experienced dynamic developments, mainly influenced by processing industries. Before wood pellets entered bioenergy markets, SBP were mainly used by the paper and panel industry at relatively low prices. However, the European wood pellet market was growing rapidly in the last decades, mainly due to policies such as the Renewable Energy Directive (RED) and high prices for fossil fuels in the early 2000s (Olsson, 2009). SBP prices started to rise as the pellets industry entered the market (Kristöfel et al., 2014). The analysis of price developments requires tests of cointegration as prices are mostly not independent (Stroe-Kunold, 2005). Market integration should lead to increased market efficiency due to higher competition and opportunities of diversification (Olsson et al., 2011). Hence, analysing market integration (e.g. between wood and bioenergy markets as well as between bioenergy and fossil fuels) is important to understand the effects of the integration of Europe's energy markets promoted by the EU energy policies. Furthermore, the analysis of price cointegration can reveal the effects of existing policies. For instance, Rajcaniova et al. (2013) investigated which country is price leading in world's biofuel markets and which biofuel policy determines international biofuel prices. Moreover, cointegration of (fossil) energy markets has also been investigated before, for example for natural gas (Siliverstovs et al., 2005), coal (Wårell, 2006) and electricity (Zachmann, 2008). However, such a market integration cannot only occur in a spatial sense for one good, but also between different commodities or between products and raw materials. For example, Rajcaniova et al. (2013) highlight that biofuel and feedstock prices are closely related. Furthermore, price cointegration was found between wood pellets and sawmill by-products (Kristöfel et al., 2014). In contrast, cointegration was not found between refined wood fuels and industrial by-products as well as forest wood chips, both commonly used for energy (Olsson and Hillring, 2013).

Due to rather complex interlinkages in wood and bioenergy markets and the increasingly important role of SBP in material and energy markets, we provide an analysis of price cointegration for SBP. Several relationships are of interest: (1) Analyzing cointegration between SBP and roundwood markets allows to identify linkages of by-product to raw material prices. (2) Interlinkages between SBP markets and energy/material markets are of interest to reflect the position of material and energy products in the competition for raw materials. (3) Cointegration with crude oil was tested to assess the linkages of wood and bioenergy markets to fossil fuel markets. In addition, crude oil prices can have an influence on wood harvesting costs (Härtl and Knoke, 2014). By investigating these relationships, underlying influences of recent price developments can be supported with empirical evidence.

Methods

Econometric methods are employed to analyse price cointegration of wood and bioenergy markets in Austria using monthly price data listed in Table I. The period covered by all prices and thus used for analyses was January 2005 to November 2019.

***Table I**: Raw Data and sources*

Roundwood	
Sawlogs spruce/fir	Producer prices, nominal; source: Statistics Austria, 2020
Pulpwood spruce/fir	Producer prices, nominal; source: Statistics Austria, 2020
Sawmill by-products	
Wood chips without bark	Nominal; sources: Vienna Stock exchange, 2015; Timber Online, 2021
Sawdust	Nominal; sources: Vienna Stock exchange, 2015; Timber Online, 2021
Wood products	
A1 wood pellets	Consumer prices, nominal; source: proPellets Austria, 2021
Particle board	Wholesale price index, base January 2005; source: Statistics Austria, 2020
Fossil fuel	
Crude oil	Europe Brent Spot Price FOB; source: EIA U.S. Energy Information Administration, 2020

Statistical analyses were done using R Studio (RStudio Team, 2019), in particular the "tseries" (Trapletti and Hornik, 2020) and "urca" (Pfaff, 2008) packages.

The following statistical tests have been conducted:

Using the **Augmented-Dickey-Fuller (ADF) unit-root test** allowed to test the null hypothesis of stationarity for all time series listed in Table I. If the null hypothesis was rejected, first differences were built. If first differences are stationary, a time series is called integrated of order 1 or I(1) (Cryer and Chan, 2008). Engle and Granger (1987) introduced a concept called cointegration, which allows to jointly model two time series which are integrated of same order. If cointegration is present between two time series, there is a linear combination which is stationary, meaning a long-term balance between both of them. Deviations from this balance are only short-term (Engle and Granger, 1987). Hence, **the Johansen Cointegration test** was pairwise applied to the price data. If cointegration is present between two prices, there has to be a Granger causality as well, which can either be uni- or bi-directional. Granger causality means that past values of one price help to predict present values of another one (Lütkepohl, 2005). To analyse such a power of forecasting, the **Granger Causality test** was applied. Finally, **Vector Error Correction Models (VECM)** were estimated to investigate further the long-term and short-term behaviour of wood chips and sawdust prices. Therefore, cointegration relationships were taken into consideration. In general, a VECM can be written as (Karakas, 2017):

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_{p-1} \Delta y_{t-p+1} + u_t$$

In the equation, Δ denotes the first differences, Π and Γ are the model's parameters. If there are r cointegrating vectors, Π can be written as $\Pi = \alpha\beta'$, while α and β represent (K x r) matrices. K represents the dimensions of the process and r is the cointegration rank (Lütkepohl, 2005). The cointegrating vectors are contained in β, while α contains the adjustment parameters (Rajcaniova et al., 2013).

Results

According to the results of the ADF test as shown in Table II, the null hypothesis of stationarity can be rejected on a 1% significance level in all cases. Hence, all time series are non-stationary, but integrated of order 1. Therefore, all price combinations were tested for cointegration in a pairwise way (Table III).

Table II: Results of the Augmented-Dickey-Fuller unit-root test

	Prices (p-value)	**Returns** (p-value)
Sawlogs	-1.2014 (0.9038)	-5.8377 (< 0.01)
Pulpwood	-1.1677 (0.9091)	-4.5735 (< 0.01)
Wood chips	-1.6984 (0.7023)	-5.4856 (< 0.01)
Sawdust	-2.8863 (0.2058)	-6.2440 (< 0.01)
Wood pellets	-3.5043 (0.440)	-6.3969 (< 0.01)
Particle board	-2.5910 (0.3292)	-4.4350 (< 0.01)
Crude oil	-2.5336 (0.3532)	-6.285 (<0.01)

*Table III: Results of Johansen Cointegration Test. Critical values for *** 1% ** 5% and * 10% significance level: r=0 (no cointegration vector) ***19.19 ** 14.90 * 12.91; r≤1 (max. one cointegration vector) *** 11.65 ** 8.18 * 6.50.*

	Sawlogs	**Pulpwood**	**Wood chips**	**Sawdust**	**Wood pellets**	**Particle board**	**Crude oil**
Pulpwood							
r=0	12.06	-	-	-	-	-	-
r≤1	3.88						
Wood chips							
r=0	13.31	**18.34****	-	-	-	-	-
r≤1	4.79	**6.84***					
Sawdust							
r=0	12.00	10.85	10.71	-	-	-	-
r≤1	5.19	9.13	3.84				
Wood pellets							
r=0	13.49*	**16.31****	**19.34*****	**25.00*****	-	-	-
r≤1	3.86	**5.12**	**6.91***	**7.43***			
Particle board							
r=0	**18.94****	**18.94****	**17.70****	14.54*	**19.36*****	-	-
r≤1	**4.41**	**4.41**	**8.07***	5.96	**3.51**		
Crude oil							
r=0	8.80	8.61	8.0	10.36	11.62	8.66	-
r≤1	4.52	4.70	7.26	6.51	6.65*	2.36	

A significance level of 5% was taken into consideration for analysing price cointegration and further testing for Granger causality. According to Table III, highly significant price cointegration was found between wood pellets on the one side and particle board, pulpwood, sawdust and wood chips on the other side. Cointegration between product and raw material was found for particle board as well, namely with pulpwood and wood chips. Cointegration was not found between crude oil and all other prices. Hence, in this case there is no price cointegration between bioenergy and fossil fuels. As Granger causality has to be present between cointegrated time series, the Granger causality test was applied in the next step, with the results shown in Table IV. In this case, a significance level of 10% was taken into consideration.

*Table IV: Granger Causality Test. Null hypothesis: Time series 1 does not Granger cause time series 2. Significance level: *** 1%, ** 5%, * 10%*

Time series 1	Time series 2	p-value
Sawlogs	Particle board	4.799e-09***
Particle board	Sawlogs	8.525e-06***
Particle board	Pulpwood	0.09815*
Pulpwood	Particle board	6.748e-09***
Wood Chips	Pulpwood	2.863e-06***
Pulpwood	Wood Chips	0.02882**
Particle board	Wood Chips	0.03114**
Wood Chips	Particle board	0.0007673***
Particle board	Wood pellets	0.2778
Wood pellets	Particle board	0.0008148***
Wood pellets	Pulpwood	0.0137**
Pulpwood	Wood pellets	0.001315***
Wood pellets	Sawdust	4.396e-08***
Sawdust	Wood pellets	0.328
Wood pellets	Wood Chips	3.456e-08***
Wood Chips	Wood pellets	0.08538*

The relationships described by Johansen cointegration and Granger causality are jointly illustrated in Figure III. Regarding the categories wood products, sawmill by-products and roundwood, cointegration was found between all of them. In particular considering SBP, wood pellets have a dominant position, influencing both, wood chip and sawdust prices. The price developments illustrated in Figure IV show similar movements according to the results and thereby confirm the influence of wood pellet on SBP prices.

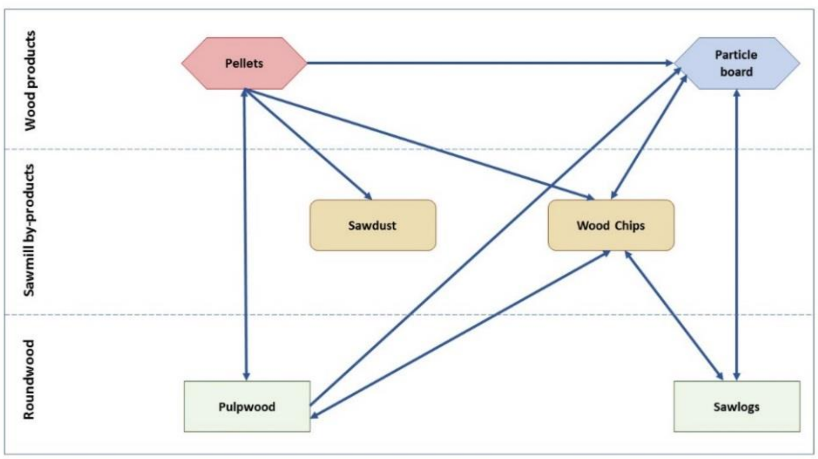

Figure III: Price cointegration in Austrian roundwood, sawmill by-product and wood product/bioenergy markets. Arrows represent the direction of Granger causality between cointegrated time series. (own illustration)

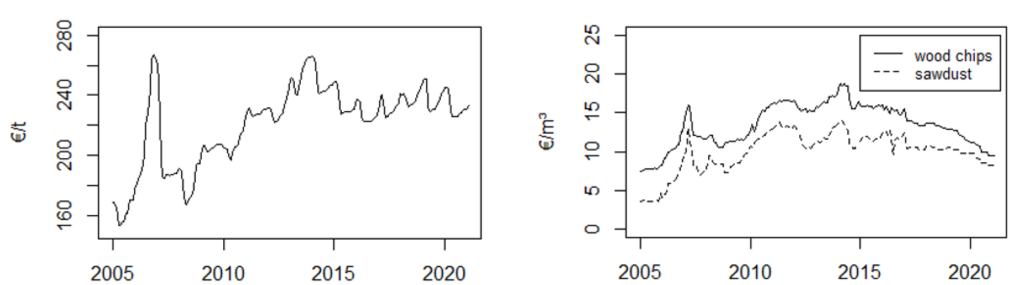

Figure IV: Price development of A1 wood pellets in €/t (left side) and sawmill by-products in €/m³ (right side) in Austria (data sources: proPellets Austria, 2020; Holzkurier, 2020; own illustration)

Cointegration and Granger causality were taken into consideration for the selection of explanatory variables in the VECM. Hence, sawdust prices were modelled with its own values as well as pellet prices. Accordingly, the Error Correction Term for sawdust is |0.2352|, which means that after short-term deviations, sawdust prices return to the long-term balance by 23.5% per month. After 3 months, more than half of the balance is regained. In comparison, deviations of wood chip prices are only reduced by 7.9% each month. Hence, it takes 8.5 months to regain the long-term balance. Explanatory variables are wood chip, pulpwood, particle board, pellet and sawlog prices.

Analysing price cointegration in Austrian wood markets delivers basic information about recent price developments and underlying influences. First, linkages between wood pellet (product) and SBP (raw material) markets have to be discussed.

The wood pellet market has benefited from the EU Renewable Energy Directive (RED). A first boost in pellet boiler installations has led to shortages in pellet supply. Hence, prices increased significantly in 2006/07. After expansion of capacities and a decrease in demand, prices dropped and stabilized again (Kristöfel et al., 2014). Currently, national subsidies promote the substitution of previously installed oil boilers by renewable energy systems. In addition, new installations are not allowed anymore as step to an energy transition. These measures induce a further boost in residential pellet boiler installations. Hence, wood pellets gained a dominant position over the last decades and thereby are determining SBP prices, for which similar movements can be observed. Through further price cointegration of wood chips with particle board and roundwood, pellet prices are indirectly influencing these markets as well. These empirical findings suggest that policies like the RED can have significant market effects in the Austrian forest-based sector. Such effects can be expected for the EAG as well. As new technologies will also enter the market, increasing use of industrial by-products and residues can mitigate shortages in raw material supply, but at the same time affect other markets.

However, after an increase of SBP prices due to the growth of the wood pellet market, prices experienced a significant decline in recent years. Two phenomena were possibly responsible for this decline: (1) High shares of calamity wood were available at low prices in recent years and thus represent a pressure on wood markets. (2) The Covid-19 crisis has led to restrictions in trade and shortages in roundwood supply and personel. Regarding 2020 onwards in Figure IV, there was obviously imperfect price transmission, thus sawmill by-product prices were more affected by Covid-19 consequences. Since wood chip prices are versatilely cointegrated, there are influences exerted from the product (pellets, particle board) as well as from the roundwood (sawlogs, pulpwood) side, which are reflected in a stronger decline in prices. This price shock is better mitigated by the sawdust market, as prices are mainly influenced by wood pellets, which are less affected by the crisis. Like also concluded by Schwarzbauer et al. (2013), the particle board industry is in general more affected by a global crises due to high export shares, while the pellets industry is less affected. In addition, the residential heating sector as big demander of wood pellets is not directly dependent on economic developments, but on other aspects like heating degree days. Hence, the wood pellet industry is able to better dampen the effect of the Covid-19 crisis on sawdust prices, while wood chip prices suffer more from influences exerted from other markets.

The cointegration between wood chips and pulpwood is not surprising as both are substitutes in some applications, for instance the particle board production. Wood chips and particle board are cointegrated with none of them being price decisive. This is due to pellet prices influencing both wood chip and particle board prices.

Conclusions

Based on the implications of this study the following conclusions can be made:

First, the concept of cointegration allows to provide empirical information to assess effects of policies and market shocks in the bioenergy sector, as it is well suited to investigate price transmission between distinct markets. Second, empirical evidence about price cointegration and price transmissions between raw material and product/bioenergy markets supports the efficient design of policies such as EAG and RED. Third, raw material markets can benefit from the promotion of products. For instance, the pellet market is less affected by the Covid-19 crisis and thus can have a stabilizing effect on other markets to some extent. This was demonstrated by the example of sawdust prices. Finally, complex interlinkages and price transmissions can both alleviate and reinforce effects like price shocks (e.g. caused by economic crises) to the forest-based sector in total.

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