ENERGY PRICE VOLATILITY: THE LINK BETWEEN FOSSIL ENERGY AND WOODY BIOENERGY

Robert Lundmark, Luleå University of Technology
Professor in economics
Luleå University of Technology
Economics unit
Email: Robert.Lundmark@ltu.se
Phone: +46 920 492346

Overview

One of the arguments for promoting renewable energy is that they are expected to lower energy price volatilities, which promotes stable economic conditions for the energy system. This argument rests on the assumption that prices for fossil energy are more volatile compared to renewable energy sources. This is usually the case for capital-intensive energy sources such as solar and hydropower. They are considered less price volatile because their operating costs (i.e., fuel cost) are low. However, bioenergy is similar to fossil fuels in the sense that their fuel cost share is usually large. Thus, is the argument of expected lower energy price volatility valid even if a large share of the renewable energy is bioenergy? That is, are bioenergy price less volatile than fossil fuel prices?

Price volatility is not consistently defined in the scientific literature. Several different methods with respect to concepts, data and estimation procedures have been applied (Regnier, 2007). Commonly though is that price volatility is associated with risk. A commodity with high price volatility will increase the risk and can be interpreted as an additional cost for using the commodity. As a measure, price volatility is the relative changes in prices over time (Sadeghi and Shavvalpour, 2006). Frequently, commodity price volatility is measured as the standard deviation of log-price differences (Regnier, 2007). This is the approach chosen in this study as well.

Price volatility has also both macro- and microeconomic implications. We will in this study focus on the microeconomic effects. In general, if output prices cannot be adjusted to compensate for fluctuations in input prices, a firm’s overall profits are vulnerable to input price volatility. The implications include evaluation of energy models conservation behavior, in particular the possible underinvestment in energy conservation technology. Moreover, commodity price volatility is relevant to pricing real investments that affect production inputs and outputs, such as investments in capacity and reductions in energy and material intensity.

Another aspect is that the price of woody bioenergy is not fully independent from the price of fossil fuel. There are two main links between the prices of fossil fuels and woody bioenergy. First, fossil fuel prices affect input prices in the forestry sector. An increasing price on fossil fuels would thus result in a decline in the production level of woody bioenergy. Secondly, fossil fuel prices also affect the output prices in the forestry sector. For instance, if the price of fossil fuels is higher than the energy equivalent of woody bioenergy, the demand and thus price for woody bioenergy would increase. Another important linkage to energy markets on the output side is when woody commodities are starting to be used in bulk as feedstocks for biofuels for the transportation sector. For example, Hertel et al., (2010) estimate that higher oil prices accounted for about two- thirds of the growth in U.S. ethanol output over the 2001 to 2006 period. An analysis of woody bioenergy price volatility is thus important for decision-makers since high price volatility can increase the production costs and create increased investment uncertainties.

The aim of this study is to analyze price volatility for woody bioenergy. In particular, we focus on the price volatilities of wood fuels compared to the price volatility of fossil fuels. This allows us to conclude which of the two types of energy fuels that is more price-volatile. The results of this study are presented as overall summaries where statistical comparisons between price series and are reported. For instance, we will test if fossil price volatility is significantly higher than woody bioenergy price series.

Method and data

Price volatility is the result of a complex set of factors. In general, the interaction of demand and supply and their elasticities together with quantity changes determine the level of price fluctuations. The volatility of commodity prices is frequently measured as the standard deviation of price differences or log price differences (e.g., Regnier, 2007; Slade, 1991). It has been argued in the scientific literature that commodity prices are in general autocorrelated and that the volatility is stochastic and mean reverting (e.g., Schwartz and Smith, 2000; Deaton and Laroque, 1992). Yet, the appropriate measure for stochastic volatility is still not determined and it might also differ across commodities. The purpose of the study is neither to settle this issue nor to develop new stochastic volatility measures, thus the standard deviation of (log) price differences is used as a general measure of price volatility.

Typically, some level of price volatility can be observed on woody bioenergy markets. The general factors affecting the price volatility of woody bioenergy and its linkage to fossil fuel prices include market fundaments, policy response and linkage between energy and commodity markets. The market fundaments can in turn be subdivided into three effects. First, forestry output varies from period to period because of natural conditions. Second, many woody bioenergy products are by-products making them inelastic to own-price changes. Third, the rotation period for forest stands are long suggesting that supply might not be able to respond to price changes, especially if harvesting levels are close to the maximum sustainable yield. In addition, policy responses could also contribute to the price volatility. Finally, the increasing linkages between energy markets and those of woody bioenergy commodities have also contributed to increased price volatility.

The price of woody bioenergy can be explained by: (*i*) the price of fossil fuels; (*ii*) the production/harvesting cost of the woody bioenergy commodities and (*iii*) economic instruments. For instance, if the price of fossil fuels were to increase we have two opposing effects on the competitiveness of woody bioenergy. First, since the price of fossil fuels has increase, the price of bioenergy has, in relative terms, decrease. Thus, the competitiveness of bioenergy increases. Secondly, if the price of fossil fuel increases the production/harvesting cost of bioenergy also increases. This will reduce the competitiveness of bioenergy. However, since the cost share of fossil fuels in the production/harvest of woody biomass is relative small, the first effect should most likely outweigh the second. But since the fossil fuel price influences the transportation cost, the longer transportation distances that are involved in the bioenergy supply chain the larger will the second effect be. Thus, due to the link between fossil and bioenergy markets, the price of bioenergy is expected to change with changing fossil fuel prices.

As argued in Kranzl et al., (2009) there is an additional characteristic of the energy system that affect the energy price volatility. This effect captures the sensitivity of the energy system to the volatility of relevant prices. However, in general this effect is reduced with a relative high capital cost share and with a relative low fuel cost share.

For fossil fuels, previous studies have found that price volatility differs between fuels. For instance, Pindyck (1999) and Regnier (2007) find that oil is more volatile compare to natural gas and natural gas is more volatile compared to coal. In the latter study the overall volatility has increased but the same ranking of the price volatility for the fossil fuels are observed. Arguably, prices of fossil fuel can be expected to be larger than other commodity prices in general and then woody bioenergy products in particular. For example, the holding cost, the geographical concentration and seasonality of fossil fuels are relatively high, contributing to its price volatility (Regnier, 2007). Frequently cited causes to the increase in oil price volatility during the 70s are market power, supply disruptions, deregulation, decline in storage capacity and idle production capacity.

If the price of fossil fuels is higher than that of bioenergy, the demand for bioenergy will increase. Figure 1 presents a schematic illustration of market integration of energy and non-energy markets and their respective equilibrium. The left panel illustrate the energy market and its equilibrium, where the total supply of bioenergy and fossil intersect the demand for energy. The equilibrium establishes the market price of energy, the total purchased quantities of energy and, indirectly, the quantity of purchased bioenergy. The right panel illustrates how the demand for bioenergy affects the market for non-energy biomass (e.g., wood products, pulp and paper). If the markets are fully integrated, the market mechanism will make sure that the price of energy and biomass will be the same. For instance, if the price of biomass on the non-energy market is lower than the price of energy on the energy market, the demand for bioenergy will increase since it is cheaper to use than fossil fuel. This price increase continues until the price levels are equal and the incentive to substitute bioenergy for fossil fuel is eliminated. Figure 3 also indicate that in the absence of a demand for non-energy biomass products, the price of bioenergy would be P_0 and a quantity corresponding to $Q_{bioenergy}$ would be consumed by the energy sector. The position and curvature of the demand and supply schedules is affected by various economics instruments and policies. For example, forestry support, such as reduced tax rates, will increase the supply of woody bioenergy and biofuel quotas will increase the demand for bioenergy.

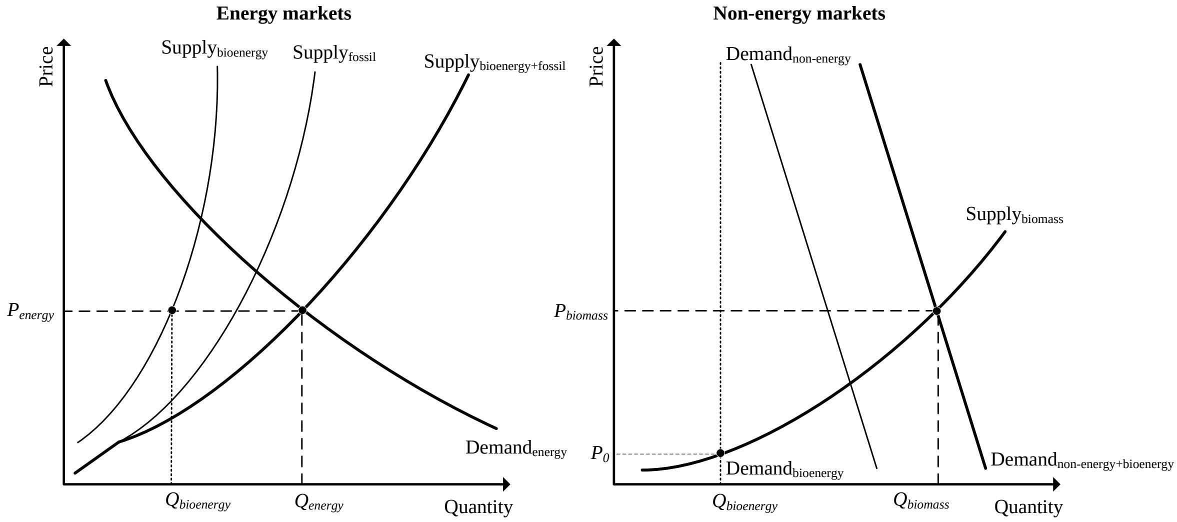

Figure 1: Schematic illustration of market integration for energy and non-energy markets and market equilibrium

The overall price effects of the integrated energy and non-energy markets are two-fold (Sedjo, 1997). First, in order to be economically interesting, the woody bioenergy must be priced low enough so that it can compete financially with, most notably, fossil fuels as a feed stock. For instance, the energy producers must find it economical to substitute woody bioenergy for fossil fuel-based ones. Second, the financial return of using woody bioenergy must be high enough so that so that it can compete with other areas of uses. For instance, if the woody biomass is to be allocated to the production of bioenergy, the bioenergy sector's willingness to pay for the woody biomass must be higher than the corresponding willingness to pay for the same resource in other production processes.

The demand on the energy sector connects the energy price to the price of bioenergy, and the supply of biomass connects the price of bioenergy to the price of non-energy biomass products. Thus, indirectly the energy price is connected to the non-energy price. The degree of connectivity depends on how well the markets are integrated. If the markets are poorly integrated the products price signal across markets are weak, and if the markets are fully integrated the products price signal across markets are complete.

Data

The woody bioenergy commodities include roundwood, wood fuel, chips & particles, wood residues and wood charcoal.[1] The included fossil fuels are natural gas, low sulphur fuel oil and steam coal. The years 1996-2013 are included, except for chips & particles which only cover 1998-2013. Comparable data restricts the time series to go further back. Finally, the data set is annual and includes 27 European countries.[2]

The woody bioenergy commodity prices are derived from UN-FAO Forestry database (FAO, 2014). First, import and export prices are calculated as the ratio between import and export values and quantities. A real domestic price is than calculated as the sum of the import and export prices weighted by their respective share and deflated using national harmonized consumer price indices - HCPI (Eurostat, 2014). Finally, an EU aggregate price is derived by adding the member states national price level weighted by their respective production share of the specific commodity, also obtained from FAO (2014). The woody commodity price level is expressed in USD per m^3, except wood charcoal that is measured in USD per ton. The oil and coal price is expressed in USD per ton and the price for natural gas in USD per MWh, collected from IEA (2014). The price for oil is the spot price using Germany's HCPI as deflator and the price series for steam coal and natural gas is real end-use prices for Germany. All prices are in 2005 price level.

Figure 2 depicts the price developments of the included woody bioenergy commodities. In general, all commodities exhibit the same overall trend. Initially the prices tended to decrease only to, in some cases, more than double between 2001 and 2010. After that the prices seems to have stabilized around a mean reverting behavior.

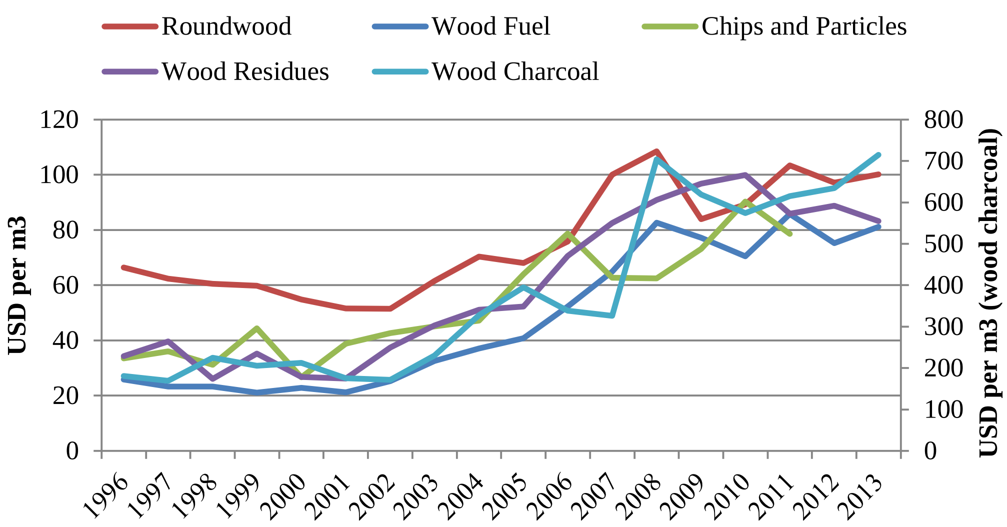

Figure 2: Weight average real price development for selected woody bioenergy in Europe
Source: FAO (2014), Eurostat (2014) and own calculations.

The price developments for the fossil fuels are presented in Figure 3 and they show a similar pattern as the price development for woody bioenergy. The price increase in fossil fuels between 2000 and 2008 can partly be explained by the rapid expansion of economic instruments introduced to curb the emission of greenhouse gases. Since the price of fossil fuels increased, the price of woody bioenergy became cheaper in relative terms, triggering an increased demand for bioenergy which resulted in a price increase as seen in Figure 1.

---

[1] A detailed definition and description of the commodities are available at FAO (2014).

[2] Austria, Belgium (including Luxemburg), Bulgaria, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Croatia, Ireland, Italy, Latvia, Lithuania, Malta, the Netherlands, Czech republic, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, Sweden and UK.

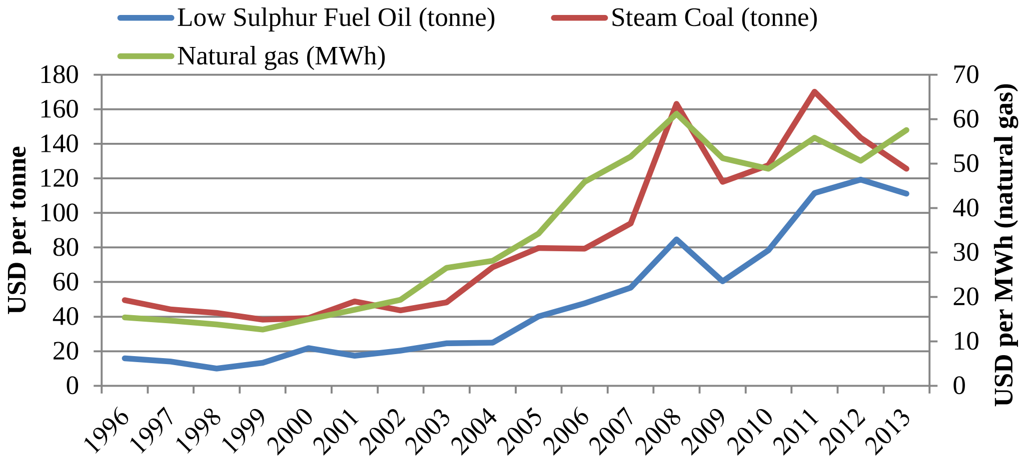

Figure 3: Real price development for fossil fuels
Source: IEA (2014), Eurostat (2014) and own calculations.

Results

The purpose of this study is to compare fossil price volatility with volatility of a broad range of woody bioenergy products to answer the question which of fossil or bioenergy that are more price volatile. Dickey-Fuller tests determine that the original price variables are integrated of order one but that the log-differences are all stationary. In the time series, structural breaks was detected suggesting that volatility has changed over time. The time period the structural breaks occurred varied between the price series indicating that there are at least some determinants for the volatility is different between the products.

In table 1 the correlation coefficients between the bioenergy commodities and fossil fuels are presented. The correlation is generally relative high for all commodities. The lowest estimate of 0.86 is between wood residues and oil suggesting even a high correlation in that case. The tentative conclusion from the correlation matrix is that the link between woody bioenergy and fossil fuels are indeed high. However, the correlation matrix is estimated using the real prices of the commodities and we are more interested in the price volatility.

Table 1: Correlation matrix for the bioenergy commodity and fossil fuel prices

	Roundwood	Wood fuel	Chips & particles	Wood residues	Wood charcoal	Oil	Coal	Natural gas
Roundwood	1.00	--	--	--	--	--	--	--
Wood fuel	0.95	1.00	--	--	--	--	--	--
Chips & particles	0.93	0.92	1.00	--	--	--	--	--
Wood residues	0.91	0.96	0.86	1.00	--	--	--	--
Wood charcoal	0.88	0.95	0.91	0.90	1.00	--	--	--
Oil	0.90	0.94	0.95	0.86	0.93	1.00	--	--
Coal	0.93	0.97	0.93	0.91	0.95	0.94	1.00	--
Natural gas	0.94	0.98	0.89	0.96	0.91	0.90	0.93	1.00

As mentioned above, statistical comparisons treating any set of series as a population are difficult. However, pairwise statistical comparisons between series are possible, as the log differences are not significantly auto-correlated. Because log differences were non-normal, a Mann-Whitney U-test (rank-based) test was used. The U-test is useful when we wish to know if two independent sets of data show a significant overall difference in the magnitude of the variable we are interested in, but we cannot use the z- or t-tests because the assumptions relating to level of measurement, sample size, normality or equality of variance are not valid. The test assumes only an ordinal level of measurement, since it is based in the ranking if scores.

The U-test is used to calculate the probability of finding any given difference in rank sums, under the null hypothesis that the samples are drawn from populations with the same distribution. The critical region contains U values lying below the critical value, so that of our calculated values are smaller than or equal to the critical value we can reject the null hypothesis. Given the even number of observations (scores) in the price volatility the U-critical value (17,17) equals 96 except for chips & particles which have two less scores and a critical value (15,17) equals 83.

The results from the U-test is summerized in Table 2. The results indicate that the null hypothesis can be rejected (p=0.05) for roundwood and all three fossil fuels. For the remaining woody bioenergy commodities we can only reject the null hypothesis with respect to oil (with the exception for chips & particles). That is, in cases the calculated U-value is less than the corresponding critical value, we can reject the null hypothesis, and claim that there is a significant difference between the two sets of ratings.

Table 2: Results of pairwise Mann-Whitney rank-sum tests of fossil and woody bioenergy fuels (*p*=0.05)

	U-statistics bioenergy(fossil)		
	Coal	**Oil**	**Natural gas**
Roundwood	0(89)*	0(50)*	0(96)*
Wood fuel	0(122)	0(81)*	0(143)
Chips & particles	117(0)	0(100)	98(0)
Wood residues	0(138)	0(93)*	142(0)
Wood charcoal	0(130)	0(92)*	0(137)

* Possible to reject H_0 of same distribution.

Thus, the price volatility is different between all woody bioenergy commodities (except chips & particles) and oil, but only between roundwood and coal and natural gas. This can be interpreted as woody bioenergy has had a larger impact on penetrating the coal and natural gas markets as a substitute, while they have had a more difficult time penetrating the oil market.

Conclusions

The purpose of this study is to analyze price volatility for woody bioenergy. In particular, we focus on the price volatilities of woody bioenergy compared to the price volatility of fossil fuels. This allows us to conclude which of the two types of energy fuels that is more price-volatile. In the time series, structural breaks was detected suggesting that volatility has changed over time. The time period the structural breaks occurred varied between the price series indicating that there are at least some determinants for the volatility is different between the products.

We are interested in examining how energy price volatility has been transmitted to woody bioenergy commodity prices. We find that biofuels have played an important role in facilitating increased integration between energy and woody biomass markets, especially as a substitute for coal and natural gas markets. However, the woody bioenergy markets are still rather immature and many rapid developments, such as the increasingly more international trade of woody biomass, with possible effects on future price volatility.

The relationship between woody bioenergy and energy markets has strengthened with the recent increase in transportation biofuel production. Energy has always been an important production inputs; however, the combination of recent high energy prices with policies aimed at promoting energy security and renewable fuel have stimulated the development and use of woody feedstocks in biofuel production. With a mandate to further increase biofuel production in Europe, it is clear that the relationship among woody biomass and energy commodities may grow even stronger. In the future, we can thus expect that also the oil markets will increase its linkage to the woody bioenergy markets when the production of biofuels for the transportation sector takes off.

References

Deaton, A. and G. Laroque. (1992). On the behaviour of commodity prices. *Review of Economic Studies* 59(1):1-23.

Eurostat. (2014). *Harmonized consumer price indices*. www.ec.europa.eu/eurostat (accessed August 2014).

FAO – Food and Agricultural Organization of the United Nations. (2014). *FAOstat – Forestry*. www.fao.org (accessed August 2014).

Henriques, I. and P. Sadorsky. (2008). Oil prices and the stock prices of alternative energy companies. *Energy Economics* 30:998-1010.

Hertel, T., W. Tyner and D. Birur. (2010). Global Impacts of Biofuels. *Energy Journal* 31(1): 75-100

Hertel, W. and J. Beckmann. (2011). *Commodity Price Volatility in the Biofuel Era: An Examination of the Linkage Between Energy and Agricultural Markets*. NBER Working Paper 2011; No. 16824.

Kranzl, L., G. Kalt, F. Diesenreiter, E. Schmid and B. Stürmer. (2009). Does bioenergy contribute to more stable energy prices? *10th IAEE European Conference*, Vienna, 7-10 September.

Kristöfel, C., C. Strasser, U.B. Morawetz, J. Schmidt and E. Schmid. (2013). Biomass price volatility: Analysis of the historic biomass and energy price volatility in the Austrian market. *21st European Biomass Conference and Exhibition*, Copenhagen, 3-7 June.

Oberndorfer, U. (2009). Energy prices, volatility, and the stock market: Evidence from the Eurozone. *Energy Policy* 37:5787-5795.

Olsson, O., J. Vinterbäck, A. Dahlberg, C. Porsö. (2010). *Price mechanisms for wood fuels*. Uppsala: Swedish University of Agricultural Sciences, Department of Energy & Technology.

Pindyck, R. (1999). The long-run evolution of energy prices. *The Energy Journal* 20(2):1-27.

Regnier, E. (2007). Oil and energy price volatility. *Energy Economics* 29:405-427.

Sadeghi, M. and S. Shavvalpour. (2006). Energy risk management and value at risk modeling. *Energy Policy* 34:3367-3373.

Sadeghi, M. and S. Shavvalpour. (2006). Energy risk management and value at risk modeling. *Energy Policy* 34:3367-3373.

Schwartz, E. and J. Smith. (2000). Short-term variations and long-term dynamics in commodity prices. *Management Science* 46(7):893-911.

Sedjo, R. (1997). The economics of forest-based biomass supply. *Energy Policy* 25(6):559-566.

Slade, M. (1991). Market structure, marketing method and price instability. *The Quarterly Journal of Economics* 106(4):1309-1340.