STUDY OF SURVIVAL TIME IN PULP EXPORT

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ABSTRACT: This study analyzed the time for a country to survive exporting pulp, using a Cox regression model. Covariates being used included data about population, Gross Domestic Product, total exports of forest products as an aggregate, pulp production and balance of trade for pulp, economic markets and blocks, and geographic regions. To select and check the most significant covariates, a proposal formulated by Collet (1994) was used. It was concluded that survival analysis via the Cox regression model proved to be a powerful tool for predicting the survival of a country exporting pulp; around 80% of countries that have pulp in their list of exports continue to export the commodity; out of the fifteen covariates selected for fitting the Cox model, four explain the model and two were found significant in explaining the survival of a country exporting pulp; international trade agreements were more significant in the Cox regression model than classes of macroeconomic forest indicators and geographic location; covariates explaining the odds of a country exporting pulp to survive, according to the hazard ratio, were, in descending order, integration between ECLAC and European Union, be a member of the European Union (V07) and be a member of ECLAC (V6); Brazil has 3.5 times as much chance of survival exporting pulp through an integration between ECLAC and the European Union than a country that is not a part of such integration; the probability that Brazil will survive exporting pulp is greater than the probability that Asian countries will.

Key words: Forest economics, survival analysis, Cox model.

ESTUDO DO TEMPO DE SOBREVIVÊNCIA NA EXPORTAÇÃO DE CELULOSE

RESUMO: *Este estudo analisou o tempo para um país sobreviver exportando celulose, via modelo de regressão de Cox. As covariáveis utilizadas foram os dados de população, Produto Interno Bruto, exportações totais do agregado de produtos florestais, produção e saldo da balança comercial de celulose, blocos e mercados econômicos e regiões geográficas. Para selecionar e verificar as covariáveis mais significativas, utilizou-se a proposta de Collet (1994). Concluiu-se que a análise de sobrevivência via modelo de regressão de Cox, demonstrou ser uma ferramenta poderosa para a predição de um país sobreviver exportando celulose; cerca de 80% dos países, que têm na sua pauta de exportação a celulose, continuam exportando essa commodity; das quinze covariáveis escolhidas para ajustar o modelo de Cox, quatro explicam o modelo e duas foram significativas para explicar a sobrevivência de um país exportar celulose; os acordos comerciais internacionais foram mais significativos no modelo de regressão de Cox do que as classes dos indicadores macroeconômicos florestais e da localização geográfica; as covariáveis que explicaram as chances (risco) de um país sobreviver exportando celulose, de acordo com a razão de risco, foram, em ordem decrescente, a integração da CEPAL com a União Europeia, pertencer à União Européia (V07) e pertencer a CEPAL (V6); o Brasil tem 3,5 vezes mais chance de sobreviver exportando celulose por meio da integração entre a Cepal e a União Europeia do que um país não pertencente a essa integração; a probabilidade de o Brasil sobreviver exportando celulose é maior que a dos países asiáticos.*

Palavras-chave: Economia florestal, análise de sobrevivência, modelo de Cox.

1 INTRODUCTION

The world has less than four (4) billion hectares of forests, which cover about 30% of the terrestrial area of the globe. Globalization has expedited trade relations worldwide, giving prominence to nonnative forests in international trade opportunities. In 2008, exports of forest products reached US$ 235.12 billion, out of which 60% derived from the pulp and paper subsector (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS - FAO, 2009).

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The per capita consumption of paper can serve as an indicator of how developed a country is. Along this line of reasoning, one could argue that countries exporting forest products regard the share of pulp and paper in their aggregate volume of exports as a status symbol of representativeness.

In 2008, the Brazilian export share of forest products was US$ 7.9 billion, which accounts for 3.37% of global exports. Out of all forest products included in the Brazilian exports list, pulp features as the most representative, reaching 49.32% of the total and placing Brazil in third position in the world ranking. The world production of pulp then was 176 million tons. The Brazilian share of this market was 12.85 million tons (7.29% of the total), which means Brazil beat even most traditional producers such as Sweden, Finland, China and Norway (FAO, 2009).

Pulp is a commodity and its market supply and demand is inelastic with regard to price. The pulp industry is characterized by capital-intensive business and economies of scale. Additionally, availability of technological expertise along with capital specificity and irreversibility add to the long maturing process of manufacturing projects.

Most nonnative forests across the globe have been fomented by government agencies. They are expanding rapidly in the tropics and subtropics, imposing their importance in supplying the world with timber in years to come (UGALDE; PÉREZ, 2001).

Today, Eucalyptus and Pinus are the most commonly used genera for industrial purposes. The high technology achieved in silviculture and forest management over the past three decades, coupled with the high yield provided by Brazilian eucalyptus, places Brazil among the countries incurring the lowest production costs for short fiber pulp in the world (REZENDE et al., 2008).

Hirschman (1961) demonstrated that an industry has the means or ability to induce new activities and demands, generated by comparative advantages. These advantages allow creating an industry that will secure domestic availability of a given product, as opposed to the risks and threats of importing that product, for instance, pulp and paper.

Once the importance of the pulp industry is verified in the industrial matrix of a country, it is also necessary to study the time required to enter the export market for the product. Reliability or Survival Analysis a set of statistical techniques intended to study data related to the time required for occurrence of an event, for instance, for a country to enter and survive the global market (COLOSIMO; GIOLO, 2006).

According to Cardoso and Colosimo (2003), censoring is the main feature of survival studies and occurs when the value of a measurement or observation is only partially known, that is, for some reason the occurrence of an event was interrupted for a given country before failure was observed. This means that every observation about pulp exporting countries is but knowledge that failure time is greater than the observed censoring time.

In conventional statistical methods, the presence of censoring obstructs analysis, requiring that every failure be known. For this reason, survival models should be given special attention in analyses of forest products. This study analyzed the time for a country to survive exporting pulp, via the Cox regression model.

2 MATERIAL AND METHODS

2.1 Data used

Survival data sets are characterized by failure time and censoring information. These two components constitute the response. In this particular study, failure time is the period a country has from the start of the study till it starts to export pulp. Censoring is considered for countries that failed to export.

Samples include 131 countries that exported pulp in the period between 1961 and 2008 (47 years), according to a database of information about the global trade of forest products provided by FAO. Failure time was considered to be the start of the studies until the relevant country starts to export pulp. Censoring was established for countries that, for some reason, stopped exporting pulp at the end of the study period (2008).

Table 1 provides covariates used in the study, which may be grouped into three classes, as follows:

Class I - Macroeconomic indicators for forestry: countries that export forest products (V01) and indicators related to the pulp subsector (V02 to V05);

Class II - International trade agreements: Economic Commission for Latin America and the Caribbean (ECLAC) (V06); European Union (EU) (V07); Latin American Integration Association (ALADI) (V08); Asia-Pacific Economic Cooperation (APEC) (V09); Free Trade Area of the Americas (FTAA) (V10);

Class III - Geographic location - continents (V11 to V15).

Table 1 – Study variables.

Tabela 1 – *Variáveis envolvidas no estudo.*

Code	Description	Categories
V1	Exports of forest products > US$ 1,000.00	0 - no 1 - yes
V2	Apparent consumption of pup > 0	0 - no 1 - yes
V3	Pulp production (t) > 0	0 - no 1 - yes
V4	Pulp importation (t) > 0	0 - no 1 - yes
V5	Balance of trade for pulp > US$ 1,000.00	0 - no 1 - yes
V6	ECLAC	0 – no 1 - yes
V7	European Union	0 - no 1 - yes
V8	ALADI	0 - no 1 - yes
V9	APEC	0 - no 1 - yes
V10	FTAA	0 - no 1 - yes
V11	Africa	0 - no 1 - yes
V12	Americas	0 - no 1 - yes
V13	Asia	0 - no 1 - yes
V14	Europe	0 - no 1 - yes
V15	Oceania	0 - no 1 - yes

Source: research data.

2.2 Cox regression model

This study used the regression model developed by Cox (1972), whose general equation is given as follows:

$$\lambda(t) = \lambda_0(t)\exp(x'\beta)$$

where,

$\lambda(t)$ and $\lambda_0(t)$ = failure rate functions;
$x' = (x_1, \ldots, x_p)$ = vector of *p* covariates;
β = vector of covariate-related parameters.

Semiparametric models, better known as Cox regression model, have greater flexibility than parametric models and also allow easy incorporation of time-dependent variables. For the development of this model, the two steps below were adopted.

2.2.1 Strategies for selection of covariates

Various methods are available for selection of covariates, consisting of automatic and manual routines. Automatic routines include forward, backward or stepwise methods. They are available in statistical packages and, as a disadvantage, they have a tendency to identify a specific set of covariates rather than possible sets equally suitable for explaining the response.

This study uses methods that involve close interference from the researcher. The strategy used for selection of covariates derives from the proposal formulated by Collet (1994), and consists of six steps after which to assign a final model:

a) Models were all fitted containing only one covariate. All covariates significant at a 0.05 level were included, as verified by the Likelihood Ratio Test (LRT), given as

$$H_0 : \beta = \beta_0 \xrightarrow{sob\ H_0} 2\left|\log L\left(\hat{\beta}\right) - \log L\left(\hat{\beta}_0\right)\right| \sim^a \chi^2_{(1)}$$

where $\log L\left(\hat{\beta}\right)$ is Maximized Likelihood for the Full Model and $\log L\left(\hat{\beta}_0\right)$ is Maximized Likelihood for the H_0 Restricted Model.

b) Significant covariates of Step 1 were then fitted collectively. Colosimo and Giolo (2006) argue that in the presence of certain covariates, other covariates may lose significance. Only those attaining significance should remain in the model.

c) With the covariates retained in Step 2, a new model was fitted and the covariates excluded in Step 2 returned to the model to confirm whether or not they were statistically significant.

d) Casually significant covariates of Step 3 were included in the model along with those of Step 2. In this step, the covariates excluded in Step 1 returned to the model to confirm whether or not they were statistically significant.

e) A model was then fitted which included the significant covariates of Step 4, testing if any of them could be removed from the model.

f) Once covariates were selected, the final model was then fitted. To complete modeling, the possibility of including interaction terms was checked.

According to Colosimo and Giolo (2006), when using this selection procedure, one should include important information researched in the decision process and avoid being too strict when testing the significance of each covariate. To decide whether a term should be included, the significance level should be close to 0.10.

2.2.2 Goodness of fit of the Cox model

According to Colosimo and Giolo (2006), the Cox regression model is fairly flexible on account of the presence of a nonparametric component. To check the goodness of fit of this model one should verify hazard proportionality. For

that, the proportional hazards ratio test was used, in addition to the graph of the logarithm of the cumulative hazard function versus time of each covariate. An extreme situation of violation for this assumption occurs when curves intersect.

3 RESULTS AND DISCUSSSION

Figure 1 illustrates the 131 countries being considered in this study, in alphabetical order, with failing countries being represented by a black line and censored countries being represented by a red line. It was noted that 108 countries failed, that is, they exported pulp, while 23 countries were censored in the study period (2008).

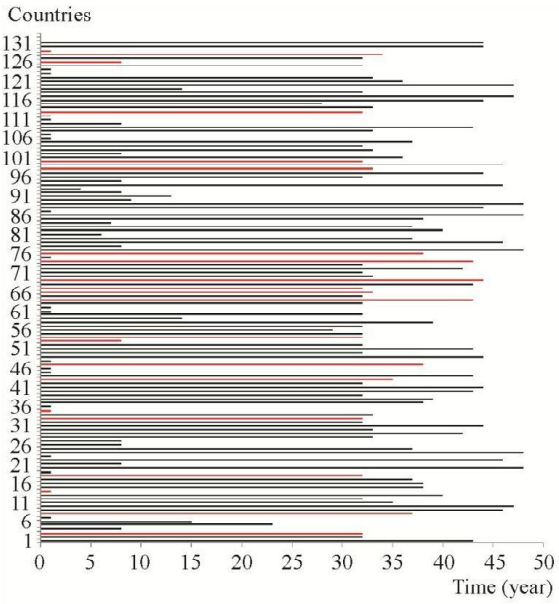

Figure 1 – Time spent by a country to export pulp, between 1961 and 2008.

Figura 1 – *Tempo gasto para um país exportar celulose, no período de 1961 a 2008.*

Table 2 shows the selection of covariates, for analyzing the time elapsed (or required), for a country to export pulp, using the proposal formulated by Collett (1994), at a 10% significance level.

In Step 1, only one covariate was noted to have influence or significance on the model at a time, with removal of covariates V01 (Exports of forest products), V04 (Importation of pulp) and V05 (Balance of trade for pulp) of Class I - vocation for forestry; V08 (ALADI) and V10 (FTAA) of Class II - trade agreements and; V12 (Americas) and V15 (Oceania) of Class III - geographic regions.

In Step 2, the following covariates were left to select the model: apparent consumption of pulp (V02), produce pulp (V03), ECLAC (V06), European Union (V07), APEC (V09), Africa (V11), Asia (V13), Europe (V14).

To test the level of significance of covariates remaining in Step 1, the covariates were removed from the model one by one. The following covariates were removed: apparent consumption of pulp (V02), ECLAC (V06), Africa (V11), Asia (V13), Europe (V14), i.e. excluding one from Class I, one from Class II, and Class III in full. The following covariates remained: produce pulp (V03), European Union (V07) and APEC (V09).

In Step 3, the covariates removed from Step 2 returned (V02, V06, V11, V13, V14), to check whether they should really be eliminated from the model. Eliminated covariates included V02, V11, V13, V14, and covariate ECLAC (V06) returned to the model. Thus, Step 3 was left with covariates produce pulp (V03), ECLAC (V06), European Union (V07) and APEC (V09).

In step 4, the covariates eliminated in Step 1 returned [V01 (Exports of forest products), V04 (Importation of pulp) and V05 (Trade balance of pulp) of Class I - vocation for forestry; V08 (ALADI) and V10 (FTAA) of Class II - trade agreements and; V12 (Americas) and V15 (Oceania) of Class III – geographic regions], to check whether indeed they should be a part of the model or not. It was concluded that all covariates included in Step 4 should be eliminated from the model, leaving only the covariates selected in Step 3.

Step 5 followed the same procedure as Step 2, removing the covariates that remained from Step 4 one by one [produce pulp (V03), ECLAC (V06), European Union (V07) and APEC (V09)], and checking whether they should remain in the model or not. All covariates were found to be significant for the model, therefore none was removed.

Step 6 consisted in checking the integration between two covariates and it was found that the model can provide fitting, where:

$$\lambda(t) = \lambda_0(t)\exp(\beta_3 V03 + \beta_6 V06 + \beta_7 V07 + \beta_9 V09 + (\beta_6 V06 \cdot \beta_7 V07))$$

Out of the 15 covariates being tested, 14 were found not to be significant, especially those of Class I - vocation for forestry and of Class III - geographic regions. The most representative class of covariates in the survival model was Class II - trade agreements.

After selecting the model, one should check whether the proportional hazards assumption of the Cox model is met. Two graphic methods were used for that, one involving the logarithm of the base cumulative hazard function (Figure 2) and another involving standardized Schoenfeld residuals (Figure 3). In both, a graph was produced for each covariate included in the final model.

Table 2 – Selection of covariates using the Cox regression model.

Tabela 2 – *Seleção de covariáveis usando o modelo de regressão de Cox.*

Steps	Model	Log-Likelihood	LRT	P Value
Step 1	Null	-428.549200	-	-
	V1	-427.395400	2.3076	0.1287
	V2	-424.115800	8.8668	0.0029
	V3	-408.535200	40.028	2.50E-10
	V4	-427.929800	1.2388	0.2657
	V5	-427.885400	1.3276	0.2492
	V6	-425.362800	6.3728	0.0116
	V7	-422.018700	13.061	0.0003
	V8	-427.797800	1.5028	0.2202
	V9	-425.576200	5.946	0.0148
	V10	-427.789200	1.52	0.2176
	V11	-425.869100	5.3602	0.0206
	V12	-427.789200	1.52	0.2176
	V13	-427.103400	2.8916	0.0890
	V14	-424.300500	8.4974	0.0036
	V15	-428.171000	0.7564	0.3845
Step 2	V02+V03+V06+V07+V09+V11+V13+V14	-397.3597000	-	-
	V03+V06+V07+V09+V11+V13+V14	-397.6466000	0.5738	0.4488
	V02+V06+V07+V09+V11+V13+V14	-408.3921000	22.0648	2.64E-06
	V02+V03+V07+V09+V11+V13+V14	-398.1221000	1.5248	0.2169
	V02+V03+V06+V09+V11+V13+V14	-400.2810000	5.8426	0.0156
	V02+V03+V06+V07+V11+V13+V14	-399.8494000	4.9794	0.0257
	V02+V03+V06+V07+V09+V13+V14	-397.5972000	0.475	0.4907
	V02+V03+V06+V07+V09+V11+V14	-397.6758000	0.6322	0.4265
	V02+V03+V06+V07+V09+V11+V13	-397.4122000	0.105	0.7459
Step 3	V03+V07+V09	-401.8344000	-	-
	V03+V07+V09+V02	-401.7814000	0.106	0.7447
	V03+V07+V09+V06	-398.0453000	7.5782	0.0059
	V03+V07+V09+V11	-401.0604000	1.548	0.2134
	V03+V07+V09+V13	-401.1484000	1.372	0.2415
	V03+V07+V09+V14	-401.8166000	0.0356	0.8503
Step 4	V03+V06+V07+V09	-398.0453000		
	V03+V06+V07+V09+V01	-397.9534000	0.1838	0.6681
	V03+V06+V07+V09+V04	-398.0405000	0.0096	0.9219
	V03+V06+V07+V09+V05	-397.0900000	1.9106	0.1669
	V03+V06+V07+V09+V08	-397.9820000	0.1266	0.7220
	V03+V06+V07+V09+V10	-398.0385000	0.0136	0.9072
	V03+V06+V07+V09+V12	-398.0385000	0.0136	0.9072
	V03+V06+V07+V09+V15	-397.0091000	2.0724	0.1500

To be continued...

Continua...

Table 2 – Continued...

Tabela 2 – *Continuação...*

Steps	Model	Log-Likelihood	LRT	P Value
Step 5	V03+V06+V07+V09	-398.0453000	-	-
	V06+V07+V09	-412.7771000	29.4636	5.70E-08
	V03+V07+V09	-401.8344000	7.5782	0.0059
	V03+V06+V09	-404.3522000	12.6138	0.0004
	V03+V06+V07	-400.8813000	5.672	0.0172
Step 6	V03+V06+V07+V09	-398.0453000	-	-
	V03+V06+V07+V09+(V03*V06)	-397.4595000	1.1716	0.2791
	V03+V06+V07+V09+(V03*V07)	-397.7333000	0.624	0.4296
	V03+V06+V07+V09+(V03*V09)	-396.7330000	2.6246	0.1052
	V03+V06+V07+V09+(V06*V07)	-396.4725000	3.1456	0.0761
	V03+V06+V07+V09+(V06*V09)	-398.0420000	0.0066	0.9353
	V03+V06+V07+V09+(V07*V09)	-398.0453000	0	1.0000
Final Model	V03+V06+V07+V09+(V06*V07)	-396.4725000		

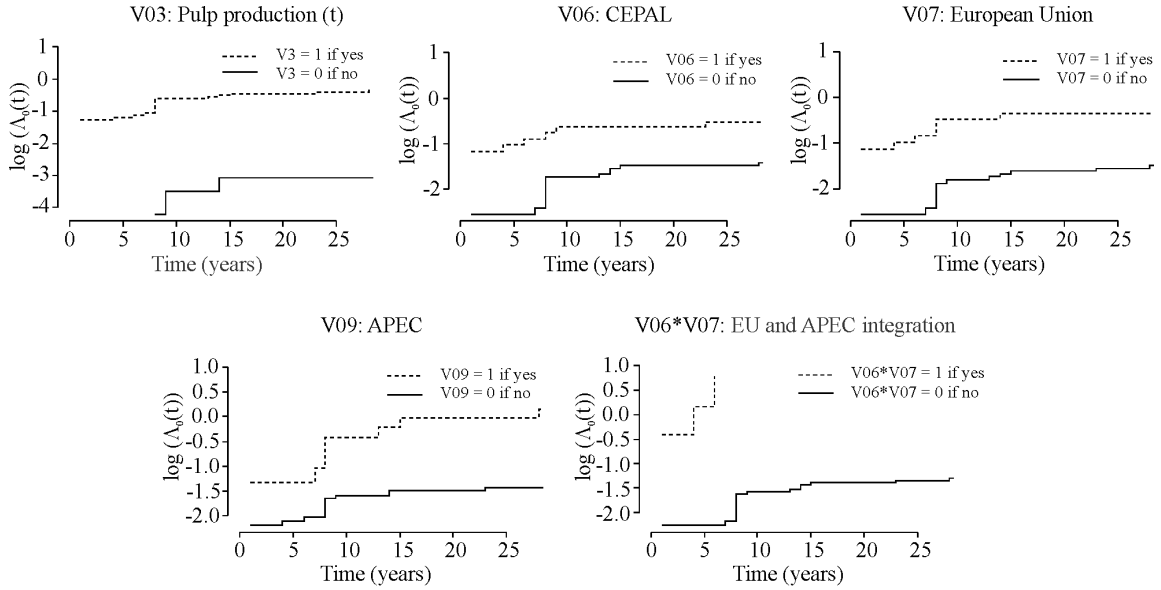

Figure 2 – Logarithm of the cumulative hazard function versus time for covariates V03, V06, V07 V09 and V06*V07.

Figura 2 – *Logaritmo da função risco acumulado versus tempo para as covariáveis V03, V06, V07 V09 e V06*V07.*

It was noted in Figure 2 that covariates V03, V06, V07, V09 and V06*V07 do not violate the proportional hazards assumption, as their graph curves show approximately constant differences over time. An extreme situation of violation for this assumption occurs when curves intersect.

Figure 3 provides standardized Schoenfeld residuals. A visual analysis of the figure confirms this fact, since tendencies are evident over time, particularly with regard to covariate (V6) ECLAC, and that indicates model validation.

Table 3 provides the proportional hazards test for covariates V03, V06, V07, V09 and V06*V07. Covariates V03 (produce pulp) and V09 (APEC) were significant, suggesting a possible failure in the proportional hazards assumption for these covariates.

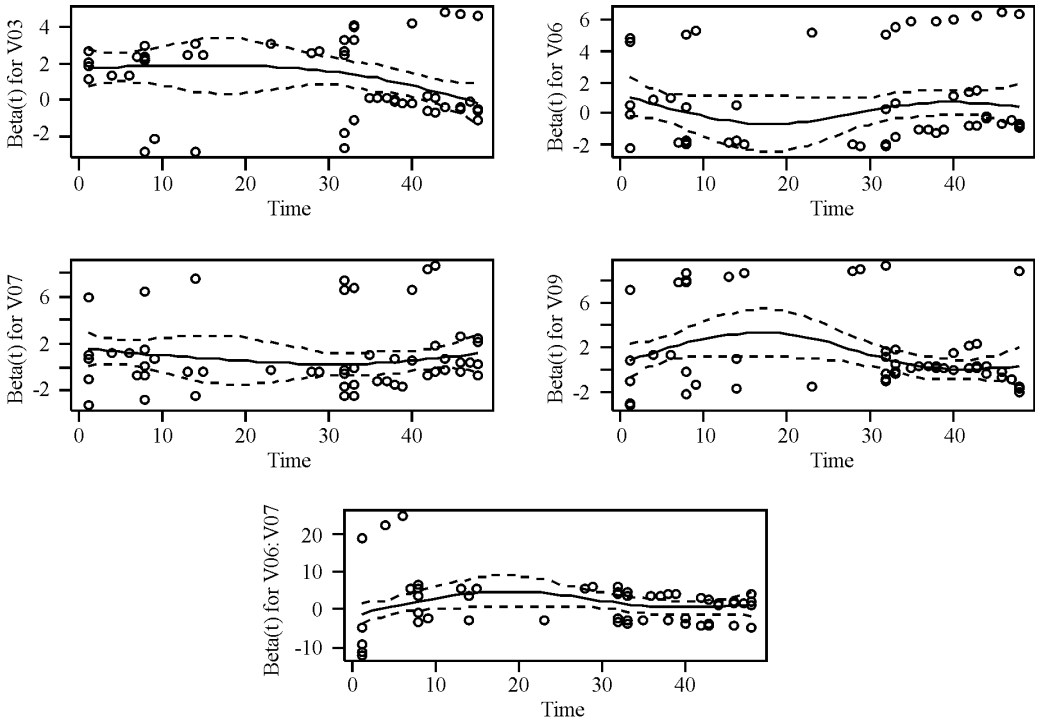

Figure 3 – Standardized Schoenfeld residuals *versus* times for covariates V03, V06, V07, V09 and V06*V07.

Figura 3 – *Resíduos padronizados de Schoenfeld versus os tempos para as covariáveis V03, V06, V07, V09 e V06*V07.*

Table 3 – Hazards proportionality tests in the Cox model, fitted for covariates V03, V06, V07, V09 and V06*V07.

Tabela 3 – *Testes da proporcionalidade dos riscos no modelo Cox, ajustado para as covariáveis V03, V06, V07, V09 e V06*V07.*

	Covariates	rho (ρ)	χ^2	*p* value
V03	Produce Pulp	-0.2946	6.45176	0.0111
V06	ECLAC	-0.0089	0.00846	0.9267
V07	European Union	-0.0930	0.89581	0.3439
V09	APEC	-0.1827	3.18397	0.0744
V06*V07	EU * APEC	0.0406	0.21117	0.6459
Overall			11.26243	0.0464

Consequently, the overall model was also significant, leading to rejection of the null hypothesis of proportional hazards of the overall model. It was thus necessary to remove these covariates and reestimate the model.

Table 4 provides the proportional hazards test for covariates V06, V07 and V06*V07. It was noted that the Pearson's correlation coefficients (ρ) are close to zero, which indicates acceptance of the null hypothesis of proportional hazards of the overall model, at a 10% significance level.

Table 5 provides results of Cox model fitting and relevant hazard ratios (HR). The odds of a member country of ECLAC (V06) exporting pulp to survive are 1.7301 times as much as the odds of a country outside ECLAC. A member country of the European Union (V07) has 2.4170 times as much chance as a country outside the EU. Likewise, a member country of the integration between covariates V06*V07 has 3.5135 times as much chance as a country outside such integration.

Table 4 – Hazards proportionality tests in the Cox model, fitted for covariates V06, V07 and V06*V07.

Tabela 4 – *Testes da proporcionalidade dos riscos no modelo Cox ajustado para as covariáveis V06, V07 e V06*V07.*

	Covariates	rho (ρ)	χ^2	*p* value
V06	ECLAC	-0.1111	1.282	0.258
V07	European Union	-0.0774	0.619	0.431
V06*V07	EU * APEC	0.0717	0.664	0.415
Overall			1.591	0.662

Source: Research results

Table 5 – Results of Cox model fitting and relevant hazard ratios (HR).

Tabela 5 – *Resultados do ajuste do modelo de Cox e razões de risco (RR) correspondentes.*

Covariates	Estimates	Standard Error	*p* Value	HR	LL(95%)	UL(95%)
V06	0.5482	2.195	0.02819	1.7301	1.060	2.823
V07	0.8825	3.163	0.00156	2.4170	1.399	4.176
V06*V07	1.2566	2.148	0.03171	3.5135	1.116	11.058

Source: Research results.

It was noted that Brazil is inserted in the selected model through covariates 'ECLAC' (V06) and 'integration between ECLAC and European Union' (V06*V07). Therefore, according to Table 5, the odds of Brazil surviving by exporting pulp are much greater than the odds of the remaining countries.

4 CONCLUSIONS

Survival analysis via the Cox regression model proved to be a powerful tool for predicting survival of a country exporting pulp;

Around 80% of the countries that have pulp in their list of exports continue to export the commodity;

Out of the 15 covariates selected for fitting the Cox model, four explain the model and two were found significant in explaining the survival of a country exporting pulp;

International trade agreements were more significant in the Cox regression model than the classes of macroeconomic forest indicators and geographic location;

Covariates explaining the odds of a country exporting pulp to survive, according to the hazard ratio, were, in descending order, integration between ECLAC and European Union, be a member of the European Union (V07) and be a member of ECLAC (V6);

Brazil has 3.5 times as much chance of survival exporting pulp through an integration between ECLAC and the European Union than a country that is not a part of such integration;

The probability that Brazil will survive exporting pulp is greater than the probability that Asian countries will.

5 REFERENCES

CARDOSO, F. A.; COLOSIMO, E. A. Avaliação da suposição de riscos proporcionais para o modelo de Cox. In: REUNIÃO DA REGIÃO BRASILEIRA DA SOCIEDADE INTERNACIONAL DE BIOMETRIA, 48.; SEAGRO, 10., 2003, Lavras. **Anais Eletrônicos…** Lavras: UFLA, 2003.

COLLET, D. **Modeling survival data in medical research**. New York: Chapman and Hall, 1994.

COLOSIMO, E. A.; GIOLO, S. R. **Análise de sobrevivência aplicada**. São Paulo: E. Blücher, 2006. 370 p.

COX, D. R. Regression models and life tables: with discussion. **Journal of the Royal Statistical Society: Serie B, Statistical Methodology**, Oxford, v. 34, n. 2, p. 187-220, 1972.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. **State of the world's forests**. Rome, 2009. 152 p.

HIRSCHMAN, A. O. **Estratégia do desenvolvimento econômico**. Rio de Janeiro: Fundo de Cultura, 1961.

REZENDE, J. L. P.; COELHO JUNIOR, L. M.; BORGES, L. A. C. Madeira e derivados: oportunidades do Brasil no mercado internacional. In: OLIVEIRA, J. T. S.; FIEDLER, N. C.; NOGUEIRA, M. (Ed.). **Tecnologias aplicadas ao setor madeireiro III**. Jerônimo Monteiro: Suprema, 2008. p. 11-42.

UGALDE, L.; PÉREZ, O. **Mean annual volume increment of selected industrial forest plantation species**. Rome: FAO, 2001.