Premysl Sedivka[1]

Estimation of Technical Efficiency in Production Technologies of Czech Sawmills

Procjena tehničke učinkovitosti proizvodnih tehnologija u češkim pilanama

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ABSTRACT • *The main aim of this paper is to determine the influence of the type of adopted production technology on the technical efficiency of Czech sawmills, using one-year data of sawmills and applying a stochastic frontier production function model. Individual technical efficiencies have been obtained for small, medium and large sawmills, and their determinants have been estimated using a procedure proposed by Battese and Coelli (1995). The results support the hypothesis that sawmills in the sample failed to achieve full technical efficiency.*

Key words: *technical efficiency, frontier production function, wood-processing industry*

SAŽETAK • *Cilj provedenih istraživanja bio je utvrditi utjecaj primijenjene proizvodne tehnologije na tehničku učinkovitost u češkim pilanama. Korišteni su jednogodišnji podaci pilana na koje je primijenjen stohastički granični funkcijski model proizvodnje. Posebne vrijednosti tehničke učinkovitosti dobivene su za male, srednje i velike pilane, a utjecajni činitelji procijenjeni su primjenom postupka što su ga predložili Battese i Coelli (1995). Dobiveni su rezultati potvrdili hipotezu da istraživane pilane nisu u potpunosti tehnički učinkovite.*

Ključne riječi: *tehnička učinkovitost, granična proizvodna funkcija, industrijska prerada drva*

1 INTRODUCTION
1. UVOD

The impact of technological change on productivity has been seriously considered in economic literature, since the continuous improvement of new production technology has a considerable impact on the economic growth of businesses.

Despite the acknowledged importance of technological innovation and of technologies, which produce products giving a relatively high added value to productivity growth, during the research a number of empirical studies (Faria *et al*, 2005; Mallok, 2005; Faforullah, 1999) mentioned that the level of technical efficiency has failed, due to the adoption of a relatively old type of production technology, as well as due to ineffective use of inputs. These scientific studies demonstrate the importance of investing in new production technologies, which can either increase the value of production (Peschler, 1974; Saljé and Meyer, 1975) (more typical for medium-sized and large businesses) or increase the variability and flexibility of production (Faria *et al*, 2005; Mallok, 2005) (more typical for small businesses), depending on the branch of industry.

Variable productivity in woodworking processes can be explained by differences in the type of production technology adopted, in the efficiency of the production process, and in the business environment (e.g.

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statutory regulations) (Lesourne and Barré, 1991). By investigating productivity and efficiency as the two major types of concepts, this study presents new empirical evidence on the relationship between the process of innovation in productive technology (decrease in automation of the technology adopted) and productivity.

For investigating the effects, a given type of woodworking technology for cutting logs of small and medium-sized diameter will be used, due to the increasing value of manufactured timber under the current conditions of increasing softwood yields and the higher flexibility of sawing, attendance to growth of cutting speed, rate of feet, assessment of deformations affecting the log forms, increasing width of saw kerf (for instance by using profiling technology where a cutting optimization system uses stored lumber dimension data to determine the highest value cutting solution for maximum yield) (LINCK, 2008), by the cutting of large logs by bandsaw technology to increase the flexibility of current cutting schemes with thin saw kerfs (EWD, 2008).

To investigate the efficiency of sawmill sawing, a stochastic frontier production function is employed, where inefficiency is measured as the deviation of the sawmill's output from an idealized frontier function, computed for the whole woodworking industry. The efficiency of a production unit is determined by comparing the observed and optimal values of its outputs or inputs (Lovell, 1993). This study extends the literature that defines the performance of firms as a function of the state of technology and economic efficiency.

The objective of this study is twofold: First, it aims to provide measurements of the technical efficiency of Czech sawmills by determining the stochastic frontier production function for a time period before the start and implementation of the Operational Program of Industry and Innovations, 2007 – 2013, in the Czech Republic. Second, it aims to investigate the impact of the different types of production technologies adopted by sawmills on their own technical efficiency. It will investigate 16 types of production technologies (wrt. Table 1) accepted by Czech sawmills.

2 MATERIALS AND METHODS
2. MATERIJAL I METODE

2.1 Data
2.1. Podaci

The data used in this study are from the database of the Creditinfo Czech Republic, s.r.o. corporation. The database is called *„Company Monitoring"* and is used by the Ministry of Trade and Industry of the Czech Republic and the CzechInvest organization for the statistical investigation of industrial sectors (researched data have been chosen from a version to be published in September 2008). This database includes the full versions of *„Profit and Loss Account"* and *„Balance Sheet Budget"*, always done separately for each timber processing unit. From these sheets, 203 sawmills were randomly separated, for which complete cross-sectional data are available for the year 2006. Data in this database have been periodically updated ever since 1998. Data used in this study were updated in the database on September 1, 2008.

This study includes corporations having the status of corporate entity (e.g. Ltd., Inc. and others) and category according to the definition of the company's size by the *I. Injunction of the European Commission, No. 70/2001, digest 364/2004 Ministry of Trade and Industry*. Companies in the database were distributed into individual groups according to the attribution of OKEC numbers.

The businesses classifed into database according to the OKEC numbers were selected from the branch category OKEC 20.1 (Sawmill Companies) up to the year 2006.

The year 2006 was selected in consideration of the time period before implementation of the Operational Program of Industry and Innovations, 2007 – 2013, in the Czech Republic, to receive financial support to invest in new types of processing technologies. According to the *Account Rules No. 563/1991, part III, §21a,* corporations having the status of corporate entity should publish their *„Profit and Loss Account"* and *„Balance Sheet Budget"*. Furthermore, the database includes information about the characteristics of businesses, including corporate entity status, ownership, number of employees and a basic overview of property structure.

The following data, used in a probability estimate model for parameters of the stochastic frontier production function, were computed from the database: number of employees, direct costs, labour costs, cost of capital, indirect costs. Data associated with the value of soft round timber, value of hard round timber, type of technology adopted, amount of working shifts and yield of sawn wood were obtained through a questionaire by owners and managers of sawmill companies and from the companies' websites.

For gross value of capital, figures of fixed assets are used given in the database, which describe the value of land, buildings, machines, and equipment. Data on the gross value of capital for the eight businesses have to be calculated with regard to data from the preceding years 2005 and 2004, because these data are missing in the database. The number of employees directly reported in the database and by the two businesses has to be calculated with regard to data from the preceding years 2005 and 2004, because these numbers are missing in the database. For the gross value of production, figures of fixed assets are used given in the database, which describe the value of production and sold depreciation write-off property. However, the 11 businesses missing in the database have to be calculated with regard to data from the preceding years 2005 and 2004. All these variables are in logarithms. Figure 1 shows the percentage of adoption according to type of main production technology.

Figure 1 shows a higher incidence of adopting 1 Band Saw Machine (horizontal) (30.0 %), than a combination of 1 Band Saw Machine (horizontal) and 1 Edger Saw Machine (18.7 %) as a main production technology. This can be explained by the fact that these

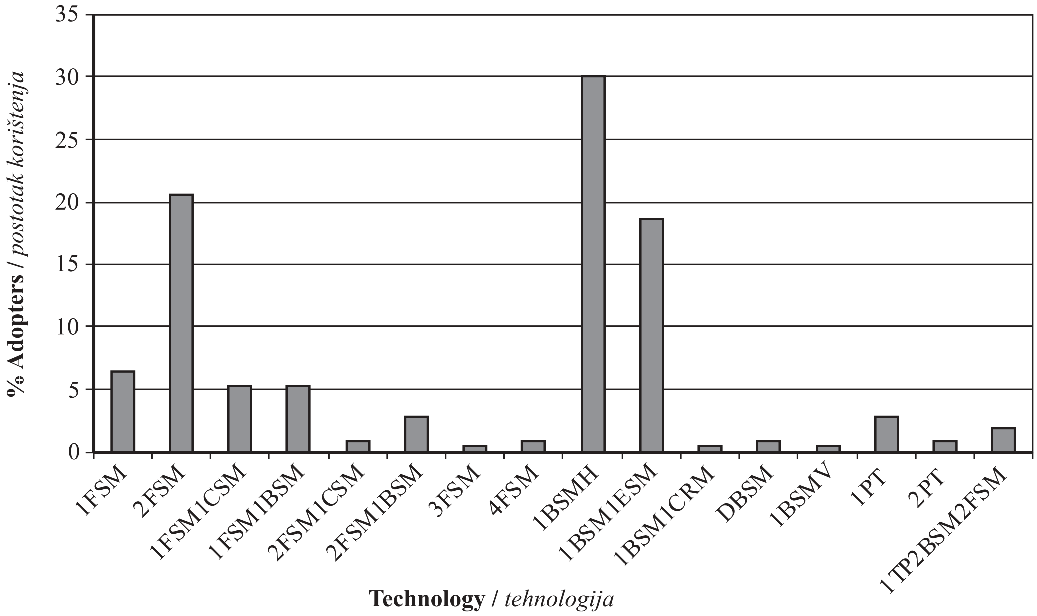

Figure 1 Adoption (%) according to type of technology (meaning of signification at *x*-axes is described in Table 1)
Slika 1. Postotak primjene određene vrste tehnologije (značenje oznaka na osi *x* navedeno je u tabl. 1)

technologies have an advantageous higher flexibility in sawing the inputs of round timber (possibilities of sawing a wide range of dimensions and diameter of round timber and the elimination of some log defects), variability of dimensions in the manufactured sawn wood, and at the same time a quick change of manufacturing programme, low capital costs of investment in the new type of technology, as well as low operating and service costs. Furthermore, Figure 1 shows a higher incidence of adopting the Double Frame Saw Machine (20.7 %), which can be explained by the fact that this type of wood processing technology has been used due to a historical tradition of using this type of production technology in the area of the Czech Republic.

Table 1 provides an overview of the contribution of production technology adopted by sawmills used in this study, and Table 2 provides values of descriptive statistics, which are used in econometric analysis.

Table 1 Type of adopted production technology
Tablica 1. Vrsta primijenjene proizvodne tehnologije

Technology / *Tehnologija*		**Signification** *Oznaka*	**Description** / *Opis*
1)	1 Frame Saw Machine *jedna pila jarmača*	1FSM	Two times cutting on one Frame Saw Machine. *Dvostruko piljenje na pili jarmači.*
2)	Double Frame Saw Machine *dvije pile jarmače*	2FSM	Second Frame Saw Machine cutting sawn-wood prism from the first Frame Saw Machine. *Druga pila jarmača raspiljuje prizmu dobivenu na prvoj jarmači.*
3)	Combination of 1 Frame Saw Machine and 1 Circular Re-saw Machine *kombinacija jedne pile jarmače i jedne kružne pile za raspiljivanje*	1FSM1CSM	Circular Re-saw Machine cutting sawn-wood prism from Frame Saw Machine. *Kružnom pilom raspiljuju se prizme dobivene na pili jarmači.*
4)	1 Frame Saw Machine + 1 Band Saw Machine (horizontal or vertical) *jedna pila jarmača i jedna tračna pila (horizontalna ili vertikalna)*	1FSM1BSM	Frame Saw Machines for cutting soft timber and Band Saw Machine for cutting of hard timber. *Pila jarmača za piljenje mekog drva i tračna pila za piljenje tvrdog drva.*
5)	Combination of 2 Frame Saw Machines and 1 Circular Re-saw Machine *kombinacija dviju pila jarmača i jedne kružne pile za raspiljivanje*	2FSM1CSM	Circular Re-saw Machine cutting sawn-wood prism from both Frame Machines. *Kružna pila raspiljuje prizme dobivene na jarmačama.*
6)	2 Frame Saw Machines + 1 Band Saw Machine (horizontal) *dvije pile jarmače i jedna tračna pila (horizontalna)*	2FSM1BSM	Frame Saw Machines for cutting soft timber and Band Saw Machine for cutting of hard timber. *Pile jarmače za piljenje mekog drva i tračna pila za piljenje tvrdog drva.*

Technology / *Tehnologija*		Signification *Oznaka*	Description / *Opis*
7)	3 Frame Saw Machines *tri pile jarmače*	3FSM	3 Frame Saw Machines are situated one after another. *Tri pile jarmače smještene jedna iza druge.*
8)	4 Frame Saw Machines *četiri pile jarmače*	4FSM	Frame Saw Machines are situated always two and two one after another. *Pile jarmače smještene su u parovima jedne iza drugih.*
9)	1 Band Saw Machine (horizontal) *jedna tračna pila*	1BSMH	Technology for flexible sawing. *Tehnologija za fleksibilno piljenje.*
10)	Combination of 1 Band Saw Machine (horizontal) and 1 Edger Saw Machine *kombinacija jedne tračne pile (horizontalne) i jednoga stroja za okrajčivanje*	1BSM1ESM	Technology for flexible sawing and edging of sawnwood. *Tehnologija za fleksibilno piljenje i okrajčivanje piljenica.*
11)	Combination of 1 Band Saw Machine and 1 Circular Re-saw Machine *kombinacija jedne tračne pile i jedne kružne pile za raspiljivanje*	1BSM1CRM	Circular Re-saw Machine cutting sawn-wood prism from Band Saw Machine. *Kružna pila raspiljuje prizme dobivene na tračnoj pili.*
12)	Double Band Saw Machine (horizontal) *dvostruka tračna pila (horizontalna)*	DBSM	Second Band Saw Machine cutting flexible sawnwood prism from the first Band Saw Machine. *Druga tračna pila raspiljuje prizme dobivene na prvoj tračnoj pili.*
13)	1 Band Saw Machine (vertical) *jedna tračna pila (vertikalna)*	1BSMV	Technology for flexible sawing. *Tehnologija za fleksibilno piljenje.*
14)	1 Profiling Technology *jedan stroj za profiliranje*	1PT	High efficiency cutting technology. *Visoko učinkovita tehnologija za piljenje.*
15)	2 Profiling Technologies *dva stroja za profiliranje*	2PT	High efficiency cutting technology. *Visoko učinkovita tehnologija za piljenje.*
16)	Combination of 1 Profiling Technology and 2 Band Saw Machines or 2 Frame Saw Machines *kombinacija jednog stroja za profiliranje i dviju tračnih pila ili dviju pila jarmača*	1TP2BSM2FSM	Second Band Saw Machines or Frame Saw Machines cutting sawn-wood prism produced from the High efficiency cutting technology. *Tračne pile ili pile jarmače raspiljuju prizmu dobivenu na stroju za profiliranje.*
17)	Finishing technology *tehnologija za završne obrade*		Technology for following woodworking (e.g. Milling machine, Edger saw, Pneumatic drill machine for nailed pallet, …). *Tehnologija za daljnju obradu piljenica (npr. blanjalica, pila za okrajčivanje, pneumatska bušilica i slično).*
18)	Drying chamber *sušionica*		Technology for drying of wood on required final wood moisture content. *Tehnologija za sušenje drva do željenoga konačnog sadržaja vode.*

Source: Computed from database "Company Monitoring Data" of CreditInfo Czech Republic, s.r.o., 2008.
Izvor: izračunano iz baze podataka "Company Monitoring Data" CreditInfo Czech Republic, s.r.o., 2008.

2.2 Methodology
2.2. Metodologija

The parametric stochastic frontier approach suggested by Battese and Coelli (1995) is used to estimate firm-level technical efficiency and investigate its determinants. This procedure was developed from Aiger (1977) and Meeusen and van den Broeck (1977) stochastic frontier model, which models the technical inefficiency effects in terms of other explanatory variables. The advantage of this model is that it gives a procedure for determining the values of companies' technical inefficiencies, and also estimates for comparing one to another.

The function of the translogarithmic production model is defined as:

$$ln(y_i) = \beta_0 + \beta_1 ln(x_{1i}) + \beta_2 ln(x_{2i}) + \beta_3 ln(x_{3i}) + \beta_4 ln(x_{4i}) + \beta_5 ln(x_{5i}) + \beta_6 ln(x_{6i}) + \beta_7 ln(x_{7i}) + (v_i - u_i)$$
$$i=1, \ldots, N \quad (1)$$

Where:

index i = represents i-th enterprise

Table 2 Descriptive statistics, Year 2006
Tablica 2. Deskriptivna statistika podataka za 2006. godinu

Variable / *Varijabla*	**Mean** *Srednja vrijednost*	**Standard deviation** *Standarna devijacija*	**Minimum** *Minimum*	**Maximum** *Maksimum*	**Number of observation** *Broj zapažanja*
Number of employees / *Broj zaposlenih*	28.103	68.569	1	598	203
Direct cost** / *Direktni troškovi*	52069.506	225200.745	0	2030980	203
Labour cost** / *Troškovi rada*	9347.656	27634.219	1.00	261664	203
Cost of capital** / *Investicijski troškovi*	5830.651	26320.497	2.08	246708	203
Indirect cost** / *Indirektni troškovi*	1500.088	5759.349	1.50	52332	203
Value of soft round timber *Vrijednost trupaca mekog drva*	19884.383	79753.645	0	756000	203
Value of hard round timber *Vrijednost trupaca tvrdog drva*	300.294	2376.302	0	31500	203
1) 1FSM	0.064	0.2454	0	1	203
2) 2FSM	0.207	0.4061	0	1	203
3) 1FSM1CSM	0.054	0.2269	0	1	203
4) 1FSM1BSM	0.054	0.2269	0	1	203
5) 2FSM1CSM	0.010	0.0990	0	1	203
6) 2FSM1BSM	0.030	0.1698	0	1	203
7) 3FSM	0.005	0.0702	0	1	203
8) 4FSM	0.010	0.0990	0	1	203
9) 1BSMH	0.300	0.4596	0	1	203
10) 1BSM1ESM	0.187	0.3910	0	1	203
11) 1BSM1CRM	0.005	0.0049	0	1	203
12) DBSM	0.010	0.0990	0	1	203
13) 1BSMV	0.005	0.0702	0	1	203
14) 1PT	0.030	0.1702	0	1	203
15) 2PT	0.010	0.0990	0	1	203
16) 1TP2BSM2FSM	0.020	0.1393	0	1	203
Finishing technology *Tehnologija završne obrade*	0.601	0.4909	0	1	203
Drying chamber / *Sušionica*	0.498	0.3012	0	1	203
Number of workshifts / *Broj smjena*	1.315	0.7241	0	4	203
Yield of sawnwood *Vrijednost piljenog drva*	9609.227	37961.560	7	360000	203

** Value in 1 000,00 CZK.
*** Vrijednost je u tisućama čeških kruna.*

y_i = total value of output of the i-th enterprise for i-th time period
$x_1, x_2 ...... x_7$ are dummy variables representing different type of adopted production technology by each company
x_1 = Number of employees
x_2 = Direct cost
x_3 = Labour cost
x_4 = Cost of capital
x_5 = Indirect cost
x_6 = Value of soft round timber
x_7 = Value of hard round timber
$\beta_0, \beta_1 ...... \beta_7$ are vectors of unknown parameters to be estimated
v_i = is random variables which are assumed to be iid. $N(0, \sigma_v^2)$ and independent of the u_i.
u_i = assumed to account for technical inefficiency in production with a half-normal distribution $|N(0, \sigma_U^2)|$.

All above mentioned variables are in logarithm.

The inefficiency model:

In this model, a half-normal distribution was expected using coefficients affecting the technical inefficiency of companies. These coefficients introduce information about the degree of use of the adopted production technology, degree of use of the technology for following woodworking (e.g. milling machine, edger saw, pneumaticdrill machine for nailed pallet, etc.), drying chamber, amount of working shifts and yield of sawn wood manufactured per year.

Also, a model for the effects of technical inefficiency for the type of cross-sectional data in the Cobb-Douglas production function, Equation 1, is then defined by:

$$u_i = \delta_0 + \delta_1 z_{1i} + \delta_2 z_{2i} + ... + \delta_{20} z_{20i} \quad (2)$$

Where:

u_i = is technical inefficiency of the i-th enterprise

$z_1, z_2 ...... z_{20}$ are dummy variables representing different type of adopted production technology by each company

z_1 = 1FSM (1 Frame Saw Machine)

z_2 = 2FSM (Double Frame Saw Machine)

z_3 = 1FSM1CSM (Combination of 1 Frame Saw Machine and 1 Circular Re-saw Machine)

z_4 = 1FSM1BSM (1 Frame Saw Machine + 1 Band Saw Machina)

z_5 = 2FSM1CSM (Combination of 2 Frame Saw Machines and 1 Circular Re-saw machine)

z_6 = 2FSM1BSM (2 Frame Saw Machines + 1 Band Saw Machina)

z_7 = 3FSM (3 Frame Saw Machines)

z_8 = 4FSM (4 Frame Saw Machines)

z_9 = 1BSMH (1 Band Saw Machine (horizontal))

z_{10} = 1BSM1ESM (Combination of 1 Band Saw Machine (horizontal) and 1 Edger Saw Machine)

z_{11} = 1BSM1CRM (Combination of 1 Band Saw Machine and 1 Circular Re-saw Machine)

z_{12} = DBSM (Double Band Saw Machine (horizontal))

z_{13} = 1BSMV (1 Band Saw Machine (vertical))

z_{14} = 1PT (1 Profiling Technology)

z_{15} = 2PT (2 Profiling Technologies)

z_{16} = 1TP2BSM2FSM (Combination of 1 Profiling Technology and 2 Band Saw Machines or 2 Frame Saw Machines)

z_{17} = Finishing technology (e.g. Milling machine, ...)

z_{18} = Drying chamber

z_{19} = Amount of workshifts

z_{20} = Yield of sawnwood

$\delta_0, \delta_1 ...... \delta_{21}$ are vectors of unknown parameters to be estimated

Parameters of descriptive statistics and estimates for parameters of the functional form of the Cobb-Douglas production model were estimated using the econometric programme LIMDEP (Green, 2002).

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

The results of parameters from the Cobb-Douglas production model, given the specifications for technical efficiency defined by Equation 1, are presented in Table 3. The estimated sigma square (σ^2) of the Czech sawmills is 0.4472 (significant to 5 %). The value is significantly different from zero (Table 3). This indicates the good fit of the model and the correctness of the specified distributional assumption. The estimated gamma (γ) parameter of Czech sawmills is 0.81 and is significant at a 5 % level. This means that 81 % of variations in the output of sawmills among the Czech sawmills in this study are due to the differences in their technical efficiencies. This result approximates the findings of Faria, Fenn and Bruce (2005) – the result of the gamma parameter in this study is $\gamma = 0.87$.

The estimate for the Cobb-Douglas production model for γ is 0.81, which is consistent with the conclusion that the true γ-value is greater than zero.

The coefficients $\beta_0, \beta_1, ... \beta_7$, mentioned in Table 3 have a 5 % level of significance. The coefficient associated with the number of employees (β_1) indicates the positive contribution of a lower labour variable to the productivity of the sample of Czech sawmills in 2006.

3.1 Coefficients associated with the production costs
3.1. Koeficijenti povezani s troškovima proizvodnje

Coefficient of direct costs (β_2) indicates the negative contribution of the direct cost variable to productivity. This means that the ranking of coefficients, in order according to their impact on the productivity of the sample of Czech sawmills in 2006, is as follows: cost of capital (β_4), labour costs (β_3) and lastly indirect costs (β_5).

The coefficient associated with the production of soft round timber (β_6) is positive, while the coefficient associated with the production of hard round timber (β_7) is relatively strongly negative. This shows that the manufacture of hard round timber has a much higher impact on the efficiency of production in comparison with the manufacture of soft round timber. The main reason for this effect is perhaps the higher added-value of sawn hardwood production not designated for building construction, but rather for cabinet making, joinery products, wooden sleepers and parquet products. Sawmills focused on hardwood production usually adopted the band saw, finishing technology (e.g. milling machine, edger saw) and drying chamber.

3.2 Technical efficiency analysis of Czech sawmills
3.2. Analiza tehničke učinkovitosti čeških pilana

Finally, estimating the Cobb-Douglas production frontier function allows for a prediction of the mean of technical efficiency (TE) of sawmills in the sample. Table 4 shows that the mean efficiency is 0.6552, meaning that Czech sawmills could theoretically improve their productivity by 34.48 % with the same quantity of inputs. Figure 2 illustrates the distribution of the estimated individual technical efficiencies. The estimation of technical efficiency differs substantially among the companies, ranging between a minimum of 29.68 % and a maximum of 85.95 %. Out of 203 companies, approximately 82.76 % have an efficiency rate between the decile range of 60 % and 80 %.

The above-mentioned Table 5 shows the distribution of mean values of technical efficiencies according

Table 3 Maximum likelihood estimates for parameters of stochastic frontier production function (Year 2006)
Tablica 3. Procjena maksimalne vjerojatnosti za parametre stohastičke granične funkcije proizvodnje (2006. godina)

Variable / *Varijabla*	**Description** *Opis*	**Parameter** *Parametar*	**Coefficient** *Koeficijent*	**Standard-error** *Standardna pogreška*
General model (Production function) / *Općeniti model (proizvodna funkcija)*				
Constant / *Konstanta*		β_0*	2.0962	0.9537
Number of employees / *Broj zaposlenih*	x_{1i}	β_1*	0.0602	0.0406
Direct cost / *Direktni troškovi*	x_{2i}	β_2*	-0.0024	0.0002
Labour cost / *Troškovi rada*	x_{3i}	β_3*	0.3109	0.0246
Cost of capital / *Investicijski troškovi*	x_{4i}	β_4*	0.2949	0.0293
Indirect cost / *Indirektni troškovi*	x_{5i}	β_5*	0.4503	0.0273
Value of soft round timber *Vrijednost trupaca mekog drva*	x_{6i}	β_6*	0.0010	0.0009
Value of hard round timber *Vrijednost trupaca tvrdog drva*	x_{7i}	β_7*	-0.1130	0.1018
Inefficiency model / *Model neučinkovitosti*				
Constant / *Konstanta*		δ_0	0.6202	0.1152
1FSM	z_1	δ_1	-0.0520	0.0142
2FSM	z_2	δ_2	-0.0173	0.0014
1FSM1CSM	z_3	δ_3	-0.0281	0.0191
1FSM1BSM	z_4	δ_4	-0.0677	0.0394
2FSM1CSM	z_5	δ_5	0.1115	0.1082
2FSM1BSM	z_6	δ_6	-0.0248	0.0156
3FSM	z_7	δ_7	0.2292	0.1809
4FSM	z_8	δ_8	-0.1284	0.1026
1BSMH	z_9	δ_9	-0.0696	0.0294
1BSM1ESM	z_{10}	δ_{10}	-0.0624	0.0248
1BSM1CRM	z_{11}	δ_{11}	-0.0864	0.0615
DBSM	z_{12}	δ_{12}	-0.1518	0.0404
1BSMV	z_{13}	δ_{13}	-0.1261	0.1807
1PT	z_{14}	δ_{14}	0.9546	0.0002
2PT	z_{15}	δ_{15}	0.0625	0.1318
1TP2BSM2FSM	z_{16}	δ_{16}	0.0598	0.1043
Finishing technology / *Tehnologija završne obrade*	z_{17}	δ_{17}	-0.0394	0.0348
Drying chamber / *Sušionica*	z_{18}	δ_{18}	0.0455	0.0343
Number of workshifts / *Broj smjena*	z_{19}	δ_{19}	0.0696	0.0490
Yield of sawnwood / *Vrijednost piljenog drva*	z_{20}	δ_{20}	-0.0398	0.0093
Variance parameters / *Parametri varijance*	σ^2 = 0.4472			
	γ = 0.81			
Log likelihood function *Logaritamska funkcija vjerojatnosti*	= -70.3831			
Observations / *Broj zapažanja*	N = 203			
LR test / *LR test*	= 31.57			

* indicates that coeficient is statistically significant at the 5 % levels.
** Označava da je koeficijent statistički značajan na razini od 5 %.*

Table 4 Decile range of frequency distribution of technical efficiencies of Czech Sawmills (Year 2006)
Tablica 4. Raspodjela učestalosti tehničke učinkovitosti čeških pilana u intervalima od 10 % (2006. godina)

Decile range, % *Raspon, %*	**Number of enterprises** *Broj tvrtki*	**Value of technical efficiency, %** *Vrijednost tehničke učinkovitosti, %*
> 90	0	0
81 – 90	3	1.48
71 – 80	53	26.11
61 – 70	115	56.65
51 – 60	25	12.32
41 – 50	3	1.48
31 – 40	3	1.48
21 – 30	1	0.49
< 20	0	0
Mean, % / *Srednja vrijednost, %*		65.52
Minimum, % / *Minimum, %*		29.68
Maximum, % / *Maksimum, %*		85.95

Source: Computed from database "Company Monitoring Data" of CreditInfo Czech Republic, s.r.o., 2008.
Izvor: izračunano iz baze podataka "Company Monitoring Data" CreditInfo Czech Republic, s.r.o., 2008.

to the size of the Czech sawmill. The lowest measured value of technical efficiency is for small sawmills (55.67). This TE result for small sawmills can be obscured during the reduction of values of Earnings before Interest and Taxes (EBIT), volume of production and other indices mentioned in their account „Balance Sheets" and „Profit and Loss Accounts" by the company managers. The highest value of TE is obtained by large sawmills (70.98).

3.3 Test of the null hypothesis
3.3. Testiranje hipoteze

The null hypothesis specifies that Czech sawmills are technically efficient in their production, and that any variation in their output is only due to random effects. The hypothesis is defined as follows: H_0: $\gamma = 0$. The generalized Cobb-Douglas model was conducted and the Chi-square (χ^2) statistics were computed. Table 6 shows the result of the generalized Cobb-Douglas model. The null hypothesis, $\gamma = 0$, was rejected among Czech sawmills in this study. This means that the effects of technical inefficiency apply to these sawmills.

3.4 Test of significance of variable coefficients in the inefficiency model
3.4. Test značajnosti koeficijenata varijabli u modelu neučinkovitosti

The null hypothesis is formulated so that each of the estimated coefficients of the explanatory variables

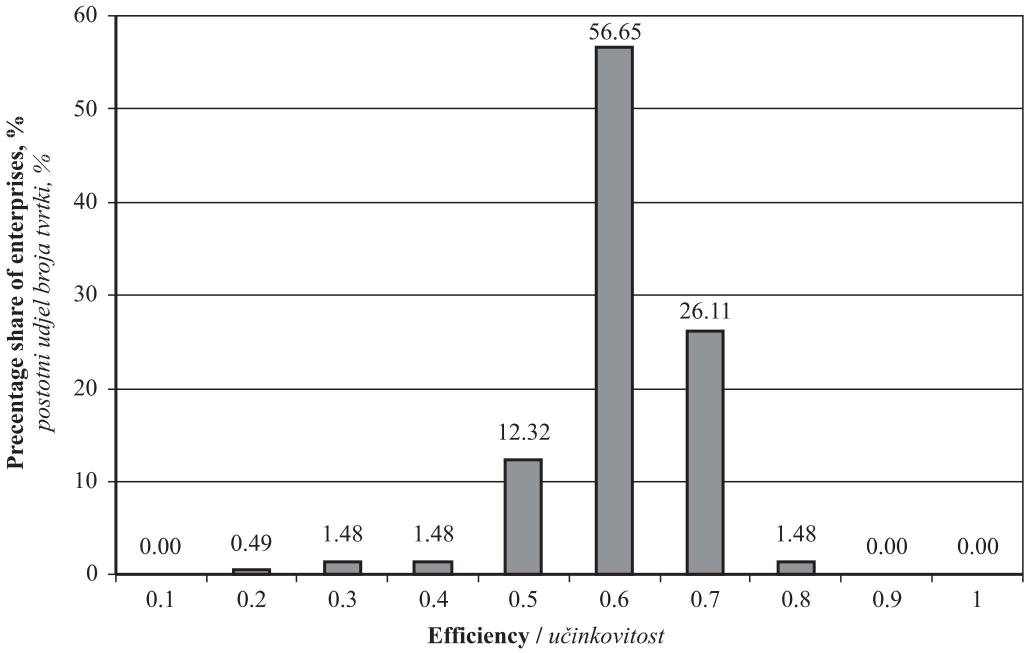

Figure 2 Frequency distribution of technical efficiencies (percentage share)
Slika 2. Raspodjela učestalosti tehničke učinkovitoste (postotni udio)

Table 5 Distribution of values of technical efficiencies (TE) according to the size of sawmills (Year 2006)
Tablica 5. Raspodjela vrijednosti tehničke učinkovitosti (TE) prema veličini pilane (2006. godina)

Size of enterprises *Veličina tvrtke*	**Number of employees***** *Broj zaposlenih****	**Number of enterprises** *Broj tvrki*	**Mean of TE, %** *Srednja vrijednost TE, %*
Micro / *vrlo mala*	< 10	160	57.22
Small / *mala*	11 - 50	29	55.67
Medium / *srednja*	51 - 250	8	59.82
Large / *velika*	250 <	6	70.98

Source: Computed from database "Company Monitoring Data" of CreditInfo Czech Republic, s.r.o., 2008.
Izvor: izračunano iz baze podataka "Company Monitoring Data" CreditInfo Czech Republic, s.r.o., 2008.
*** Distribution according the definition of the size enterprises by the I. Injunction of European Commission, no.70/2001, digest 364/2004 Ministry of Trade and Industry.
**** Raspodjela prema definiciji veličine tvrtke dana u dokumentu I. Injunction of European Commission, br.70/2001, digest 364/2004, Ministarstvo trgovine i industrije.*

Table 6 Test of hypothesis on technical efficiency
Tablica 6. Testiranje hipoteze o tehničkoj učinkovitosti

H_O: Czech sawmills are fully technically efficient (γ = 0) *H_O: Češke pilane tehnički su potpuno učinkovite (γ = 0).*				
Equation *Jednadžba*	**Null hypothesis** *Nul-hipoteza*	**Log (Likelihood)** *Log (vjerojatnost)*	$\chi^2_{Computed}$	$\chi^2_{0,95;7}$
1	H_0: γ = 0	-0.7038	31.57****	14.07

Source: Computed from database "Company Monitoring Data" of CreditInfo Czech Republic, s.r.o., 2008.
Izvor: izračunano iz baze podataka "Company Monitoring Data" CreditInfo Czech Republic, s.r.o., 2008.
**** Indicates that null hypothesis is rejected at the 5% level.
***** Označava da se nul-hipoteza odbacuje na razini značajnosti od 5 %.*

of the inefficiency model of the stochastic frontier production function is statistically significant (variables have some significant relationship with the TE of Czech sawmills).

The hypothesis of the inefficiency model is defined as: H_0: $\delta_i = 0$, where δ_i is the coefficient associated with the given adopted production technology ($\delta_1\ \delta_2 \ldots \delta_{16}$), with the given adopted finishing technology (δ_{17}) and drying chamber (δ_{18}), with the number of working shifts (δ_{19}) and with the yield of sawn wood production (δ_{19}). The statistical test used to test the null hypothesis in this model is the t-ration test, where the coefficient α is statistically significant at a 5 % level, with a 203 degree of freedom. Table 7 shows the results of t-ration tests for coefficients of the inefficiency model of the stochastic frontier production function for Czech sawmills. It was determined that all inefficiency variables were significantly different from zero; hence, the null hypothesis was accepted by the coefficients associated with 1FSM, 2FSM, 1FSM1CSM, 1FSM1BSM, 2FSM1BSM, 1BSMH, 1BSM1ESM, 1BSMV, 1PT, 1TP2BSM2FSM, finishing technology, drying chamber, number of working shifts and yield of sawn wood. All these coefficients, except for the number of working shifts, have a negative sign, which suggests that using these technologies has a positive effect on the efficiency of companies.

The coefficients associated with 2FSM1CSM, 3FSM, 4FSM, 1BSM1CRM, DBSM and 2PT technology are not statistically significant at a 5 % level, given a 203 degree of freedom, because in the sample of sawmills, there is statistically a relatively small number of the above-mentioned types of adopted production technologies.

The positive value (0.0696) of the coefficient *number of working shifts* means that this coefficient has a negative impact on the companies' technical efficiency. This negative effect can be explained by the fact that over 80% of the producers in the sample of sawmills have only one working shift daily.

4 CONCLUSION
4. ZAKLJUČAK

This study has investigated the technical efficiency of Czech sawmills. A model of a stochastic frontier production function is proposed for cross-sectional data observed from the year 2006. This study has established that Czech sawmills were not fully technically efficient in the use of production inputs. The mean technical efficiency of Czech sawmills is about 65.52 %. This means that companies could theoretically improve their productivity by 34.48 % with the same quantity of inputs. Estimates of technical efficiency differ substantially among the companies, ranging between a minimum of 29.68 % and a maximum of 85.95 %. Out of 203 companies, approximately 82.76 % have a technical efficiency rate between 60 % and 80 %.

The analysis of the influence of variables associated with an adopted type of production technology is accepted for 1FSM, 2FSM, 1FSM1CSM, 1FSM1BSM, 2FSM1BSM, 1BSMH, 1BSM1ESM, 1BSMV, 1PT,

Table 7 T-ratio test for significance of coefficients of variables of the inefficiency model of Czech Sawmills
Tablica 7. T-test značajnosti koeficijenata varijabli u modelu neučinkovitosti na primjeru čeških pilana

H_O: Variables associated with the adoptered production technology have significant effect on technical efficiency of Czech Sawmills ($\delta_i = 0$) *H_O: Varijable povezane s primijenjenom tehnologijom proizvodnje imaju značajan utjecaj na tehničku učinkovitost čeških pilana ($\delta_i = 0$).*				
Variable / *Varijabla*	**Parameter** *Parametar*	**Coefficient** *Koeficijent*	**T-ratio** *T-omjer*	**T-critical** *T-kritični*
1FSM *	δ_1	-0.0520	1.752	1.65
2FSM *	δ_2	-0.0173	1.813	1.65
1FSM1CSM *	δ_3	-0.0281	1.910	1.65
1FSM1BSM *	δ_4	-0.0677	1.757	1.65
2FSM1CSM	δ_5	0.1115	1.307	1.65
2FSM1BSM *	δ_6	-0.0248	1.761	1.65
3FSM	δ_7	0.2292	1.167	1.65
4FSM	δ_8	-0.1284	1.248	1.65
1BSMH *	δ_9	-0.0696	1.979	1.65
1BSM1ESM *	δ_{10}	-0.0624	1.866	1.65
1BSM1CRM	δ_{11}	-0.0864	1.476	1.65
DBSM	δ_{12}	-0.1518	1.181	1.65
1BSMV *	δ_{13}	-0.1261	1.791	1.65
1PT *	δ_{14}	0.9546	1.688	1.65
2PT	δ_{15}	0.0625	1.074	1.65
1TP2BSM2FSM *	δ_{16}	0.0598	1.673	1.65
Finishing technology * / *Tehnologija završne obrade*	δ_{17}	-0.0394	1.933	1.65
Drying chamber / *Sušionica* *	δ_{18}	0.0455	1.828	1.65
Number of workshifts / *Broj smjena* *	δ_{19}	0.0696	1.719	1.65
Yield of sawnwood * / *Vrijednost piljenog drva*	δ_{20}	-0.0398	2.258	1.65

Source: Computed from database "Company Monitoring Data" of CreditInfo Czech Republic, s.r.o., 2008.
Izvor: izračunano iz baze podataka "Company Monitoring Data" CreditInfo Czech Republic, s.r.o., 2008.
* Indicates that coeficient is statistically significant at the 5 % levels.
** Označava da je koeficijent statistički značajan na razini od 5 %.*

1TP2BSM2FSM, finishing technology, drying chamber and the yield of sawn wood production. All these mentioned technologies had a significant influence on their TE in the study area.

2FSM1CSM, 3FSM, 4FSM, 1BSM1CRM, DBSM and 2PT technology did not have a significant influence on their TE because there was a relatively small number of sawmills in the observed sample which adopted this production technology.

The coefficient *number of working shifts* has a negative impact on a company's technical efficiency. This effect can be explained by the fact that over 80% of producers in the sample of sawmills have only one daily working shift. The above-mentioned Table 5 shows the distribution of the mean values of technical efficiencies according to the size of Czech sawmills. The lowest measured value of technical efficiency is shown by small sawmills (55.67). This TE result of small sawmills can be obscured during the reduction of values of Earnings before Interest and Taxes (EBIT), volume of production and other indices mentioned by the managers of the companies. The highest technical efficiency has been established for large sawmills (70.98).

Technical efficiency increases with the increasing size of sawmills. This means that larger sawmills in the sample of companies are more effective.

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