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The Swiss market for construction wood : estimating elasticities with time series simultaneous equations

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Résumé

Nous estimons les élasticités-prix et élasticités croisées de l'offre et de la demande sur le marché suisse pour le bois brut de construction entre 1949 et 2013. Grâce au modèle à correction d'erreurs, nous considérons les relations de long terme et de court terme et utilisons un système d'équation offre-demande pour tenir compte de l'endogénéité du prix. L'importance de la séquestration du carbone dans les produits en bois implique qu'une utilisation plus importante de bois local dans la construction permettrait de réduire les émissions nettes de CO_2. Cependant, l'industrie forestière suisse souffre d'un prix trop bas qui n'incite pas à produire davantage, malgré l'important potentiel. Des subventions peuvent aider à améliorer la durabilité environnementale et économique si les acteurs adaptent leur comportement suite aux changements de prix. Nous trouvons que l'offre et la demande sont sensibles aux changements de prix sur le court et long terme mais que l'augmentation de la demande pour le bois-énergie pourrait avoir un effet contreproductif sur la production du bois de construction.

Mots-clés

Bois de construction, séries temporelles, équations simultanées, Suisse

Summary

We use a rich yearly time series dataset to estimate demand and supply price- and cross-elasticities on the market for construction round wood in Switzerland, on the period 1949-2013. We consider both short term and long term relationships, thanks to the Error Correction Model and correct for the price endogeneity using a supply-demand equations system estimated with the 3 Stages Least Squares approach. Given the importance of wood products in CO_2 sequestration, an increase in the use of local wood for construction purposes may help reducing the CO_2 net emissions. Yet, the Swiss forest industry suffers from the low price of wood and is unwilling to produce more timber, despite the important potential of wood mobilization in Switzerland. Financial incentives may help meeting the goals of both environmental and economic sustainability, if actors respond to price changes. We find that both demand and supply are sensitive to price changes in the long and short run but that the simultaneous increasing demand for energy wood may have counterproductive impacts on the construction wood production.

Keywords

Timber wood, time series, simultaneous equations, Switzerland, construction

JEL classification : Q02, Q21, Q23, C31

The Swiss market for construction wood: estimating elasticities with time series simultaneous equations[*]

Nicolas Borzykowski[†][‡][§]

6th April 2017

Abstract

We use a rich yearly time series data set to estimate demand and supply price- and cross-elasticities on the market for construction round wood in Switzerland, on the period 1949-2013. We consider both short term and long term relationships, thanks to the Error Correction Model and correct for the price endogeneity using a supply-demand equations system estimated with the 3 Stages Least Squares approach. Given the importance of wood products in CO_2 sequestration, an increase in the use of local wood for construction purposes may help reducing the CO_2 net emissions. Yet, the Swiss forest industry suffers from the low price of wood and is unwilling to produce more timber, despite the important potential of wood mobilization in Switzerland. Financial incentives may help meeting the goals of both environmental and economic sustainability, if actors respond to price changes. We find that both demand and supply are sensitive to price changes in the long and short run but that the simultaneous increasing demand for energy wood may have counterproductive impacts on the construction wood production.

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1 Introduction

Wood is an important resource for the building industry. Indeed, while steel, concrete and cement have substituted timber to a large extent in the last century, the environmental advantage of wood in construction still makes a case in favor of the latter material. As illustrated in figure 1, wood sequesters carbon and, if used in building, prevents CO_2 to spill in the atmosphere (Lippke et al., 2010). Also, the production of timber requires less energy and wooden building are, on average, as energy-efficient as concrete buildings. Wooden buildings hence cause less CO_2 emissions throughout their life than buildings made out of other materials such as cement or concrete (Gustavsson et al., 2006). A more intensive use of wood in construction can therefore be useful as an additional tool to mitigate climate change. It is estimated that substitution of non-wood products by wood products could save up to 110 million tons of CO_2 up to the year 2096 in Switzerland (FOEN, 2007), which corresponds approximately to what Switzerland emits during two years. To encourage the use of wood and reach this goal, the Swiss government allows firms to domestically offset their CO_2 emissions through wood products (Swiss Federal Council, 2016). Also, since 2015, norms regarding fires prevention do not limit the use of wood in buildings anymore. These changes engender a renewed interest for the use of wood by the construction sector.

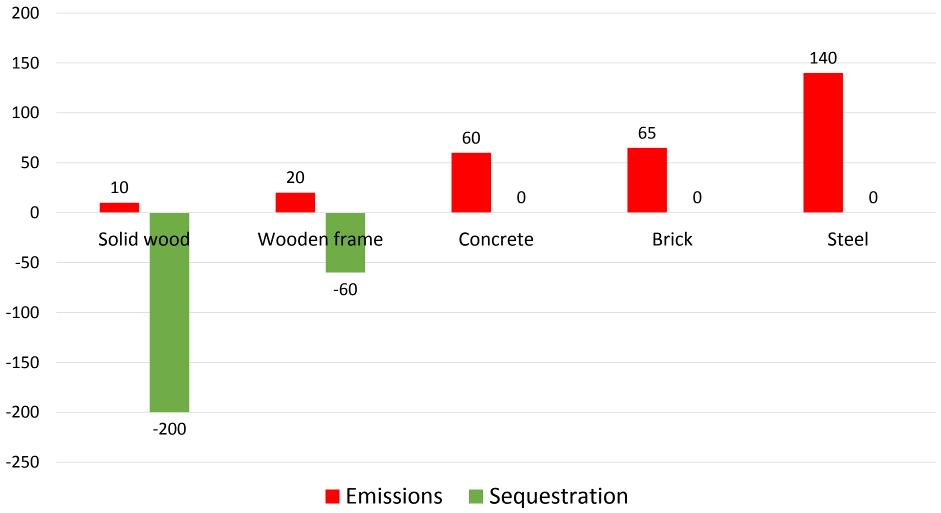

Figure 1: CO_2 emissions and sequestration in kg/m^2 of wall (Source: KBOB, 2009)

Swiss forests grow and the volume of standing wood has increased since the 19th century. Given the relative environmental friendliness of wood, the sustainable aspect of an increase in wood production (Borzykowski and Kacprzak, 2017) and the potential of wood mobilization, the Swiss government decided to promote the use of this material in the Forest policy 2020 (FOEN, 2013) and the wood resource policy (FOEN, 2008). Yet, the Swiss forest industry suffers from the low price of wood for decades and stakeholders claim that the current price does not give any incentive for more mobilization. Given the goal of the Swiss government and the financial bad health of the forest sector, understanding whether the Swiss forest industry responds to price changes is of particular importance. Indeed some doubts emerge regarding the responsiveness of wood market actors to financial incentives. With micro-data at the firm level, Farsi and Krähenbühl (2015) have shown that the Swiss wood supply may not be profit driven but rather target a given revenue. This result supports the fact that financial incentives may be ineffective in increasing the wood production.

We use a rich yearly time series data set to estimate demand and supply price- and cross-elasticities on the market for round wood in Switzerland. Our analysis covers the period 1949-2013 and considers both short term and long term relationships, thanks to the Error Correction Model (ECM) (Engle and Granger, 1987). We present an approach that also corrects for the price endogeneity using a supply-demand equations system estimated with the 3 Stages Least Squares (3SLS).

Section 2 presents the economic specificities of the Swiss wood market and section 3 reviews the time series analyses of wood markets in developed countries. Section 4 explains our econometric approach and section 5 presents our data set. Results are available in section 6. We discuss them and conclude in section 7.

2 Economic context

The Swiss wood market is composed of a multitude of small decentralized actors such as forest owners, logging companies for the harvest, sawmills for the transformation and end-users, which can be institutional actors, private firms or households and hence respond to different factors. Represented by the two-way arrow in figure 2, our interest market is comprised between forest owners and wood traders on the supply side and sawmills on the demand side. The demand for round wood is therefore indirectly driven by the construction sector and marginally by the demand for other wood products.

From raw wood, a large panel of products can be produced. Differences in the wood quality, assortment or essence increase the heterogeneity, which comes with heterogeneous prices (Kostadinov et al., 2014). Also, there is some complementarity and substitutability in the supply of wood products. Indeed, from a particular harvested tree, both energy wood and timber can be produced and wood waste from sawn wood can also be turned into valuable energy. Prices of energy wood may therefore have an impact on the production of construction wood. This effect may be positive, if energy wood is a complement to construction wood on the production side, or negative if producers substitute construction wood with energy wood. Indeed, the production of construction wood comes with a higher marginal cost than energy wood[1] and the profit may be higher with the production of energy wood rather than timber.

Another interesting specificity is the important externalities associated with the wood supply. Indeed, the exploitation of wood impacts the different forests functions such as recreation, protection against landslides, water and air purification and habitat for biodiversity. On the one hand, a reasonable forest exploitation has positive effects as it secures forest zones and gives more room to particular fauna and flora species. On the other hand, a too intensive exploitation reduces forest's ability to provide its other services. Given these external effects and the important deficit of forestry since the 90's, forest companies are usually heavily subsidized or public owned in Switzerland.

Finally, wood is a storable good (Hendel and Nevo, 2004). Entrepreneurs may either choose not to harvest at time t and let the tree standing until $t+1$ or cut it at time t and store the wood until $t+1$ before the sales. Consumers may also choose to buy at time t and store it until the next period. This may impact the short vs. long term elasticities: since adaptation becomes easier with time, entrepreneurs and consumers reactions to a change in price (or in any other factor) should be higher in the long term than in the short term, and hence short term price-elasticities should be lower than long term price-elasticities. This principle, first outlined by Samuelson (1948), has been confirmed for US forestry markets (Daigneault et al., 2016). However, the opposite is also possible if, in the short term, entrepreneurs boost their production

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[1] At the exit of the forest, costs of energy wood do not include the costs of processing the wood. Also, transportation of energy wood is cheaper since it does not require as large trucks as construction wood.

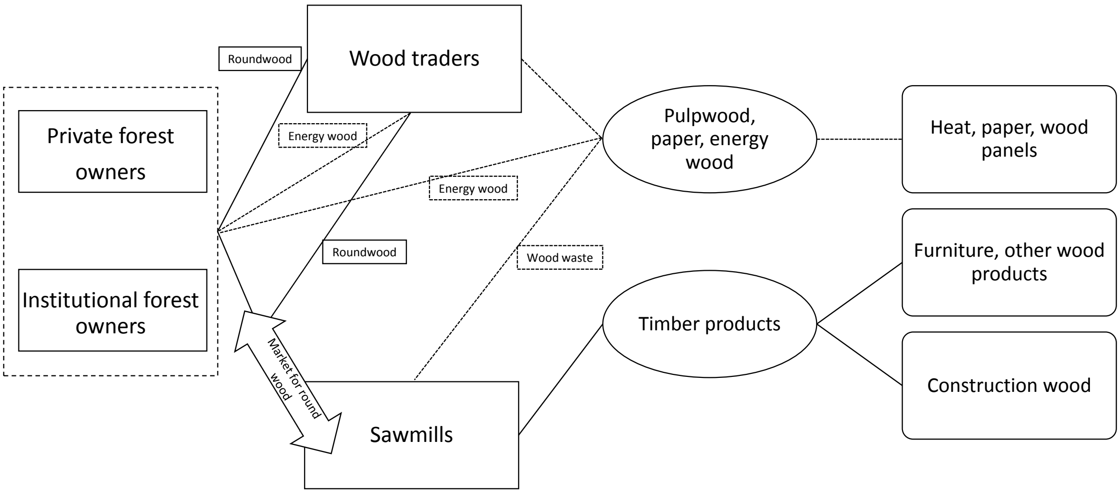

Figure 2: Swiss wood markets in a nutshell (Adapted from Kostadinov et al. 2014)

in reaction to a temporary price rise, at the cost of the long run productivity. On the demand side, if consumers anticipate their purchase in reaction to a temporary price fall (Roberts and Schlenker, 2013), short run demand elasticities may be larger than long run elasticities.

3 Literature review

Time series analysis of the wood market may help to understand the reaction of the demand and supply to particular factors along time. Buongiorno (1979; 1996) and Buongiorno et al. (1988) extensively studied wood markets in Western countries in the 80's but time series analysis has become less common in the last decade according to Toppinen and Kuuluvainen (2010). We observe a recent renewed interest in this type of approaches, as shown by the number of recent articles on forest products markets (Parajuli et al., 2016; Kristöfel et al., 2016; Daigneault et al., 2016; Kinnucan, 2016; Jochem et al., 2016; Sun and Niquidet, 2017). However, most of the studies are based on North America and Scandinavian data (Mutanen and Toppinen, 2005) and the scarce papers about central Europe usually focus on energy wood only (Kristöfel et al., 2016; Sun and Niquidet, 2017).

Some papers have analyzed parts of the wood market over time: Michinaka et al. (2011) estimated price- and income-elasticities of the demand for forest products using a cluster analysis on a panel of 44 countries on the period 1992-2007. They found that elasticities are in general higher in the long run than in the short run and that dynamic models fit better than static models, acknowledging an important evolution over time.

With time series on Great Britain, Iriarte-Goñi and Ayuda (2012) analyze the impact of wood use on economic development. They first calculate the apparent consumption of wood as the quantity produced minus net exports on the period 1871-1936 and find that the series are trend stationary. They then estimate price and income elasticities with OLS on 3 different periods: according to their results, income elasticity was particularly high ($\varepsilon_I^D = 6.23$) during the first world war (WW1) and lower ($\varepsilon_I^D = 1.22$) before and after that period. Wood can still be considered as a luxury good during the whole period. With respect to prices, these authors find that the demand for wood was relatively price-elastic during WW1 ($\varepsilon_P^D = -1.5$) and relatively price-inelastic after ($\varepsilon_P^D = -0.49$). They also find an interesting positive cross-relationship with iron, meaning that iron was a substitute to wood in the building and shipbuilding sector.

As reviewed in Daigneault et al. (2016), the literature before the year 2000 finds relatively low short run demand and supply price elasticities of softwood stumpage ($\varepsilon_P^D = -0.001\ to\ -0.85$; $\varepsilon_P^S = 0.23 = 0.06\ to\ 0.63$). These authors confirm this general inelasticity thanks to a lagged adjustment model and a dynamic capital adjustment model between 1950 to 2000. In a study on softwood lumber with the same type of methodology as ours, Song et al. (2011) estimated a supply-demand system of equations using US monthly time series data from 1990 to 2006. Their results reveal relatively low demand and supply elasticities ($\varepsilon_P^D = -0.18$; $\varepsilon_P^S = 0.23$). Another interesting result is the negative trend on the demand side, meaning that, *ceteris paribus*, technological progress reduces the demand for wood.

To the best of our knowledge, the only analysis of wood markets over time in Switzerland is Pauli et al. (2009). These authors regressed the supply on prices, costs, natural disasters and a time trend and the demand on prices, GDP, import prices and storage costs. Their results reveal low supply elasticities but very high demand elasticities, which “do not seem realistic” (Pauli et al., 2009, p.84). However, their econometric analysis contains two major drawbacks: first, the price endogeneity is not correctly taken into account and supply and demand are estimated separately via a simple OLS regression. Second, the stationary nature of the series is not discussed, which casts doubts on the reliability of statistical inference from their results.

Scholars usually consider that markets are competitive, and so do we. However, one needs to acknowledge that this is a strong simplifying assumption, all the more in Switzerland. In particular, wood markets are not completely integrated. If they were, the Law of One Price (Richardson, 1978) should hold but some evidence reject it (Hänninen, 1998), acknowledging the lack of global competitiveness (Kallio, 2001; Olsson, 2009). Anecdotal evidence also suggest that the Swiss wood market is far from the ideal perfect competition as prices are usually bargained over the counter on a case-by-base basis.

4 Econometric approach

The use of Ordinary Least Squares (OLS) in a time series context is not recommended if series are not stationary. Indeed the non-stationary nature of series leads to the problem of spurious regressions and thus to unreliable statistical inference (Granger and Newbold, 1974). We therefore first test for stationarity using the Dickey-Fuller test (Dickey and Fuller, 1979), the Philips-Perron test (Phillips and Perron, 1988) and the KPSS test (Kwiatkowski et al., 1992), that are standard procedure with longitudinal data.

Non-stationary time series require the Error Correction Model developed by Engle and Granger (1987) for multivariate analysis. This approach is composed of three steps: First, if series have a unit-root, estimate the long-run relationship with OLS on variables' levels as in equation 1:

$$Y_t = \alpha_{LR} + X_t'\beta_{LR} + z_t \tag{1}$$

With Y_t the explained variable, α_{LR} a constant, X_t a matrix of covariates, β_{LR} a vector of regression coefficients, which can be interpreted as the long run impact of X on Y, and z_t the error term. The second step is to get the residuals and test them for stationarity[2]. If they are stationary, then the series are co-integrated, meaning that a short run relationship can consistently be estimated with the ECM on first differences with the following model[3]:

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[2] A simple Dickey-Fuller or Philips-Perron test can be used but critical values are not the usual ones. Critical values for the test of co-integration are available in Engle and Yoo (1987)

[3] This result calls upon the superconsistency theorem. See Engle and Granger (1987).

$$\Delta Y_t = \alpha_{SR} + \Delta X_t' \beta_{SR} + \gamma \hat{z}_{t-1} + \varepsilon_t \qquad (2)$$

With ΔY_t the first differences of the explained variable, α_{SR} a constant, ΔX_t a matrix of explanatory variables' first differences, β_{SR} a vector of coefficients, interpreted as the short run impact of X on Y, and $\hat{z}_{t-1}$ the lag of the residuals from model 1. The associated coefficient of the latter variable, γ, is the lagged error-correction term and can be interpreted as the "adjustment speed" to the long run equilibrium.

In addition to the stationarity issue, as we analyze the whole market, it is important to deal with the issue of endogeneity. Indeed, at the equilibrium, prices and quantities are simultaneously determined by the market according to both demand and supply. Therefore, a system of simultaneous equations, accommodating both sides of the market, is necessary, to instrumentalize the endogenous variables. This model can then be estimated using a Two Stage Least Squares (2SLS) or 3SLS approach. 3SLS is usually more efficient and thus preferred (AlDakhil, 1998).

To sum up, to account for series' non-stationarity and price endogeneity, we run an ECM on a simultaneous demand-supply equations system. This approach is accepted since Hsiao (1997a; 1997b). Interestingly, Parajuli et al. (2016) compared results from 2SLS with ECM on the sawtimber market in Louisiana and find that resulting coefficients are similar in both estimations. However, they do not combine those methods, which allows to correct both endogeneity and non-stationarity simultaneously. Some authors have applied the same type of approach on forest products. Song et al. (2011), for example, apply a 2SLS-ECM on monthly data from 1990 to 2006 to model the US market for softwood lumber. More recently Kristöfel et al. (2016) analyzed the wood pellet market in Austria with this kind of approach as well.

5 Data description

Our time series analysis covers the period 1949-2013 on a yearly basis. The dependent variable (Q_t) is the quantity of round wood extracted from forests in Switzerland in millions of m^3. Various data sources have been used and hence we had to make different assumption to make series consistent[4]. In particular, Q_t corresponds to round lumber and industrial wood for construction purposes and a marginal part of Q_t is also used for the production of furniture.

We consider different covariates, presented in table 1, constrained by data availability:

P_t: The volume weighted average real price of wood for construction purposes in 2011CHF/m^3. Given the lack of consistent data, aggregation and weighted averages had to be used. In general, those prices correspond to wood sold at the closest railway station or at the exit of the forest, Free On Board. This variable enters both supply and demand decision. We expect it to take a negative sign on the demand side and a positive sign in the supply side, in line with classical economic theory.

$Psubs_t$: The average real import price of steel, iron and other metallic materials in 2011CHF/kg. We use this variable as an indicator for the price of a substitute in the building industry. If steel is indeed a substitute to wood, we expect the coefficient associated with this variable to be positive.

Px_t: An index of volume weighted average production prices of raw wood from all assortiments and essence from public-owned forests in Germany (DESTATIS, 2017). This exogenous index is likely to proxy the price of foreign wood in Switzerland, since Germany is the

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[4] Data sources, units and variables description are available in table A.1, in the appendix. A complete document with all assumptions can be provided by the authors, upon request.

Table 1: Descriptive statistics

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Q_t	3.25	0.92	1.74	7.61
P_t	254.46	143.81	71.17	498.74
$Psubs_t$	1.69	0.58	0.87	3.13
Px_t	68.03	23.17	24.3	123.60
$Investment_t$	39.54	14.68	7.69	61.88
$Wage\ in\ forestry_t$	15.14	10.57	1.96	32.53
$Penergy_t$	102.98	36.96	57.56	186.87
$Storm_t$	0.38	1.86	0	13.98
Observations		**65**		

biggest exporter of wood in Switzerland (about 45% of the value of all imported wood products come from Germany in 2013, followed by Italy with 11% (FOEN,2013)).

$Investment_t$**:** The real amount invested in construction in Switzerland in billion of 2011CHF. We use it as an indicator of the economic health in the building sector and of general conjuncture, since this variable is correlated with Gross Domestic Product (corr.=0.88). It enters the demand side and is expected to come with a positive coefficient.

$Wage\ in\ forestry_t$**:** The real wage paid to the logging crew in Switzerland in 2011CHF/hour (Niederer and Bill, 2015). We use this variable as an indicator of the cost of labor, the main input in the logging industry. We expect that this variable will have a positive impact on the marginal cost and thus a negative impact on the supplied quantity.

$Penergy_t$**:** The volume weighted average real price of energy wood in 2011CHF/m^3. Again, given the lack of consistent data, aggregation and weighted averages had to be used. In general, those prices correspond to wood sold at the closest railway station or at the exit of the forest, Free On Board. We use this variable to test whether energy wood is a production substitute or complement to construction wood. We formulate no a priori assumption on the sign of this variable coefficient. Indeed, as wood can either be transformed into construction or energy wood there are some substitution possibilities on the production side. However, the production of construction wood also causes wooden waste, which can only be used as energy provider. Therefore, both energy wood and construction wood can also be complementary in production.

$Storm_t$**:** The volume of fallen wood due to major natural calamities in millions of m^3 (Usbeck, 2015). Two major events need to be noted: Vivian, a major storm that happened in 1990, and Lothar, which happened in December 1999 but whose effects were observable in 2000. These storms destroyed large parcels of forests. It is estimated that 10 millions trees (13 millions m^3 (FOEN, 2009)) fell because of Lothar. In 2000, the Swiss government decided to subsidize the forest industry in order to extract fallen trees from forests, which certainly had an impact on the supplied quantity.

T_t**:** A time trend that takes into account technological or preferences changes.

We do not include any indicator of household income because the demand is only indirectly driven by households. Investment in construction is probably a better driver of the demand for timber and mostly arises from firms or the public sector. The latter variable is also correlated with Gross Domestic Product.

Figure 3 shows both endogenous series, namely the quantity of timber wood (Q_t) and its associated price (P_t). The quantity produced has been increasing on average since the beginning

Figure 3: Timber wood production and price

of the period but starts declining after 2008. We observe 2 main peaks: Vivian in 1990 and Lothar in 2000. These storms and the subsidies that followed Lothar increased the production of wood by roughly 44 for Vivian and 103% for Lothar (FOEN, 2009). Between 1949 and 2013, the production of construction wood has increased by 44%.

The real price of timber remained high until the mid 60's and started declining after that. This price in 2013 is 70% lower than in 1949 but stabilized after 2000.

Figure 4 shows the evolution of our independent variables (at levels and not-logtransformed) for our period of interest. The real price of steel decreased since the beginning of the period until the 2000's. We then observe a slight rebound. The price of wood in Germany is usually increasing over the whole period but there are some periods of slower growth from 1955 to 1965 and 1980 to 2000. The economic crisis of the mid-70's caused by the oil shock caused a decrease of investment in construction, similarly to the burst of the Swiss housing bubble in the beginning of the 90's. This is visible in the third graph. According to the fourth graph, wages in forestry increase on the entire period. The price of energy wood has decreased until 2000. It started increasing slowly since as shown in the sixth graph. On the last graph, three peaks of fallen wood are clearly observable and correspond to the three strongest storm in 1967, 1990 (Vivian) and 2000 (Lothar).

As we deal with time series, we run stationarity tests on levels and on first differences. Results of these tests are presented in table 2. All variables, except $Storm_t$ are found to be non-stationary on levels but stationary on first differences.

We test for structural breaks using a supremum Wald test[5] on the univariate regression $Q_t = \alpha + \beta P_t + \epsilon_t$ and identify a regime break in 1962[6]. The approach provided by Gregory and Hansen (1996) identifies other breaks[7]: level breaks in 1991 and 2000 that corresponds to the storms Vivian and Lothar respectively and regime breaks in 1996 and 1998. The fact that

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[5] This command is provided by the `estat sbsingle` command on Stata14

[6] Except for the statistical reason, the year 1962 is marked by the adoption, in the Swiss Constitution, of the article on nature and landscape protection, which may have had an impact on the forest harvesting policy.

[7] Stata14 command: `ghansen`

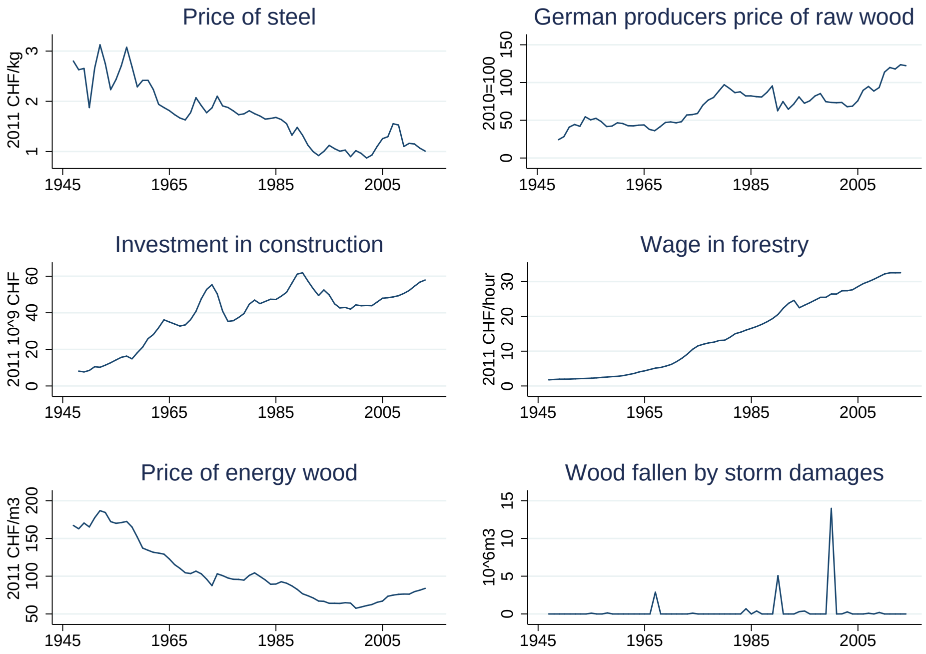

Figure 4: Annual time series

Table 2: Stationarity tests

Variable	**ADF**			**Phillips-Perron**			**KPSS**		
	Z_t	lags	form	Z_ρ	lags	form	η	lags	form
Q_t	-1.16	2	no t	-9.66	2	no t	0.88***	6	no t
ΔQ_t	-5.30***	1	no t	-86.61***	1	no t	0.13	5	no t
P_t	-1.47	0	t	-8.11	0	t	0.18**	6	t
ΔP_t	-7.08***	1	t	-61.58***	1	t	0.16**	8	t
$Psubs_t$	-0.49	1	no t	-3.75	1	no t	0.94***	6	no t
$\Delta Psubs_t$	-7.42***	1	no t	-68.26***	1	no t	0.05	7	no t
Px_t	-2.15	0	t	-13.85	0	t	0.10	5	t
ΔPx_t	-7.77***	0	t	-67.36***	0	t	0.077	5	t
$Investment_t$	-1.60	1	t	-4.38	1	t	0.23***	6	t
$\Delta Investment_t$	-4.10***	1	t	-40.25***	1	t	0.09	4	t
$Wage\ in\ forestry_t$	-0.70	1	t	0.92	1	t	0.24***	6	t
$\Delta Wage\ in\ forestry_t$	-4.03***	0	t	-28.34***	0	t	0.14*	5	t
$Penergy_t$	-0.55	0	no t	-3.77	0	no t	0.93***	6	no t
$\Delta Penergy_t$	-8.07***	0	no t	-68.72***	0	no t	0.33	4	no t
$Storm_t$	-8.34***	0	no t	-70.70***	0	no t	0.22	6	no t
$\Delta Storm_t$	-14.09***	0	no t	-68.72***	0	no t	0.04	4	no t

***p<0.01, ** p<0.05, * p<0.1

t: trend, no t: no trend

For augmented Dickey-Fuller tests (ADF) (Dickey and Fuller, 1979) and Phillips-Perron tests (Phillips and Perron, 1988), lags and functional forms have been chosen thanks to the Bayesian Information criteria. H0: The series is non-stationary For KPSS (Kwiatkowski et al., 1992) test, the number of lags was selected by automatic bandiwdth selection and autocovariances weighted by Bartlett Kernel. H0: The serie is stationary the storms produce structural breaks is not a surprise. However, our results tend to contradict the findings of Kinnucan (2016) that natural disasters cause a regime break (i.e. a rotation in the curves), since, in our case, the tests indicate a shift in levels only.

All tests of co-integration provided by this methodology reject the null hypothesis of no co-integration. We also use Clemente et al. (1998) approach for structural innovative outliers structural breaks[8] and find significant breaks in 1968 and 1977 for the quantity and price variable respectively.

Our time series cover a long period and a number of structural breaks are therefore expected (Toppinen and Kuuluvainen, 2010). While level breaks are relatively easy to handle with a dummy, regime breaks are more difficult in a simultaneous equation context. As the price variable is endogenous, each regime break of price must come with its instruments. The lack of appropriate additional variable in our data set thus constrain the possibilities to account for regime breaks. Also, post-estimation tests are not available with more than 2 endogenous variables. We thus choose to only allow for a single regime break on the effect of price but provide results of different specifications in the next section.

With the exception of $Storm_t$[9], we transform all variables in the natural logarithm form to directly interpret coefficient as elasticities. We end up with the following long run basis model:

$$\begin{cases} Q_t^D = & \alpha^D + \beta_1^D P_t + \beta_2^D P_{t-1} + \beta_3^D Psubs_t + \beta_4^D Px_{t-1} + \beta_5^D Investment_t + \beta_6^D T_t + \epsilon_t^D \\ Q_t^S = & \alpha^S + \beta_1^S P_t + \beta_2^S P_{t-1} + \beta_3^S Wage\ in\ forestry_t + \beta_4^S Penergy_t + \beta_5^S Storm_t + \epsilon_t^S \end{cases} \tag{3}$$

To take into account the storage possibility either on the supply side by letting the trees standing or, on the demand side by anticipating or delaying purchase and correct for serial correlation, we also add a lag variable of price. This variable is assumed to model actors anticipation regarding prices. On the demand side, if prices were lower at time $t-1$, consumers should have anticipated their purchase and hence the demanded quantity at time t would be lower. This variable should thus take a positive coefficient. On the supply side, if prices were higher at time $t-1$, suppliers may have boosted their production, at the expenses of production at time t. This variable should thus come with a negative coefficient. We decide to include the variable accounting for foreign prices with a lag. Indeed, foreign prices at time t, contrarily to its lag, have a statistically insignificant impact on the demanded quantity. This suggests that foreign prices take more time to impact the Swiss market than domestic prices.

6 Results

6.1 Long run co-integration results

We first present the results of the long run estimation. Column (1) of table 3 presents the long run model[10], without structural breaks. Column (2) adds two level breaks in 1968 and 1977 compared to model (1), as recommended by the Clemente et al. (1998) test. Column (3) and (4) add a regime structural break in 1962 and 1996 respectively as recommended by the supremum Wald test and Gregory and Hansen (1996) test. We opt not to add level breaks for these models because the added dummy variables are insignificant[11].

Coefficients in table 3 all have the appropriate signs on the demand side estimation. In particular, we observe that the price-elasticity of demand is negative. The magnitude of this effect is close to 3 and indicates that the demand for construction wood is highly price-elastic.

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[8] Stata14 command: `clemio1`

[9] As this variable contains many 0, a log-transformation would cause an important loss of observations.

[10] A plot of coefficient for this model is available in figure A.1 in the appendix.

[11] We do not present results with a regime break in 1998, which was recommended by Gregory and Hansen (1996) test, because all coefficients with this specification are not significant.

The addition of regime breaks does not result in any statistically significant change in slope, as shown by models (3) and (4). A 1% increase in price should therefore lead to about 3% decrease in demanded quantity in the long run.

We find that the lag of price has an important positive impact on the demand. If the price was 1% higher at $t-1$, consumers will tend to postpone their purchase and buy 1.2 to 1.6% more in t. Oppositely, if prices are higher in $t+1$, consumers anticipate their consumption in t. As expected, the cross-elasticity between construction wood and steel is positive. Steel is thus a substitute to wood in the construction sector. Indeed if the price of steel increases, the latter becomes less attractive, which causes an increased demand for construction wood of 0.8% for a 1% increase in steel prices. The German price of wood is positively correlated with the demanded quantity. Indeed, if foreign prices increase by 1%, the Swiss wood becomes relatively more attractive and the demanded quantity increases by 0.3 to 0.9%. Investment in construction also has a positive impact on the demand, which is an expected result. For the latter variable, a 1% increase in investments comes with a 0.7 to 1% increase in wood consumption. Finally, similarly to Song et al. (2011), we observe a negative trend. That may mean that, thanks to technological changes, construction became more efficient in using wood or that preferences changes have diminished the attractivity of wood with time.

On the supply side, we observe a positive and relatively large price-elasticity close to 1.5. Supply is indeed found to be price-elastic. Again, structural breaks do not result in any significant changes in slope. The lag of price has a negative impact on the supply: if the price was higher at $t-1$, suppliers may have anticipated the price fall and produce more at $t-1$, at the expense of production at time t. This also means that actors do anticipate the market changes correctly. The price of energy wood negatively affects the supply of construction wood. This result means that suppliers may have some room to substitute the production of construction wood with energy wood if it becomes more profitable. An increase of 1% in the price of energy wood leads to a 0.5% decrease in construction wood production. We also observe an important effect of the fallen wood caused by storms that significantly increased the wood supply. A million m^3 of fallen wood comes with an increase of 0.08 million m^3 of construction wood supply[12]. Finally, the effect of the labor cost ($Wage\ in\ forestry$) is surprisingly positive[13]. This may indicate a problem of reverse causality. Wages in the logging industry may be driven by the log men productivity rather than exogenously given.

In general, given the values of the Akaike Information Criteria (AIC), our preferred model is model (2).

After estimating the long run co-integration relationships, we predict the residuals and test them for stationarity. For all models, residuals are found to be stationary, which confirms the co-integration relationship of the series.

It is worth noting that first stage OLS regressions from the 3SLS come with a much higher F-statistic than the usual rule of thumbs of 10 for strong instruments (Staiger and Stock, 1997). Also, tests provided by the `ivreg2` command on Stata14 and presented in table A.2 show that, according to the Cragg-Donald F-statistics, the maximal IV relative bias is 30%. The Anderson canonical correlation statistics presented in the same table reject the hypothesis that equations are underidentified. Results from the Sargan statistic for overidentifying restrictions show that model (1) is not overidentified contrarily to model (2). These tests hence generally confirm our specification choices and instruments.

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[12] This effect is surprisingly low, given the large impacts of Lothar and Vivian on the production. Indeed, a rough look at the data indicates between 1990 and 2000, the production increased by 3.9 millions m^3, while the fallen wood reached 14 millions m^3. The expected impact of one m^3 of fallen wood would therefore be around 0.28 and we observe approximately the same expected impact in 1990 and 1967.

[13] The addition of a lag gives similar results.

Table 3: Long run co-integration relationships

		(1)	(2)	(3)	(4)
		No breaks	Level break in 1968 and 1977	Regime break in 1962	Regime break in 1996
Demand	P_t	-2.72***	-3.24***		
		(0.64)	(0.75)		
	$P_t(1947 - Break)$			-2.95***	-2.98***
				(0.77)	(0.71)
	$P_{t(}Break - 2013)$			-2.99***	-2.89***
				(0.58)	(0.70)
	P_{t-1}	1.37***	1.21***	1.57***	1.39***
		(0.47)	(0.44)	(0.58)	(0.50)
	$Psubs_t$	0.82***	0.83***	0.83***	0.82***
		(0.26)	(0.25)	(0.29)	(0.28)
	Px_{t-1}	0.29*	0.87***	0.24	0.54**
		(0.16)	(0.33)	(0.19)	(0.25)
	$Investment_t$	0.71***	0.95***	0.92***	1.04***
		(0.15)	(0.22)	(0.32)	(0.29)
	T_t	-0.043***	-0.066***	-0.045***	-0.070***
		(0.012)	(0.018)	(0.014)	(0.023)
	$D_t(Break1 - 2013)$		-0.044		
			(0.13)		
	$D_t(Break2 - 2013)$		-0.56***		
			(0.21)		
	$Constant$	88.37***	134.8***	92.70***	140.9***
		(24.24)	(35.95)	(27.35)	(45.84)
Supply	P_t	1.61***	1.34***		
		(0.30)	(0.26)		
	$P_t(1947 - Break)$			1.58***	1.54***
				(0.31)	(0.33)
	$P_{t(}Break - 2013)$			1.58***	1.53***
				(0.31)	(0.34)
	P_{t-1}	-1.33***	-1.03***	-1.29***	-1.27***
		(0.27)	(0.22)	(0.29)	(0.28)
	$Wage\ in\ forestry_t$	0.24***	0.21***	0.25***	0.25***
		(0.049)	(0.064)	(0.066)	(0.054)
	$Penergy_t$	-0.52***	-0.55***	-0.51***	-0.47***
		(0.12)	(0.11)	(0.14)	(0.12)
	$Storm_t$	0.086***	0.077***	0.084***	0.084***
		(0.0095)	(0.0078)	(0.010)	(0.0098)
	$D_t(Break1 - 2013)$		-0.074		
			(0.067)		
	$D_t(Break2 - 2013)$		0.14***		
			(0.051)		
	$Constant$	1.44**	1.46**	1.36**	1.26
		(0.67)	(0.60)	(0.68)	(0.81)
	Demand Residuals ADF^a	-5.45***	-5.72***	-5.55***	-5.29***
	Supply Residuals ADF^a	-5.65***	-5.28***	-5.57***	-5.61***
	Observations	64	64	64	64
	AIC	-115.9	-117.9	-102.8	-105.6

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

[a] Augmented Dickey-Fuller test for residuals stationarity (See Engle and Yoo (1987) for critical values)

6.2 Short run results

Results of the short run estimation are presented in table 4[14]. On the demand side, price-elasticities are again negative. Short run demand elasticities are smaller than long run elasticities but remain high. The demand for construction wood is hence relatively price-elastic in the short run as well as in the long run and a 1% increase in prices comes with a 2.2 to 2.8% decrease in demanded quantity in the short run. The cross-elasticity between wood and steel is again positive. The nature of the relationship between steel and wood is therefore unchanged and steel remains a substitute of wood, in the short run as well as in the long run. Finally, the impact of investments on the demand in the short run is less clear cut. Model (1) predicts a positive and significant impact of 0.9% for a 1% increase in investment, model (2) and (3) a positive but insignificant impact and model (4) a negative but insignificant impact.The price of foreign wood has a positive impact on the quantity demanded of Swiss wood on the short run as well, as shown by the significant positive coefficients of models (1) and (3).

The supply significantly reacts to prices. All models, except (2), suggest that the price-elasticity of the supply for construction wood is higher than 1 in the short run. These coefficients also show that the supply responsiveness to price is lower in the short run as in the long run. The latter result thus contradicts Roberts and Schlenker (2013), who suggest that supply price-elasticity for storable goods may be higher in the short run if suppliers decide to increase their production in reaction to a temporary price rise at the cost of the long run productivity. In the case of wood harvest, forest entrepreneurs might decide to cut more wood when prices are higher in period t and be leftover with hillier or more uneven zones, thus more costly to harvest. However, given the restrictive laws and the relatively low supply, this point is not confirmed by our results.

The cost of labor in the logging industry is again generally positively associated with the supply but the coefficients are not significant. The elasticity of the supply for construction wood with respect to price of energy wood is again negative, which tend to show that both types of wood are again substitutes on the production side. Regarding natural hazards, our results show that storms have an important short term impact on the wood supply. In particular, following Lothar, the strongest storm in the scrutinized period, the Swiss government decided to subsidize the extraction of fallen trees, which boosted the short-run production.

The post-estimation tests results provided by the `ivreg2` command are available in table A.3. Again, all Anderson canonical correlation statistics show that equations are not underidentified. Similarly to the long run equations, according to the Cragg-Donald F-statistic, the instruments are relatively strong, since the maximal IV relative bias does not exceed 30%. However, Sargan statistics show that equations may be overidentified. Excluding non-significant variables unfortunately does not reduce the Sargan statistic.

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[14] A plot of coefficient for model (1) is available in figure A.2 in the appendix.

Table 4: Short run relationships

		(1)	(2)	(3)	(4)
		No breaks	Level break in 1968 and 1977	Regime break in 1962	Regime break in 1996
Demand	ΔP_t	-2.17***	-0.11		
		(0.64)	(0.27)		
	$\Delta P_t(1947 - Break)$			-2.82**	-1.48
				(1.26)	(1.88)
	$\Delta P_{t(}Break - 2013)$			-2.55**	-1.92
				(1.09)	(1.25)
	$\Delta Psubs_t$	0.56**	0.16	1.03*	0.013
		(0.28)	(0.17)	(0.58)	(0.46)
	ΔPx_{t-1}	1.05***	0.31	1.21*	0.89
		(0.38)	(0.23)	(0.67)	(1.42)
	$\Delta Investment_t$	0.85**	0.10	0.76	-0.015
		(0.40)	(0.25)	(0.68)	(2.19)
	$D_t(Break1 - 2013)$		0.052		
			(0.071)		
	$D_t(Break2 - 2013)$		-0.0026		
			(0.058)		
	$Demand\ Residuals_{t-1}$	0.052	-0.14	0.16	-0.056
		(0.10)	(0.093)	(0.17)	(0.28)
	$Constant$	-0.15	0.12	-0.30	0.053
		(0.13)	(0.093)	(0.24)	(0.51)
Supply	ΔP_t	1.27***	0.35**		
		(0.41)	(0.17)		
	$\Delta P_t(1947 - Break)$			1.15***	1.11
				(0.40)	(0.81)
	$\Delta P_t(Break - 2013)$			1.07***	1.02
				(0.41)	(098)
	$\Delta Wage\ in\ forestry_t$	0.10	-0.0094	0.28	0.061
		(0.36)	(0.34)	(0.40)	(0.37)
	$\Delta Penergy_t$	-0.82*	-0.20	-0.59	-0.81
		(0.49)	(0.28)	(0.50)	(0.87)
	$\Delta Storm_t$	0.062***	0.041***	0.061***	0.056***
		(0.0066)	(0.0049)	(0.0066)	(0.011)
	$D_t(Break1 - 2013)$		-0.022		
			(0.045)		
	$D_t(Break2 - 2013)$		-0.013		
			(0.044)		
	$Supply\ Residuals_{t-1}$	0.081	0.059	0.041	0.092
		(0.075)	(0.078)	(0.075)	(0.096)
	$Constant$	-0.071	-0.037	-0.027	-0.078
		(0.089)	(0.074)	(0.088)	(0.12)
	Observations	63	63	63	63
	AIC	-101.2	-203.0	-45.09	-57.53

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

7 Conclusion

The commitment of the Swiss government to encourage the production of Swiss wood and its use in buildings is a step towards a more carbon neutral economy. Achieving these goals require to mobilize more wood from Swiss forests, what the forest industry is currently unwilling to do given the lack of financial incentives. Encouragements through subsidies would be useful only if suppliers and consumers react to price changes. We analyze the effect of the price on construction wood supply and demand thanks to a rich annual time series data set on the period 1949-2013. The use of the Error Correction Model allows to derive long-run and short-run elasticities, while correcting for price endogeneity thanks to the estimation of a simultaneous supply-demand equations system with 3 Stages Least Squares.

Our results are in line with the international literature and show that the demand and supply of construction wood are quite sensitive to prices changes both in the long run and in the short run. Financial incentives to increase the production and use of Swiss construction wood may therefore be a useful tool to meet the goals of the Forest Policy 2020, increase the production and use of construction wood and thus reduce the CO_2 emissions of the construction sector.

Given the carbon neutrality of energy wood, the wood policy (FOEN, 2008) encourages the use of wood for energy purposes as well. The latter policy may however be counterproductive to increase the production of construction wood. Indeed, our results show that construction wood and energy wood can be substitutes on the supply side. If the demand and thus the price of energy wood increases, suppliers may switch from construction wood to energy wood, the marginal cost of the latter being lower. This would reduce the available Swiss wood quantity for construction purposes and thus decrease the CO_2 sequestration potential of wood buildings.

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Appendix

Table A.1: Data sources, units and description

Variable	Unit	Description	Sources
Q_t	Millions of m^3	Quantity of wood produced for construction	Siegenthaler and Ritzman-Blickenstorfer (1996) FSO (1990), FOEN, (1996; 2014)
P_t	$2011CHF/m^3$	Weighted average of construction wood price	FSO (1976; 2015)
$Psubs_t$	2011CHF/kg	Import average price of steel, iron and other metallic material	FSO (2015)
Px_t	Index 2010=100	Average producer price of raw wood from German public forests	DESTATIS (2017)
$Investment_t$	Mio of 2011CHF	Investment in building infrastructure	FSO (2015)
$Wage\ in\ forestry_t$	2011CHF/hour	Average wage paid to forest workers	Niederer and Bill (2015)
$Penergy_t$	$2011CHF/m^3$	Weighted average of energy wood price	FSO (1990), FOEN, (1996; 2014) FSO (1976; 2015)
$Storm_t$	$1000m^3$	Quantity of fallen wood due to natural calamities	Usbeck (2015)

Table A.2: Long run post-estimation tests

		(1)	(2)
		No breaks	Level break in 1968 and 1977
Demand	Anderson canon. corr. stat.[b]	18.41***	21.93***
	Cragg-Donald F-stat.[c]	5.55+	6.91++
	Sargan statistic[d]	0.24	8.51**
Supply	Anderson canon. corr. stat.[b]	18.40***	19.00***
	Cragg-Donald F-stat.[c]	7.40++	7.46++
	Sargan statistic[d]	3.11	1.65

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

+ 30% maximal IV relative bias , ++ 20% maximal IV relative bias, +++ 10% maximal IV relative bias

[b] Underidentification test (H0: Equations are underidentified)

[c] Weak identification test (Stock and Yogo, 2005)

[d] Overidentifying restrictions test (H0: instruments are valid and excluded instruments are correctly excluded)

Table A.3: Short run post-estimation tests

		(1)	(2)
		No breaks	Level break in 1968 and 1977
Demand	Anderson canon. corr. stat.[b]	19.89***	23.18***
	Cragg-Donald F-stat.[c]	6.11+	7.42++
	Sargan statistic[d]	11.58***	9.75**
Supply	Anderson canon. corr. stat.[b]	25.26***	19.72***
	Cragg-Donald F-stat.[c]	8.87++	5.81+
	Sargan statistic[d]	12.68***	11.09**

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

+ 30% maximal IV relative bias , ++ 20% maximal IV relative bias, +++ 10% maximal IV relative bias

[b] Underidentification test (H0: Equations are underidentified)

[c] Weak identification test (Stock and Yogo, 2005)

[d] Overidentifying restrictions test (H0: instruments are valid and excluded instruments are correctly excluded)

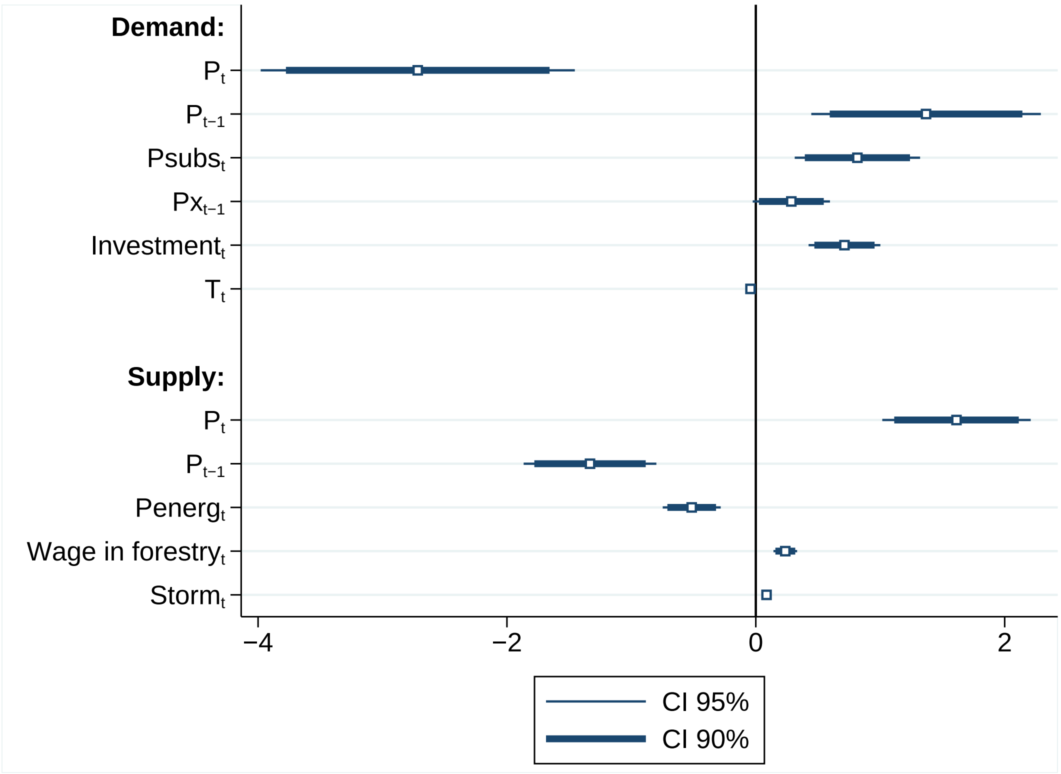

Figure A.1: Coefficients plot for the long run model (1)

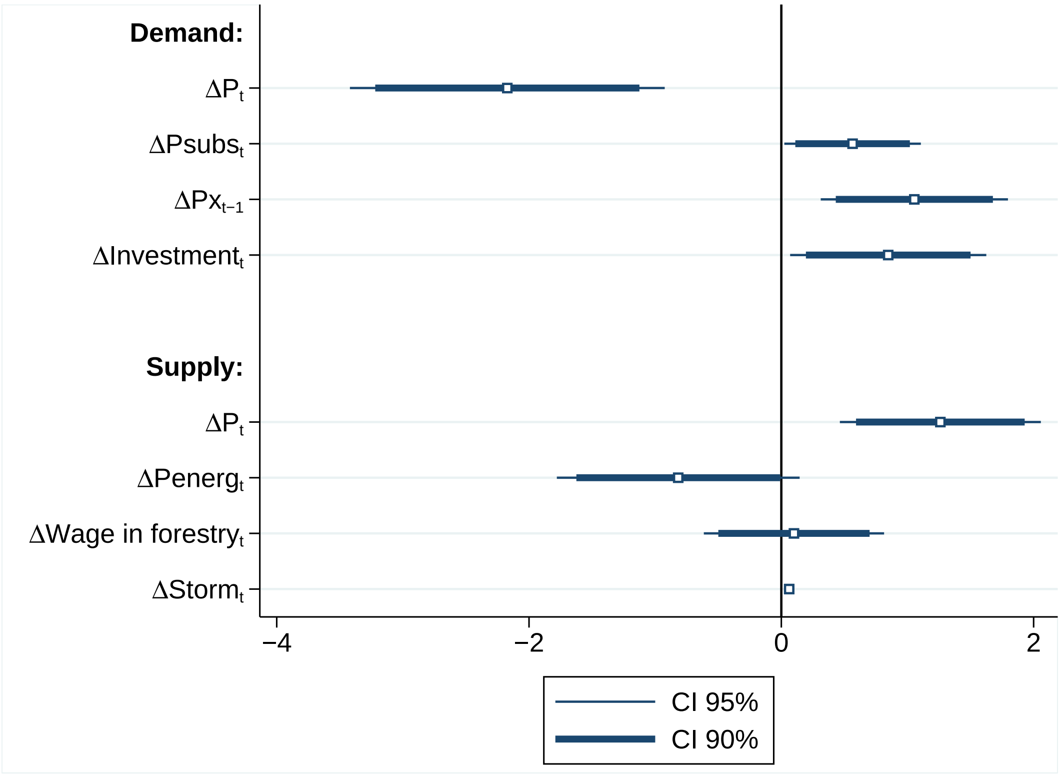

Figure A.2: Coefficients plot for the short run model (1)

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