University of Warsaw
Faculty of Economic Sciences

Working Papers
No. 34/2015 (182)

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Selling Timber in Poland

Warsaw 2015

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Abstract

The paper looks at how the foresters try to reconcile sustainable management practices with economic viability of their operations within the legal framework they operate in. In particular, we compare prices received by the State Forest Enterprise in Poland in two types of timber auctions: constrained and unconstrained ones. While the latter allow for higher revenues, the former are maintained for political reasons. The authors verify alternative hypotheses regarding market behaviour of timber buyers. The data from timber auctions in 2011-2012 demonstrate that winning prices are determined by starting prices and by the market power of the State Forest Enterprise (diversified with respect to specific timber varieties), as well as by price expectations. Based on the modelling results the paper makes policy recommendations with respect to the design of timber auctions and – more broadly – with respect to striking a balance between timber and non-timber benefits from the forestry in Poland.

Keywords:

Timber markets, Public forests, Multi-unit auction, Sustainable management

JEL:

D44, L73, Q23

1. Introduction

Forests in Poland are publicly owned to the extent larger than in many other countries. In 2010 the area of forested land was 9.3 million hectares, of which 9.1 million hectares was actually covered with forests. Public forests accounted for 7.3 million hectares, of which 7.1 million hectares were managed by the State Forest Enterprise (SFE), a firm which owns roughly 78% of the forests in Poland (GUS 2012). Given the fact that state forests are – on average – managed better than private ones (as confirmed by a recent report, *Raport* 2012), timber inventory is even more concentrated there (more than 80%). This may be somewhat surprising as economists often argue that private entrepreneurship increases efficiency. In some countries privately owned forests are managed very well. In Poland many private owners harvest timber for their domestic purposes only, so that timber market share of SFE is still higher – more than 94%. Thus it can be concluded that SFE enjoys a near-monopolistic position in the Polish timber market.

While revenues from selling timber are tangible, there are numerous studies demonstrating that non-timber benefits provided by forests are more important from the social welfare point of view. The value of timber accumulated in forested land is indeed very high (38,100 PLN/hectare). Nevertheless, only a small fraction of timber can be harvested if the forest is to be managed sustainably (Zylicz 2013). The fraction is determined by the annual regeneration rate of forest ecosystems which is low – 2% or even less. Thus an average hectare provides 762 PLN in annual timber sales revenues. At the same time there are studies which demonstrate that the total annual value of Polish forests can be as high as 2200 PLN per hectare or more (Bartczak *et al*. 2008). The problem is that – using economic jargon – timber revenues are 'private', and non-timber benefits are 'public'. The SFE is aware of the latter, but its bottom line includes only the former.

State Forest Enterprise has a hierarchical structure. Its chief director is appointed by the Minister of Environment. The chief director appoints 17 regional directors, each of which oversees twenty-thirty smaller territorial units called forest district offices (*nadlesnictwa*). There are 431 such units, headed by respective forest district managers (*nadlesniczy*). Appointed by regional directors, these managers are responsible for the forests in their districts. They are expected to be 'almost' financially sustainable. The meaning of the word 'almost' will be explained in the next two paragraphs.

The SFE does not pay a standard CIT. It is moderately taxed according to special regulations which allow foresters to pay less than other enterprises. Thus – indirectly – the Polish forestry is subsidized by the state budget. Nevertheless authorities seem to favour such a solution, since they do not subsidize the forestry directly (even though such a solution is practiced in many market economies, given the public good nature of forestry). Apparently the authorities are afraid that changing the tax regime would make the foresters claim higher net subsidies. The system is tolerated by foresters too, as they are afraid that changing the tax regime would make them pay higher taxes surely, while – given the uncertainty of the political process – getting direct subsidies is not guaranteed.

The SFE is basically self-financing, at least at the level of regions. Within regions, however, it is obvious that natural circumstances are diversified. Thus wealthier districts are expected to cross-subsidize poorer ones. To this end foresters operate a so-called Forest Fund (*Fundusz Lesny*) made out of a small charge on selling timber. The charges are subtracted from taxable revenues and they flow to regional directors. The directors distribute the Fund according to a complex algorithm which makes the poor districts net beneficiaries of the scheme while the rich ones are net payers. The system is far from being transparent. The only information which is publicly available is that the cross-subsidies are roughly 10% of timber sale revenues.

Timber sales make the most important reference for decisions of forest district managers. Apart from the Forest Fund's redistributive role, revenues from timber sales determine district budgets. It is therefore in the foresters' interest to maximize these revenues. Nevertheless buyers of timber – including paper and pulp industry, construction, furniture and others – lobby against timber price increases. They insist that timber sale contracts continue to be non-competitive. In contrast, forest managers prefer these contracts to be based on auctions. As a result of the political process, the scope of auctioned sale increased in 2011-2012, but still most of the contracts are based on bargaining rather than competition. Both foresters and government officials do not take effective steps to abandon the status quo. As a result, timber contracts became even less competitive in 2013.

As explained later, there were two basic auction types used by the SFE in 2011-2012. In the first type – the less competitive one – only buyers with an 'established record' were accepted. In the second type – the more competitive one – any buyers were invited. Only a part of timber was sold in the second-type auctions. Moreover, all auctions were launched with fairly law minimal (starting) prices. As a result of likely collusions, winning prices were only moderately higher than the minimal ones, especially in first-type auctions. Because of political considerations, minimal prices were set at the level justified by production costs. Thus, by the very design, they did not capture resource rents which went to timber buyers rather than sellers.

To the extent that there is an international market for timber, the Polish SFE cannot enjoy a monopolistic position. Nevertheless timber is characterized by a relatively low price-to-volume ratio. Consequently transport costs account for a fairly high share of the total. As a result, the more a timber variety is valuable, the easier it is for a prospective buyer to switch to an alternative seller. The paper verifies the hypothesis that the relative difference between the winning price and the minimal price is lower for highly valuable timber varieties (such as e.g. oak) than for low valuable timber varieties (such as e.g. birch). Of course, the difference may result from a number of additional factors, but we identify this as a key one.

The rest of the paper is organized as follows. The next section (2) develops a theoretical model to explain differences between minimal and winning prices in Polish timber auctions. Then our data set is characterized (3), and the hypotheses are tested (4). Policy recommendations (5) and (6) conclude the paper.

2. The model

The essence of the model is to understand the behavioural rules that govern placing bids and establishing minimal (starting) prices. Both bidding and establishing minimal (starting) prices is subject to rigid and bureaucratic procedures. Afraid of being accused of monopolistic practices, forest managers tend to 'justify' minimal prices by production costs, rather than by demand characteristics. Despite that, as experienced market agents, they may be aware of their market power in certain circumstances.

Let us assume – for simplicity – that forest production exhibits constant returns to scale, i.e. MC=AC=c, where MC and AC stand for marginal and average cost, respectively, and everything refers to a specific timber variety. In a market characterized by a linear demand curve $p=a-by$ the competitive (Walrasian) price is $p^c=c$, and the monopolistic price is $p^m=c+a/2$. Of course, $p^c<p^m$.

As behavioural assumptions governing the choice of starting and winning prices (bids) are not clear, from now on it will be assumed that they are either established in a competitive or in a monopolistic manner. Our conjecture is that – as a rule – highly valuable varieties (such as e.g. oak) are traded in a more 'competitive' manner, since their transport cost is relatively low with respect to their price-to-volume ratio. There are three cases to be considered.

1. First, let us assume that forest managers set starting prices proportionally to production costs, i.e. at the level λc, where $\lambda>1$ is a uniform coefficient (considered a politically 'defensible' mark-up). Thus the starting price is likely to be

$$p^s=\lambda c.$$

At the same time, buyers expect the winning price p^w to be determined by the market power of SFE, i.e.

$$p^w=\mu c \text{ or } p^w=\mu(c+a/2)$$

depending on whether this is a competitive or a monopolistic case, with $\mu>\lambda$. Consequently the ratio p^w/p^s is $\mu c/\lambda c=\mu/\lambda$ in the competitive, and $\mu(c+a/2)/(\lambda c)=(\mu/\lambda)(1+a/(2c))$ in the monopolistic case. Clearly it is higher in the monopolistic rather than in the competitive case, since $a/(2c)>0$.

2. Alternatively, let us assume that forest managers set starting prices proportionally to anticipated market prices, i.e. at the level λc and $\lambda(c+a/2)$ for the competitive and monopolistic case, respectively, where $\lambda>0$ is a uniform coefficient (considered a politically 'defensible' mark-up). Thus the starting price is likely to be

$$p^s=\lambda c \text{ or } p^s=\lambda(c+a/2)$$

depending on whether the variety is sold in a competitive or in a monopolistic market. At the same time, buyers expect the winning price p^w somewhat above the level implied by c, and λ, i.e.

$$p^w=\mu c$$

irrespective of whether this is a competitive or a monopolistic case, with $\mu>\lambda$. Consequently the ratio p^w/p^s is $\mu c/\lambda c=\mu/\lambda$ in the competitive, and $\mu c/(\lambda(c+a/2))=(\mu/\lambda)(c/(c+a/2))$ in the monopolistic case. Clearly it is higher in the competitive rather than in the monopolistic case, since $c/(c+a/2)<1$.

3. Finally, it cannot be excluded that both the forest managers and timber buyers assess the market power adequately. The former set starting prices as

$$p^s=\lambda c \text{ or } p^s=\lambda(c+a/2)$$

depending on whether the variety is sold in a competitive or in a monopolistic market. At the same time, buyers expect the winning price p^w to be determined by the market power of SFE, i.e.

$$p^w=\mu c \text{ or } p^w=\mu(c+a/2)$$

depending on whether this is a competitive or a monopolistic case, with $\mu>\lambda$. Consequently the ratio p^w/p^s is $\mu c/\lambda c$ in the competitive, and $\mu(c+a/2)/(\lambda(c+a/2))$ in the monopolistic case. Therefore in either case the ratio is the same (μ/λ).

The next step is to measure the competitiveness of the timber market. No part of this market can be characterized as a full monopoly. Timber is a globally tradable good but – to the extent transport cost may influence its price – local suppliers may ask prices that are significantly higher than marginal costs (Minot 1999). All varieties of timber that are produced in a boreal forest (like in Poland) have a similar weight-to-volume ratio, and can travel for extended periods. Hence their transport cost p^t is roughly proportional to the volume. As those varieties may have very different market prices p, the importance of the travel cost p^t/p varies widely; for low-price varieties it is very important, while for high-price varieties its importance is lower. Thus in the remainder of the paper it is assumed that the competitiveness of the Polish timber market is a monotonically increasing function of timber prices f(p), i.e. a monotonically decreasing function of p^t/p.

Namely, it is assumed that $p^w/p^s = f_\beta(p^s)$, where β is the parameter to be estimated. In order to econometrically estimate this equation, it is further assumed that
$p^w/p^s = \beta_0+\beta_1 p^s+\beta_2(p^s)^2+\varepsilon$
where β_0 is a constant coefficient, β_1, β_2 are coefficients characterizing the competitiveness (their signs may depend on conjectures on the price-setting behaviour), and ε – an error term satisfying standard assumptions. In particular, if a linear form is acceptable (i.e. if $\beta_2=0$) then the sign of β_1 suggests which of the conjectures is more likely to be adequate. If $\beta_1<0$ then p^w/p^s is higher in the 'monopolistic' case, i.e. for low-price varieties (e.g. birch). If $\beta_1>0$ then it is the other way around: p^w/p^s is higher in the 'competitive' case, i.e. for high-price varieties (e.g. oak). If $\beta_1=0$ then p^w/p^s does not depend on the competitiveness of the timber market.

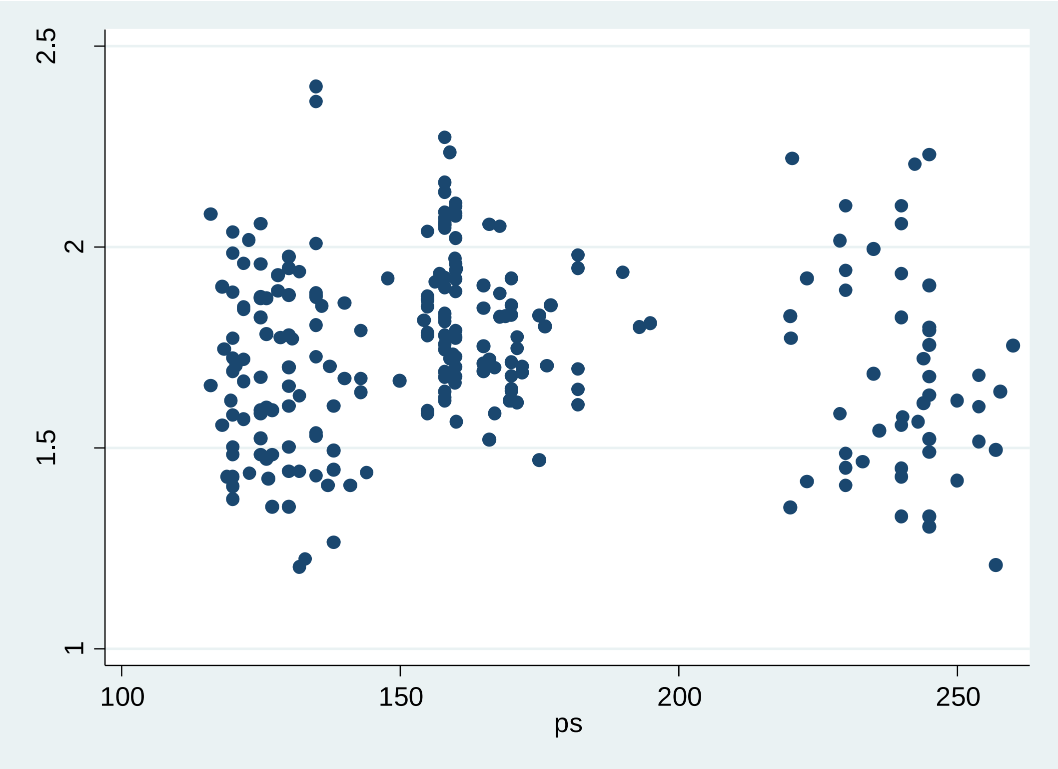
3. The data set

The data are taken from records of the SFE whose district offices run timber auctions (see Annex 1). The minimal prices are uniformly set by regional offices for each variety. Individual observations are regional prices for five selected standard varieties – beech, birch, oak, pine, and spruce – in three semiannual periods (2011-I, 2011-II, and 2012-I). The total number of observations is 245, almost uniformly distributed over the three periods. Oak is the high value variety while the other ones are characterized by much lower prices.

The organization of the auctions is somewhat complicated. In the first place, the supply of timber resulting from exogenous assessments is split into two halves to be sold in two auctions with the same starting price. The auctions differ with respect to the eligibility of their participants. In the first auction – called PLD – only buyers with an 'established purchasing record' are allowed. The rationale for this rule (strongly advocated by 'traditional' buyers) is tolerated by foresters in order to please the political establishment. For political-economy reasons, the establishment is sensitive to the predicament of timber users rather than the revenues of the SFE. Even though SFE is a state-owned firm, for reasons explained earlier, its contribution to the state budget is modest. At the same time, high timber prices make the life of downstream industries more difficult which translates into political problems. The second series of auctions – called E-D – allows any agents to bid. This results in much higher winning prices.

In the PLD (constrained) auction, an average winning price is 16% higher than the starting price. In contrast, in the E-D (unconstrained) auction winning prices are 75% higher than the starting prices on average (see Figure 1 below). With very few exceptions, all markets clear, i.e. there is virtually no timber left. In the rare cases it is the other way around, forest district offices arrange additional auctions which are not accounted for in our model.

Figure 1. Observations from the E-D auctions



4. Model results

There are two basic versions of our model corresponding to the two auction types (PLD and E-D) run by the SFE. It is not surprising that the PLD auction seems to be independent of the market power. Apparently the foresters do not wish to exercise their market power when they deal with buyers with an 'established purchasing record'. Several functional forms (including logarithms and polynomials) were tested, but none turned out to be adequate except for a linear one with $\beta_1=0$. In other words, the PLD auction would be very difficult to interpret in terms of standard microeconomic theories. The following is the best approximation achieved which nevertheless fails to have statistically significant coefficients (see Annex 2 for econometric details):

PLD:
$p^w/p^s = 1.021514 + 0.0008504\ p^s - 0.0000000178\ (p^s)^2$

The E-D auction has more interesting economic characteristics. Several alternative specifications were tested using Stata 11, but most of them failed standard statistical tests. Additionally, attempts were made to introduce dummies for the three periods or seventeen regions. They did not introduce any significant improvements in the quality of estimates. The following quadratic form turned out to be acceptable (see Annex 3 for econometric details):

E-D:
$p^w/p^s = 0.4434 + 0.0152781\ p^s - 0.0000421\ (p^s)^2$

The right-hand side is increasing for $p^s<181$, and decreasing afterwards. Thus buyers seem to bid relatively higher than the starting price for high-value varieties, and this tendency reverses only for the highest-value one, mainly for oak (there are only three cases of the spruce starting price higher than 181). Perhaps there are some additional factors influencing the local demand for oak that were not included in the model and yet they are important in competitive (E-D) auctions. Nevertheless – to the extent that the price ratio p^w/p^s increases with p^s for a wide range of starting prices – the econometric conclusion is consistent with our hypothesis that the higher price varieties are traded in less monopolistic markets since their transport cost is relatively lower.

To sum up, the model suggests that SFE tends to set starting prices at the level 'justified' not only by production costs, but also by some additional mark-ups characteristic for its market power. In the unconstrained – i.e. more 'competitive' – (E-D) auction buyers understand that low-price varieties are traded in less competitive markets (Case 2 in Section 2 above). However, they seem to anchor their bids to production costs. Consequently they bid relatively higher for high-value varieties. This pattern reverses for the most precious types of timber only.

5. Discussion

Timber auctions undertaken by SFE were aimed at enhancing its revenues, as well as overcoming complaints about the lack of transparency in awarding contracts. Theoretical foundations of these auctions are weak for the following reasons. First of all, unlike in Poland, in many countries with public commercial forests, land to be harvested rather timber logged is auctioned. In the United States there are timber auctions, but in European countries public forests prefer to sell harvest rights to logging companies. Moreover, economists advanced a theory of single-unit auctions which is not sufficient to recommend an appropriate design for timber auctions (Athley *et al*. 2011). In a typical timber auction there are many units to be sold to different buyers and two questions need to be addressed. First, should all the buyers pay the same price? Second, how to implement an incentive compatible design to prevent the strategic demand reduction implied by declaring alternative buying offer schedules?

One of the fundamental results in the theory of auctions is the *Revenue Equivalence Theorem* (RET) stating that several auction types identified by Vickrey (1961) let the seller enjoy identical revenues (Meyerson, 1981; Riley and Samuelson 1981). The theorem also asserts that the auctions are efficient, i.e. they allocate their object to the highest bidder.

For this to hold, RET requires the following assumptions to be satisfied:

- all the bids are independent and they are sampled from the same statistical distribution;
- all the bidders are risk-neutral;
- a single object is auctioned.

While it is possible to argue that statistical and behavioural assumptions (the first two ones) are likely to be satisfied, Polish timber auctions clearly violate the last assumption. Bidders are expected to quote price-quantity schedules, not only their price for a single identified object.

There are compelling theoretical arguments for the 'pay-as-bid' system where each buyer may pay a different price. This system, however, is not well understood by the buyers (and public at large) who complain about the lack of transparency and discriminatory practices. Hence it seems that a 'uniform price' system is politically more acceptable. Nevertheless in a multi unit auction, there must be a fairly complicated system of setting a market clearing price since potential bidders will quote different price-quantity schedules. In this exercise, they may strategically lower the demand for larger quantities in order to determine lower market clearing prices for (earlier) units they purchase. An appropriate incentive compatible mechanism is fairly complicated – and for this reason it may turn out politically unacceptable – so that it has been an object of patents [Ausubel and Cramton 2002].

The Polish SFE insists on timber rather than harvesting-right auctions, and justifies its position by social policy considerations. By selling timber rather than harvesting rights, foresters claim that they maintain higher employment (almost 25,000 in 2010 (GUS 2012)) with very small seasonal variations.

Thus a typical timber auction is a multi-unit auction with many potential buyers competing for different quantities of the stock available for sale. According to the theory developed for such auctions, their starting prices are crucial for the result both in terms of efficiency and revenue maximization.

In particular, the system of starting prices will benefit from studying historic bids. Riley and Samuelson (1981) demonstrated that the revenue-maximizing minimal price v^* satisfies the following equation:

$v^* = v_0+1-F(v^*)/F'(v^*)$,

where:

- v_0 – private assessment of the seller (approximated e.g. by production cost),
- F – distribution function of buyers' assessments, and
- F' – density function of these assessments.

Distribution function F and its derivative F' are difficult to estimate. Some hints regarding their values can be estimated by analyzing individual bids. In the forestry statistics only the winning prices can be traced. The formula, however, requires the knowledge of F which cannot be acquired unless individual – also losing – bids are recorded.

According to our studies, there is a large discrepancy between starting and winning prices for high value varieties (e.g. oak). At the same time, the discrepancy between these prices for low value varieties (e.g. birch) is significantly smaller. It is impossible to rule out collusions in any of the cases, and especially in PLD auctions where buyers are less numerous and they know themselves from earlier transactions. Nevertheless proving the collusion in such auctions would be a difficult task (Saphores *et al*. 2006).

While the most striking difference is between PLD and E-D, a closer look at the relative prices reveals important differences in buyers' price offering behaviour. In PLD (constrained) auctions buyers bid only slightly above the starting price for a given variety. In the first trading period it was 27%, but in subsequent periods it dropped to 11%-12%. This may suggest a collusion, but the data do not allow for such a conclusion.

In E-D (unconstrained) auctions the average winning price was 75% higher than the starting one. This suggests two things. First, starting prices fall much below the market ones which means that SFE could enhance its revenues by making use of the Riley-Samuelson formula. Second, different timber varieties lead to very different bidding patterns. Our econometric modelling exercises demonstrate that these patterns can be explained by the SFE market power.

6. Conclusions

It is not clear, however, if the SFE would be willing to aggressively advocate for an improved efficiency of their timber operations. One reason is that it denies any market power considerations. While it clearly has a monopoly power, the foresters are right to claim that their timber supply is based on some sustainable management schedules established by an external body (Minister of Environment). Consequently the SFE cannot manipulate prices as a conventional monopoly does. On top of that, it may be afraid of opening up a discussion on foresters' commercial revenues as this may result in changing its privileged tax status.

Environmental sustainability is indirectly present in these deliberations. SFE provides a valuable public good that the state budget should pay for. It does not, but on the other hand, it absolves itself of this obligation by reminding the SFE of the privileged tax status leading to a *de facto* budgetary subsidy. Also many politicians prefer the unclear *status quo* where neither the value of the public good is monetized nor financial losses implied by sustainability constraints imposed on SFE are assessed.

Increasing the revenues from timber sales may enhance non-timber benefits provided by the forests. As the state budget is reluctant to finance the provision of these benefits, they are to be supplied by the foresters themselves. Therefore the amount to be spent on non-timber benefits may depend on timber prices. In other words, the higher the revenue from selling timber, the more money can be spent on providing non-timber benefits (or deeper 'sacrifices' can be made in order to continue 'sustainable management' practices).

The most recent developments in SFE marketing behaviour demonstrate that foresters prefer not to maximize their timber sale revenues. They withdrew from insisting on unconstrained auctions. In 2013, the supply of timber allocated to E-D auctions was only 30% of the supply sold in less competitive procedures, i.e. much below what was practised in 2011-2012. Moreover, buyers with an 'established record' now have a possibility of signing long-term contracts which lowers the competition even further.

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Annex 1

The data set

		Prices [PLN/m3]			
Region	Variety	Minimal	Winning PLD	Winning E-D	Period
BIAŁYSTOK	BEECH	132	178.6	215.1	1
BIAŁYSTOK	BIRCH	125	154.3	257.2	1
BIAŁYSTOK	OAK	240	369.1	464.1	1
BIAŁYSTOK	PINE	158	196.4	324.4	1
BIAŁYSTOK	SPRUCE	158	186.9	323.6	1
GDAŃSK	BEECH	132	170.2	255.9	1
GDAŃSK	BIRCH	120	134.5	178	1
GDAŃSK	OAK	223	343.7	428.8	1
GDAŃSK	PINE	158	192.8	324.5	1
GDAŃSK	SPRUCE	160	207.7	332.4	1
KATOWICE	BEECH	137.4	178.3	233.9	1
KATOWICE	BIRCH	125	138.3	234.5	1
KATOWICE	OAK	245	358.9	438.9	1
KATOWICE	PINE	160	189.9	336.2	1
KATOWICE	SPRUCE	182	234.8	360.4	1
KRAKÓW	BEECH	118.4	154.1	206.7	1
KRAKÓW	BIRCH	125	135.9	209.5	1
KRAKÓW	OAK	245	372.8	441	1
KRAKÓW	PINE	157.1	185.9	303.8	1
KRAKÓW	SPRUCE	177	223.1	328.3	1
KROSNO	BEECH	125	171.2	228.1	1
KROSNO	BIRCH	119.6	134.5	193.5	1
KROSNO	OAK	245	367.6	466.7	1
KROSNO	PINE	147.8	172.4	284.1	1
KROSNO	SPRUCE	154.3	169.3	280.3	1
LUBLIN	BEECH	135	190.5	318.9	1
LUBLIN	BIRCH	120	134.8	226.4	1
LUBLIN	OAK	230	353.1	483.4	1
LUBLIN	PINE	155	185.5	289.3	1
LUBLIN	SPRUCE	155	171.2	276	1
ŁÓDŹ	BIRCH	135	147.8	254.5	1
ŁÓDŹ	OAK	230	343.9	435.3	1
ŁÓDŹ	PINE	158	188.6	341.6	1
ŁÓDŹ	SPRUCE	158	175	337.8	1
OLSZTYN	BEECH	126	156.3	224.7	1
OLSZTYN	BIRCH	130	145.6	244.5	1
OLSZTYN	OAK	240	392.7	504.4	1
OLSZTYN	PINE	158	185.4	325.6	1
OLSZTYN	SPRUCE	158	181	304.1	1
PIŁA	BEECH	135	185.2	324	1
PIŁA	BIRCH	122.9	138.9	248	1
PIŁA	OAK	220.4	336.7	489.3	1
PIŁA	PINE	158.2	186.2	328.6	1
PIŁA	SPRUCE	160.1	196.6	311.6	1
POZNAŃ	BIRCH	128	146.3	242	1
POZNAŃ	OAK	245	355	546.2	1

POZNAŃ	PINE	158	184.6	325.1	1
POZNAŃ	SPRUCE	158	187.9	329.6	1
RADOM	BIRCH	122	135.6	224.9	1
RADOM	OAK	220	323.1	402.3	1
RADOM	PINE	155	181.7	316	1
RADOM	SPRUCE	155	171.6	291.1	1
SZCZECIN	BEECH	122	159.8	239	1
SZCZECIN	BIRCH	118	125.2	224.3	1
SZCZECIN	OAK	235	342.7	468.8	1
SZCZECIN	PINE	160	189.6	323.5	1
SZCZECIN	SPRUCE	160	201.1	313.2	1
SZCZECINEK	BEECH	120	160.1	244.4	1
SZCZECINEK	BIRCH	116	127.9	241.5	1
SZCZECINEK	OAK	229	342.6	461.6	1
SZCZECINEK	PINE	158	184.8	327.4	1
SZCZECINEK	SPRUCE	160	201.5	333.2	1
TORUŃ	BIRCH	135	149.1	254	1
TORUŃ	OAK	230	350.8	446.7	1
TORUŃ	PINE	158	188.9	359.2	1
TORUŃ	SPRUCE	159	174.6	355.5	1
WARSZAWA	OAK	240	343.6	438	1
WARSZAWA	PINE	159.9	186	315.3	1
WARSZAWA	SPRUCE	156.3	185.2	298.9	1
WROCŁAW	BEECH	130.7	178.9	231.4	1
WROCŁAW	BIRCH	120	133.7	189.8	1
WROCŁAW	OAK	242.4	362.4	534.7	1
WROCŁAW	PINE	166	201.1	341.3	1
WROCŁAW	SPRUCE	182	232.4	354.4	1
ZIELONA GÓRA	BEECH	120	167.8	212.7	1
ZIELONA GÓRA	BIRCH	120	131.7	206.7	1
ZIELONA GÓRA	OAK	240	360.7	493.7	1
ZIELONA GÓRA	PINE	160	196.2	337.4	1
ZIELONA GÓRA	SPRUCE	160	209.5	310.5	1
BIAŁYSTOK	BIRCH	125	145.1	234	2
BIAŁYSTOK	OAK	240	275.4	342.8	2
BIAŁYSTOK	PINE	158	170.9	255.6	2
BIAŁYSTOK	SPRUCE	158	172.1	259.1	2
GDAŃSK	BEECH	120	129.2	164.8	2
GDAŃSK	BIRCH	120	136.8	168.5	2
GDAŃSK	OAK	223	239.3	315.6	2
GDAŃSK	PINE	158	171.3	281.4	2
GDAŃSK	SPRUCE	160	191.1	284.2	2
KATOWICE	BEECH	132	137.5	159	2
KATOWICE	BIRCH	125	134.7	244.7	2
KATOWICE	OAK	245	265.6	325.7	2
KATOWICE	PINE	160	181.5	283.5	2
KATOWICE	SPRUCE	182	227.9	299.3	2
KRAKÓW	BEECH	138.1	144.8	174.7	2
KRAKÓW	BIRCH	130	137.5	195.3	2
KRAKÓW	OAK	257	270.1	310.7	2
KRAKÓW	PINE	166	176.9	252.6	2
KRAKÓW	SPRUCE	182	217.8	292.4	2

KROSNO	BEECH	119	124	169.9	2
KROSNO	BIRCH	120.6	128.8	205.5	2
KROSNO	OAK	245	255.2	319.6	2
KROSNO	PINE	149.9	160.1	250	2
KROSNO	SPRUCE	160.1	177.9	250.6	2
LUBLIN	BEECH	125	130.1	190.6	2
LUBLIN	BIRCH	120	132.6	238.1	2
LUBLIN	OAK	230	250.3	341.7	2
LUBLIN	PINE	155	169.6	245.9	2
LUBLIN	SPRUCE	155	166.8	246.9	2
ŁÓDŹ	BEECH	135	154.2	206.5	2
ŁÓDŹ	BIRCH	135	146.5	233.1	2
ŁÓDŹ	OAK	230	249.5	323.3	2
ŁÓDŹ	PINE	158	181.8	275.6	2
ŁÓDŹ	SPRUCE	158	166.1	288.3	2
OLSZTYN	BEECH	126	132.5	185.7	2
OLSZTYN	BIRCH	130	146.7	231.4	2
OLSZTYN	OAK	240	272.8	347.9	2
OLSZTYN	PINE	158	170.5	277.8	2
OLSZTYN	SPRUCE	158	172.5	256.6	2
PIŁA	BEECH	122	139.5	203.2	2
PIŁA	BIRCH	122	135.3	209.9	2
PIŁA	OAK	220.2	262.4	390.3	2
PIŁA	PINE	158.1	165.6	286.9	2
PIŁA	SPRUCE	160	182.1	276.1	2
POZNAŃ	BEECH	135	153.3	206.5	2
POZNAŃ	BIRCH	128	150.1	247	2
POZNAŃ	OAK	245	280.7	430.3	2
POZNAŃ	PINE	158	176.6	289.8	2
POZNAŃ	SPRUCE	158	188.8	300.1	2
RADOM	BEECH	132	144	190.2	2
RADOM	BIRCH	122	139.2	225.8	2
RADOM	OAK	220	235	297.6	2
RADOM	PINE	155	172.9	289.8	2
RADOM	SPRUCE	155	170.4	287.1	2
SZCZECIN	BEECH	122	133.4	191.8	2
SZCZECIN	BIRCH	118	131.3	183.6	2
SZCZECIN	OAK	235	251.3	396	2
SZCZECIN	PINE	160	174	286.7	2
SZCZECIN	SPRUCE	160	186.8	268.3	2
SZCZECINEK	BEECH	120	124.6	180.2	2
SZCZECINEK	BIRCH	116	134.8	192	2
SZCZECINEK	OAK	229	242.1	363	2
SZCZECINEK	PINE	158	163.9	264.7	2
SZCZECINEK	SPRUCE	160	181.3	272.1	2
TORUŃ	BEECH	130	140	176	2
TORUŃ	BIRCH	135	146.6	207.5	2
TORUŃ	OAK	230	244.9	333.5	2
TORUŃ	PINE	158	173.7	267.1	2
TORUŃ	SPRUCE	159	176.4	273.7	2
WARSZAWA	BIRCH	135	147	193.1	2
WARSZAWA	OAK	240	263.1	319	2

WARSZAWA	PINE	159.9	172.2	265.9	2
WARSZAWA	SPRUCE	155	181.9	277	2
WROCŁAW	BEECH	133	143.8	162.6	2
WROCŁAW	BIRCH	120	136.1	171.5	2
WROCŁAW	OAK	240.3	265.5	378.7	2
WROCŁAW	PINE	166	194.6	285.6	2
WROCŁAW	SPRUCE	182	213.1	308.8	2
ZIELONA GÓRA	BEECH	125	135.5	199.2	2
ZIELONA GÓRA	BIRCH	120	142.4	202.9	2
ZIELONA GÓRA	OAK	240	265.5	373.6	2
ZIELONA GÓRA	PINE	160	190.7	307.2	2
ZIELONA GÓRA	SPRUCE	160	186.3	302.1	2
BIAŁYSTOK	BIRCH	135	160.3	271.1	3
BIAŁYSTOK	OAK	254	291.4	385.2	3
BIAŁYSTOK	PINE	167	180.8	264.9	3
BIAŁYSTOK	SPRUCE	167	182.3	283.7	3
GDAŃSK	BEECH	127	135.1	171.9	3
GDAŃSK	BIRCH	127	142.7	188.3	3
GDAŃSK	OAK	236	256.8	364.2	3
GDAŃSK	PINE	170	185.1	279.2	3
GDAŃSK	SPRUCE	172	203.1	290.3	3
KATOWICE	BEECH	137	145.7	192.6	3
KATOWICE	BIRCH	135	147.5	253.3	3
KATOWICE	OAK	245	269.8	373	3
KATOWICE	PINE	175	202.2	320.3	3
KATOWICE	SPRUCE	190	245.4	368.1	3
KRAKÓW	BEECH	144	153.4	207	3
KRAKÓW	BIRCH	135	143.4	243.7	3
KRAKÓW	OAK	257	281.8	384.4	3
KRAKÓW	PINE	176.3	193.3	300.5	3
KRAKÓW	SPRUCE	195	238.5	353.2	3
KROSNO	BEECH	126.3	134.7	179.8	3
KROSNO	BIRCH	128.5	138.6	228	3
KROSNO	OAK	245	267	399.6	3
KROSNO	PINE	159.6	171.8	276.5	3
KROSNO	SPRUCE	171.1	189.8	298.8	3
LUBLIN	BEECH	130	135.4	220.9	3
LUBLIN	BIRCH	130	147	256.9	3
LUBLIN	OAK	244	272.3	420	3
LUBLIN	PINE	165	179.2	282.3	3
LUBLIN	SPRUCE	165	181.8	289.4	3
ŁÓDŹ	BEECH	140	156.9	234.1	3
ŁÓDŹ	BIRCH	140	155.7	260.5	3
ŁÓDŹ	OAK	245	270.6	364.7	3
ŁÓDŹ	PINE	168	192	306.8	3
ŁÓDŹ	SPRUCE	168	199.4	316.6	3
OLSZTYN	BEECH	130	138.1	187.4	3
OLSZTYN	BIRCH	138	156.8	221.2	3
OLSZTYN	OAK	254	298	426.8	3
OLSZTYN	PINE	170	184.7	275	3
OLSZTYN	SPRUCE	170	187.5	275.4	3
PIŁA	BEECH	130	140.3	221.1	3

PIŁA	BIRCH	130	144.8	208.4	3
PIŁA	OAK	245	288.1	410.8	3
PIŁA	PINE	170	179.6	280	3
PIŁA	SPRUCE	175	189.4	257.3	3
POZNAŃ	BEECH	143	170.1	256.1	3
POZNAŃ	BIRCH	136	162.5	252.2	3
POZNAŃ	OAK	260	297.4	456.2	3
POZNAŃ	PINE	170	191.7	326.9	3
POZNAŃ	SPRUCE	168	213.3	344.6	3
RADOM	BEECH	138	150.8	206.2	3
RADOM	BIRCH	130	153.8	253.3	3
RADOM	OAK	233	255.4	341.3	3
RADOM	PINE	165	185.8	304.9	3
RADOM	SPRUCE	165	188.6	314.3	3
SZCZECIN	BEECH	126	135.6	201.7	3
SZCZECIN	BIRCH	125	136	198.2	3
SZCZECIN	OAK	250	266.4	354.7	3
SZCZECIN	PINE	171	186.5	303.6	3
SZCZECIN	SPRUCE	171	189.7	275.8	3
SZCZECINEK	BEECH	125	129.7	185.4	3
SZCZECINEK	BIRCH	123	140.6	176.7	3
SZCZECINEK	OAK	243	258.5	380.6	3
SZCZECINEK	PINE	170	176.8	291.2	3
SZCZECINEK	SPRUCE	172	193	292.7	3
TORUŃ	BEECH	138	152.5	199.6	3
TORUŃ	BIRCH	143	156.4	234.4	3
TORUŃ	OAK	244	268.6	393.2	3
TORUŃ	PINE	170	188	285.4	3
TORUŃ	SPRUCE	169	193.6	308.9	3
WARSZAWA	BIRCH	143	151.4	239.2	3
WARSZAWA	OAK	254	282.9	406.8	3
WARSZAWA	PINE	169.7	184.9	274.5	3
WARSZAWA	SPRUCE	165	191.2	279	3
WROCŁAW	BEECH	141	155.6	198.2	3
WROCŁAW	BIRCH	127	139.2	202.5	3
WROCŁAW	OAK	257.7	288.8	422.8	3
WROCŁAW	PINE	176	202.4	317.4	3
WROCŁAW	SPRUCE	193	228.6	347.6	3
ZIELONA GÓRA	BEECH	130	151.2	214.8	3
ZIELONA GÓRA	BIRCH	126	145.8	236	3
ZIELONA GÓRA	OAK	250	278.4	404.4	3
ZIELONA GÓRA	PINE	170	196.7	311.3	3
ZIELONA GÓRA	SPRUCE	170	200.3	315.5	3

Annex 2

The econometric model for PLD

```
xi: regress pwpspldps ps2

      Source |       SS       df       MS              Number of obs =     245
-------------+------------------------------           F(  2,   242) =   11.81
       Model |  .303624987     2  .151812493           Prob> F      =  0.0000
    Residual |  3.11136205   242  .012856868           R-squared     =  0.0889
-------------+------------------------------           Adj R-squared =  0.0814
       Total |  3.41498703   244  .013995849           Root MSE      =  .11339

------------------------------------------------------------------------------
     pwpspld |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          ps |   .0008504   .0017793     0.48   0.633    -.0026545    .0043554
         ps2 |  -1.78e-08   4.79e-06    -0.00   0.997    -9.45e-06    9.42e-06
       _cons |   1.021514   .1565771     6.52   0.000     .7130862    1.329942
------------------------------------------------------------------------------
```

Annex 3

The econometric model for E-D

```
xi: regress pwpsed ps ps2

      Source |       SS       df       MS              Number of obs =     245
-------------+------------------------------           F(  2,   242) =   10.95
       Model |  1.0344491     2  .517224552            Prob > F      =  0.0000
    Residual |  11.4345641   242  .047250265           R-squared     =  0.0830
-------------+------------------------------           Adj R-squared =  0.0754
       Total |  12.4690132   244  .051102513           Root MSE      =  .21737

------------------------------------------------------------------------------
      pwpsed |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          ps |   .0152781   .0034111     4.48   0.000     .0085589    .0219973
         ps2 |  -.0000421   9.18e-06    -4.59   0.000    -.0000602   -.0000241
       _cons |    .443434   .3001669     1.48   0.141    -.1478394    1.034707
------------------------------------------------------------------------------
```

hettest

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of pwpsed

         chi2(1)      =     3.61
         Prob > chi2  =   0.0575
```

ovtest

```
Ramsey RESET test using powers of the fitted values of pwpsed
       Ho:  model has no omitted variables
                 F(3, 239) =      1.25
                  Prob > F =      0.2925
```

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