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Governance of forestry transactions in southern Brazil: an analysis based on Transaction Cost Economics

The Brazilian forestry sector plays a significant role in Brazil's economy. Rio Grande do Sul is the southernmost state in the country, and its forestry sector is a sustainable development activity. Transaction Cost Economics (TCE) is an economic approach that offers an analytical framework for understanding how institutions shape the functioning of agro-industrial chains. This article aims to analyse the governance of forestry transactions in southern Brazil in the light of TCE. The research methodology is descriptive and uses a mixed methods approach. The qualitative stage used semi-structured interviews with key players in the forestry chain. The quantitative part sought to measure the characteristics of farm-level transactions by applying a questionnaire to 24 producers who own forests in 16 cities in southern Brazil. Content analysis (qualitative stage), descriptive statistics, non-parametric hypothesis tests, and logistic regression (quantitative stage) were used as data analysis techniques. The research results show that the largest eucalyptus production areas are used for cellulose production, the sale of which to paper industries is negotiated via contracts. On the other hand, the forestry production of the smaller areas is destined for firewood, whose suppliers trade via the market and transact, as a rule, with end consumers. The logistic regression results indicate that asset specificity and uncertainty are essential in determining the type of contractual arrangement chosen (market or contract). The research highlights the importance of governance structures in the forestry production chain, including how they are chosen and organised.

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Introduction

The Brazilian forestry sector plays a significant role in the country's economy, contributing to the Gross Domestic Product (GDP) through the production and sustainable exploitation of forest resources. In 2021, the global extension of reforested areas reached 9.93 million hectares. Eucalyptus stands out among the different varieties of trees grown, occupying approximately 75.8% of this total area, equivalent to 7.53 million hectares. According to the Brazilian Tree Industry, the pine species accounts for 19.4% of the total area, covering around 1.93 million hectares (IBA, 2022).

In Rio Grande do Sul, Brazil's southernmost state, forestry is vital to the region's sustainable development and economy. In 2021, forestry generated revenues of approximately $460 million and recorded the creation of 65,000 direct jobs from activities related to planted forests (AGEFLOR, 2023). As such, the forest-based production chain in Rio Grande do Sul is an essential economic option for generating employment and income, including for small rural producers.

The constitution of a production chain becomes both an element of analysis and an object of policy action, where economic specialisation and competition are reinterpreted. Within an economic analysis, the perspective of Transaction Cost Economics (TCE) goes beyond understanding an organisation's production costs, admitting the existence of costs to transact its goods in a relationship between agents and organisations (Coase, 1937; Mendes *et al.,* 2009; Goldin *et al.,* 2019).

As a result, organisational aspects such as property rights and governance structures are objects of TCE analysis to minimise transaction costs and uncertainties and increase the collective social benefits of coordinated or cooperative conduct (Canitez, 2019; Rutherford, 2001). From the perspective of TCE, the analysis of transactions in the forestry sector in southern Brazil is very appropriate and relevant since most of the actors and institutions involved in marketing production processes are unaware of or do not realise the costs arising from such transactions.

Thus, the research is based on Transaction Cost Economics (TCE), more precisely from the governance perspective. According to Joskow (1995), the aim of research using this approach is to interpret the explanatory motives behind institutional arrangements, such as protection from postcontractual adversity and planned arrangements in response to economic conflicts over the costs of carrying out negotiations between economic agents.

TCE therefore offers an analytical framework for understanding how economic institutions shape the functioning of the forestry chain. By analysing the rules, contracts, regulations, and other institutions involved, opportunities for improving efficiency, sustainability, and the distribution of benefits along this forestry chain in southern Brazil will be identified. Therefore, this article aims to analyse the governance of forest producers' transactions in southern Brazil in the light of Transaction Cost Economics.

This study makes three contributions. The first is the applicability of TCE theory to the forestry chain since the approach can help to understand how institutions affect the use of forest resources, economic growth and the sustainable development of a region. The second refers to discussing specific recommendations for producers and other forest market agents regarding choosing the most appropriate contractual arrangements for their negotiations. Finally,

the research proposes a model for analysing the governance of transactions in the forest production chain, as well as stimulating future studies on the subject and expanding knowledge about the choice of contractual arrangements in other areas of agribusiness.

This article is structured in five sections. The first, the introduction, presents an overview of the topic studied, addressing the problem situation. The second section discusses the New Institutional Economics and the Economics of Transaction Costs. Section three refers to the methodology used in the study to gather the relevant data to answer the research problem. Sections four and five present the results and discussions, respectively, and the final considerations are presented in section six.

New Institutional Economics (NIE) and Transaction Cost Economics (TCE)

In the 1970s, a school of economic thought called the New Institutional Economics (NIE) emerged in the United States. The school argues that institutions, such as laws, rules and social norms, are fundamental to understanding the economy and the functioning of society. The NIE highlights the importance of organisations in the economy and economic theory. Ronald Coase, Oliver Williamson and Douglass North are the principal authors of the New Institutional Economics (NIE).

Coase's work (1937), "The Nature of the Firm", established the concept of the theory of the firm based on transaction costs. In his pioneering concept, Coase describes transaction costs as the costs of using the price system. In order to produce goods and services more efficiently, firms aim to minimise the costs of transacting in a market (Coase, 1937). His work provided the framework and theoretical orientation for the New Institutional Economics (Zylbersztajn, 1995).

In the NIE, agents' economic and social universe is marked by uncertainty from transaction costs. To reduce these costs, societies develop institutions, which are durable sets of defined and juxtaposed social rules that form social relations, allow for structured thought, expectation, and action, and establish form and consistency in human activities (Hodgson, 2006).

The New Institutional Economics (NIE) has as an offshoot of its theory the Transaction Cost Economics (TCE), whose central element of the study is the transaction. Therefore, transaction costs refer to the costs incurred by agents whenever they resort to the market. In other words, they are the costs associated with negotiating, drawing up and executing a contract, making this agreement the basis for assessing transaction costs.

By stipulating that transaction costs make the economy work, Williamson (1985) not only differentiated them from production costs, the object of study in neoclassical economics but also verified the existence of a more efficient way of organising a transaction.

However, this theory was further developed in the 1970s, with the work developed by Williamson (1975, 1985) in his works Markets and Hierarchies and The Economics Institutions of Capitalism. In these works, Williamson (1975, 1985) establishes that the organisation's main objective is to minimise transaction costs. This perspective emphasises the relevance of asset specificity and behavioural assumptions and advocates a comparative approach to institutional analysis with a specific focus on the firm. Instead of seeing the firm solely as a productive unit, TCE sees it as a governance structure. Williamson (1985) identifies two main transaction costs: *ex-ante* costs, which include the costs of preparation and negotiation, and *ex-post* costs, which include maintaining and monitoring the agreement.

Governance structures: transaction attributes and behavioural assumptions

The governance structure is the institutional structure in which a transaction occurs, i.e. the coordination of the agents directly involved in the deal and the guarantee of its completion. According to Furubotn and Richter (2000), governance structure is a set of rules and necessary coercion mechanisms specific to each institution to save transaction costs, reduce conflicts and increase profits. In other words, governance structures are like cogs in a wheel that work together to enable transactions to be carried out and reduce costs (Zylbersztajn and Sztajn, 2005).

How governance is determined portrays the relationship between the attributes of transactions and behavioural assumptions and is capable of indicating whether agents intend to relate through different governance structures, which are the market, vertical (or hierarchical) integration and contracts (or hybrid forms) (Williamson, 1985). In this sense, for negotiations to be more efficient, it is necessary not only to reduce transaction costs, but also to reduce the problems related to the opportunistic behaviour of agents and uncertainty in transactions. In this way, in the view of TCE, governance structures are tools the agents involved use to make transactions more efficient (Williamson, 1985).

Thus, the attributes of the transactions and the behavioural assumptions present in them are fundamental elements in the choice of governance structures. To achieve efficient limits in negotiations, those involved combine the transaction attributes with the most appropriate governance structure, thus improving the organisation's performance based on the alignment hypothesis (Crook *et al.,* 2013).

According to Williamson (1985), there are three fundamental attributes of transactions: frequency, uncertainty and asset specificity. Frequency is determined by the number of times a transaction is carried out, i.e. the more significant the repetition of negotiations, the greater the likelihood of a reduction in costs, which will influence the mode of governance constructed by the agents. The second attribute of transactions is uncertainty, defined as the lack of complete knowledge about all the variables that affect a transaction. The third and final attribute is asset specificity. Asset specificity is associated with the extent to which an asset is specific to a particular activity and its applicability in an alternative, too-costly activity. A transaction with specific assets can create a bilateral dependency and result in difficulties in contractual relations (Williamson, 1989). Kupfer and Hasenclever (2002) consider that investing in a specific

asset creates an exclusive or almost exclusive link between buyers and sellers.

TCE is based on two assumptions regarding the conduct of the agents involved in a transaction: it believes that individuals can be opportunistic and are limited in rationality (Williamson, 1985). Regarding the opportunism assumption, Williamson (1996) conceptualises it as acting astutely to pursue one's interests, often using strategies calculated to deceive, mislead, confuse and obscure information. In a governance structure, opportunistic agents tend to pursue their interests to the detriment of the interests of the organisation or group.

On the other hand, according to Williamson (1985), bounded rationality is related to the inability to predict and control all the circumstances surrounding the transaction, i.e. the ability of agents to retain and process information consciously and without making mistakes. For Simon (1959), bounded rationality shows the limitation of economic agents, such as individuals and companies, in processing and interpreting information to make a complete and rational decision.

Therefore, the attributes of transactions and behavioural assumptions directly influence the choice of contractual arrangements. Williamson (1996) argues that less specific transactions can be managed more economically through more straightforward institutional arrangements (such as the market). On the other hand, transactions involving highly specific assets require more complex institutional arrangements (such as vertical integration) to avoid conflicts and reduce transaction costs. In short, the complexity of the required institutional arrangements is directly related to the specificity of the transaction's assets and the individuals' behavioural assumptions.

Methodology

The research undertaken was descriptive, using a mixed research method, which consists of collecting, recording and analysing qualitative and quantitative data to understand better the problem. The research strategy adopted was sequential exploratory, which consists of first collecting qualitative data and then conducting quantitative research to test or corroborate the initial data. The study object was the transactions of forestry producers in the state of Rio Grande do Sul, Brazil. To this end, the research targeted the "Gaucho Association of Planted Forest Producers".

The first stage consisted of collecting qualitative data. This was done using semi-structured interviews with producers who work in the association's management. The interviews sought to gather data on the producers' forms of production, the types of transactions carried out, the forms of governance adopted, the main characteristics of the transactions, and the behavioural assumptions of the individuals. Table 1 shows the production and demographic characteristics of the interviewees.

At the end of the qualitative part, documentary research techniques and semi-structured interviews provided input for the quantitative data collection stage, conducted using the questionnaire technique. The questionnaire was adapted from Lopes (2017) instrument and applied by random sampling to twenty-four (24) producers, representing 53% of the members in southern Brazil.

In the qualitative research stage, the Content Analysis technique was used to analyse the data. In the quantitative stage, the data from the questionnaire was analysed using descriptive statistics, non-parametric hypothesis tests and logistic regression. The sample was divided into two groups: i) 12 producers who trade their forest products via the market and ii) 12 producers who trade their forest products via contracts. Non-parametric hypothesis tests were used to compare the transactions' characteristics and the agents' behavioural assumptions between the governance structures adopted (market versus contract). The data was ordinal (Likert scale) and came from a small sample, so the Mann-Whitney, Kruskal-Wallis and Dunn's multiple comparison tests were used. The maximum significance level used was 5%.

Logistic regression is a statistical method to model the relationship between a binary categorical dependent variable and a set of independent variables. It is a technique that estimates the probability of an observation belonging to a particular category. In the specific case of this study, we sought to determine the likelihood of a producer adopting a specific form of governance depending on the attributes of the transactions and the behavioural assumptions of the individuals.

In the study, the dependent variable was defined as the type of transaction, with values of 0 for the market and 1 for the contract. According to Equation 1, the independent variables were the attributes and behavioural assumptions of the transaction: asset specificity, uncertainty, and opportunism.

Table 1: Socio-demographic and production survey of the interviewees.

Inter-viewee	AGAFLOR	Total Area (ha)	Forest Area (ha)	Forestry crops	Activity	Training	Sex	Age
A	Associate producer	2,000	1,500	Eucalyptus, Acacia and Pinus	Rural producer, entrepreneur	Higher education completed	Men	71
B	Associate producer	388	370	Eucalyptus	Rural producer, entrepreneur	Higher education incomplete	Men	58
C	Associate producer	42	8.50	Eucalyptus	Rural Producer, Agronomist	Higher education completed	Men	58

Source: Elaborated by the authors

$$Y_T = \beta_0 + \beta_1\text{Specificity} + \beta_2\text{Uncertainty} + \beta_3\text{Opportunism} + \varepsilon \quad (1)$$

where: Y_T = transaction type dependent variable (0=market; 1=contract); β_0 = intercept; $\beta_{1,2,3}$ = angular coefficient; ε = residual.

The independent variables used to calculate the logistic regression were taken from the questionnaire. The questionnaire was made up of variables on Likert-type scales, where it was possible to measure the perceptions of forestry producers about their production activity. To form the independent variable "Asset Specificity", an arithmetic mean was calculated from a scale of 1 to 5 on questions related to Local, Physical, Human, Brand, Temporal and Dedicated to Production specificity, where 1 was not very specific, and 5 was the maximum specificity. In addition, to form the independent variable "Uncertainty", i.e. how uncertain the forest production and marketing environment is, an arithmetic mean was calculated for the variables related to climate, credit, price, commercial partners, payment, management, technology and labour – on a scale of 1 to 5, where 1 represents low uncertainty and 5 high uncertainties. Finally, to form the independent variable "Opportunism", an arithmetic mean was calculated for the variables relating to trust, the importance of commercial partners and disputes during the transaction – on a scale of 1 to 5, where 1 represents low opportunism and 5 high opportunism.

Results

Characteristics of transactions in forestry production of southern Brazil

The survey covered a total area of 13,028 hectares. The area used exclusively for forestry production amounted to 7,331.5 hectares, comprising the cultivation of pine, acacia and eucalyptus, with 3,359.5 hectares dedicated to eucalyptus. Table 2 shows the descriptive measures of the area of the producers surveyed.

Table 2: Descriptive statistics for the total area and forests of the producers surveyed.

Descriptive Statistics	Total Area	Forest Area	Eucalyptus Area
Median	180.00	90.00	50.00
Mean	529.50	297.14	137.37
Standard Deviation	660.43	425.30	200.54
Minimum	20.00	4.00	4.00
Maximum	2000.00	1500.00	800.00

Source: Elaborated by the authors

The firewood is the main product sold in the market and the cellulose is the most traded product via contract. Most sales via the market are made directly to the end consumer, accounting for almost 60% of producers' negotiations, with firewood being the product most often sold via the market. On the other hand, most sales via contract are made to the industry, involving pre-established agreements and transaction terms, such as price, quantity, delivery time and other clauses, which are defined in advance and formalised in commercial contracts between producers and the industry. Marketing through this means exceeds 80% of negotiations via contract.

Table 3 shows the degree of specificity of the forestry assets of the producers surveyed, divided into the six types of specificity determined by Williamson (1985, 1996). The scale used was a five-point Likert scale, where 1 indicates low specificity, and 5 is high specificity. The non-parametric Kruskal-Wallis test was carried out to check for differences between the means of the different types of asset specificity. There was no significant difference between the means of the types of specificity of forest products ($p>0.05$).

Table 3: Degree of specificity of the forestry assets of the producers surveyed.

Asset Specificity	Mean	Standard Deviation	Coefficient of Variation
Temporal	3.708	1.486	40.1%
Dedicated	3.333	1.435	43.0%
Physical	3.167	1.606	50.7%
Brand	3.042	1.628	53.5%
Human	2.750	1.294	47.0%
Local	2.583	1.123	46.9%
Kruskal – Wallis	Statistics KW	df	P-value
	9.477	5	0.091

Source: Elaborated by the authors

When analysing the coefficients of variation, which indicates the relative variability of the data about the average, the "Brand" and "Physical" categories have higher coefficients, which shows a greater dispersion of the degree of specificity in these categories. Table 4 compares the degree of specificity of forest assets by governance structure adopted (market versus contracts). The Mann-Whitney non-parametric hypothesis test was used to assess the difference between the means of each type of specificity by governance structure.

Table 4: Degree of specificity of the forestry assets of the producers surveyed in different governance structures (market and contract).

Asset Specificity	Mean			Coefficient of Variation	
Type of trade	Market	Contract	Value p	Market	Contract
Temporal*	2.833	4.583	0.008	58.0%	11.2%
Dedicated	2.917	3.750	0,169	47.3%	37.9%
Physical*	2.250	4.083	0.009	68.7%	26.5%
Brand*	2.000	4.083	0.002	67.4%	28.5%
Human	2.333	3.167	0.110	64.2%	29.6%
Local	2.250	2.917	0.223	63.2%	30.9%
General specificity	2.431	3.764	0.005	44.5%	19.6%

* Significant difference between market and contract averages at a 1% significance level.
Source: Elaborated by the authors

It can be seen from the overall specificity that the degree of specificity of the forestry asset marketed via contract is statistically higher than the degree of specificity of the product marketed via the market (p<0.01). The coefficients of variation are lower for contract marketing than the market, suggesting greater homogeneity in the specificity of the assets of contract producers.

When comparing the different types of specificity, there is no statistical evidence to reject the null hypothesis of equal means for dedicated, human and local specificity between the governance structures (p>0.05). However, there was a significant difference between the degrees of temporal, physical and brand specificity, with a significance level of 1%.

Uncertainty and opportunism in forestry production of southern Brazil

The production and commercial environment in which the forest operates is affected by factors that can lead to uncertainties in both production and marketing. Table 5 shows the degree of uncertainty in AGAFLOR's forestry production environment.

Table 5: Degree of uncertainty in the forestry production of the producers surveyed.

Source of Uncertainty	Mean*	Standard Deviation	Coefficient of Variation
Price	2.375[a]	1.408	59.3%
Handling	2.333[a]	1.465	62.8%
Payment	2.208[a]	1.414	64.0%
Commercial partner	2.167[a]	1.341	61.9%
Labor	2.042[ab]	1.429	70.0%
Climate	1.875[ab]	0.992	52.9%
Technology	1.333[bc]	0.637	47.8%
Credit	1.250[c]	0.737	59.0%
Kruskal–Wallis	Statistics KW	df	P-value
	21.415	7	0.003

* Distinct letters indicate a difference between the means of the source of uncertainty using the Dunn test (p<0.05).
Source: Elaborated by the authors

We see averages positioned at low to medium uncertainty when analysing the absolute values. There was a significant difference between the averages (p<0.01). Dunn's multiple comparisons test showed higher degrees of uncertainty for the Price, Management, Payment and Commercial Partner sources, which differed significantly from Technology and Credit (p<0.05), with the lowest uncertainty. Table 6 compares the degree of uncertainty by governance structure adopted (market versus contracts). The Mann-Whitney non-parametric hypothesis test was used to assess the difference between the means of each source of uncertainty by governance structure.

General uncertainty shows that market negotiations are 62% higher than contract negotiations, indicating a significant difference between the averages (p<0.01). For example, uncertainty in price and payment is greater in the market since, in contract trading, the price and payment

are defined and safeguarded. Table 7 shows the degree of opportunism present in the forestry marketing of the producers surveyed.

Table 6: Degree of uncertainty in the forestry production of the producers surveyed in different governance structures (market and contract).

Uncertainty	Mean			Coeff. of Variation	
Source of Uncertainty	Market	Contract	P-value	Market	Contract
Price**	3.083	1.667	0.007	40.2%	73.9%
Handling*	2.917	1.750	0.028	47.3%	77.5%
Payment*	2.917	1.500	0.014	49.5%	66.7%
Commercial partner*	2.750	1.583	0.032	51.7%	62.9%
Labor*	2.917	1.167	0.002	51.6%	49.5%
Climate	2.000	1.750	0.805	60.3%	43.1%
Technology	1.333	1.333	1.000	48.9%	48.9%
Credit	1.333	1.167	0.581	66.6%	49.5%
General uncertainty**	2.406	1.490	0.003	25.2%	45.6%

* Significant difference between market and contract averages at a 5% significance level.
** Significant difference between market and contract averages at a 1% significance level.
Source: Elaborated by the authors

Table 7: Degree of opportunism in forest marketing among the producers surveyed.

Opportunism	Mean	Standard Deviation	Coeff. of Variation
Business relations	2.500	1.532	61.3%
Trust in partners	2.292	1.429	62.4%
Conflicts between business partners	2.042	1.301	63.7%
Trade disputes	1.667	0.816	49.0%
Kruskal – Wallis	Statistics KW	df	P-value
	3.684	3	0.298

Source: Elaborated by the authors

Producers have a moderate perception of opportunism in commercial relations. They recognise that unfair commercial practices, opportunistic behaviour, or a lack of transparency in negotiations are possible. Table 8 presents data on the degree of opportunism by type of negotiation, with a focus on comparing market and contract trading.

Table 8: Degree of opportunism present in the forestry marketing of the producers surveyed in different governance structures (market and contract).

Opportunism	Mean			Coeff. of Variation	
	Market	Contract	P-value	Market	Contract
Business relations*	3.167	1.833	0.037	48.2%	69.1%
Trust in partners*	2.833	1.750	0.046	53.9%	65.0%
Conflicts – business partners	2.250	1.833	0.250	54.0%	76.6%
Trade disputes	1.833	1.500	0.080	31.5%	66.7%
General opportunism*	2.521	1.729	0.043	40.7%	59.3%

* Significant difference between market and contract averages at a 5% significance level.
Source: Elaborated by the authors

Opportunism related to trust in commercial relations is higher in market transactions. This is because negotiations via the market often take place quickly, not creating a history of transactions between trading partners, which can lead to low levels of trust.

Determinants of the structure of governance – the logistic regression

Table 9 shows the parameters of the estimated logistic regression. The chi-squared test (χ^2) shows that the model is valid, i.e. there is at least one independent variable that affects the chance of a transaction being carried out by contract ($p<0.05$).

Table 9: Estimated logistic regression parameters.

	Coefficient	Wald statistics	P-value
Asset specificity*	2.570	4.828	0.028
Uncertainty*	−3.898	4.699	0.030
Opportunism	1.653	2.802	0.129
Intercept	−3.559	0.999	0.318
χ^2	19.074		<0.01
R² Nagelkerke	0.731		

* Stands for p<0.05.
Source: Elaborated by the authors.

The Nagelkerke R² measures model fit, which is often used in logistic regression analyses. The Nagelkerke R² ranges from 0 to 1. The closer it is to 1, the better the model fits the data. A value close to 0 indicates that the model explains very little of the variations in the dependent variable. Nagelkerke's R² is 0.731, which indicates that the model's independent variables explain 73.1% of the variations in the probability of an agreement being established by contract.

When analysing the significance of the model coefficients, it can be seen that the asset specificity and uncertainty variables are significant ($p<0.05$). On the other hand, the opportunism variable is not statistically significant ($p>0.05$). Therefore, the results indicate that asset specificity and uncertainty are important in determining the type of transaction, whether via contract or the market. At the same time, opportunism has no significant impact on the choice between transaction types.

When interpreting the relationship between the variables, it can be seen that an increase in asset specificity is associated with an increase in the dependent variable of transaction type, i.e. the more significant the specificity of the product, the greater the likelihood of the transaction being carried out by contract. In turn, an increase in uncertainty related to forestry production is associated with a decrease in the dependent variable of the type of transaction, i.e. the more significant the uncertainty, the less likely it is that the transaction will be carried out by contract. On this point, the research was in line with the TCE theory because most of the producers who responded and negotiated via contract already had the agreement signed, with clauses that supported the transaction for both sides, in a secure negotiation. Thus, the producers did not attach great importance to uncertainties in the forest production and marketing environment.

Discussion

Transaction Cost Economics (TCE) argues that different governance structures, such as contracts, vertical integration or market relations, are chosen based on minimising transaction costs, highlighting the relevance of institutions as a contingency factor for organisations (Williamson, 1975, 1985, 1996). Based on this understanding, the research results are approached in the light of TCE, focusing on the choice of governance structures based on transaction costs within the forestry production chain. The specificity of the asset involved in the forestry transaction is the main variable affecting the choice of the type of governance structure to be adopted (market or contract). An asset is considered specific when it is challenging to use in activities other than those for which it was initially intended without suffering a loss of value (Williamson, 1985).

The results in Table 3 indicate that the greatest specificity found was "temporal" due to the length of forest growth, which varies from 6 to 8 years for cellulose harvesting and 18 to 20 years for log production. The specificity with the lowest absolute value was "local", showing that the location of the industry is not a determining factor in obtaining forestry production. This is corroborated by Interviewee A:

"The industry values your forest according to the difficulties of removing the wood from the site, but nothing can stop them from buying it. They have structures, make roads, and improve roads" (INTERVIEWEE A).

The physical specificity of wood unfolds in different forms of use, each with its particular characteristics. Logs represent tree trunks cut and prepared for industrial processing or other purposes, such as construction and furniture making. Their quality and value vary according to the tree species, diameter, straightness and absence of defects. The logs have a high specificity; the longer the forests remain standing, the greater the added value. As Interviewee B states:

"I am the one who sets the price for my forests because in the region, I'm the only one with forests over 40 years old, trees over 70 meters high. If they do not pay me what I want, they stay there" (INTERVIEWEE B).

In turn, cellulose has emerged as one of the main raw materials in the paper industry, obtained by processing wood. Its cellulose fibers are separated from the rest of the wood to produce cellulose. The quality of a forest for cellulose production depends significantly on the quality of the seedlings of the trees planted, as mentioned by Interviewees A and C:

"The secret of planting a eucalyptus forest today lies in selecting quality seedlings. Today, some clones are real gems, let us put it that way, because in half the time they produce a tree that is better than a seedling that came from a seed" (INTERVIEWEE A).

"Of course, it is a slightly more expensive seedling, right? However, the forest does come standardised. That is a big differentiator. When the seedling does not have much of a standard, the eucalyptus passes overall sizes, and that is where the so-called dominance comes in. In a forest, a well-managed forest cannot have dominance" (INTERVIEWEE C).

Evidence suggests that institutional changes, such as the end of tax incentives, can cause changes in the governance structures of the forestry chain. In this vein, De Sousa Freitas and Da Gama (2022) investigated the Brazilian timber sector. They pointed out opportunistic behavior, high temporal specificity and low local specificity in transactions. The results in Table 2 corroborate the findings of De Sousa Freitas and Da Gama (2022) regarding the specificity of Brazilian forestry assets.

The results in Table 4 indicate greater specificity for producers who negotiate via contract, justified by the fact that most producers cultivate their forests with a focus on selling them for cellulose, with differentiated investments. As Interviewee B discusses:

"When you plant, you must know what you want the wood for. Are you going to sell it for cellulose? Well, then you will harvest it after 7 or 8 years. I planted eucalyptus, but I want to prepare this forest for logs. Good! If you want to prepare it for logs, you will do the first thinning when it is around 5 years old" (INTERVIEWEE B).

For TCE, the specificity of the asset is seen as one of the most important attributes to characterise a negotiation (Williamson, 1985). Thus, some assets can rarely be negotiated or used in a function other than that for which they were previously determined without entailing a loss of value. For example, a forest that has been prepared for cellulose can even be used to trade as firewood, but this will result in a huge loss of value.

On the other hand, the vast majority of producers who trade their forests via the market, which are destined for the sale of firewood, have smaller areas, and the planting does not require a high degree of specificity. According to Interviewee A:

"The least noble use for commercial wood from a eucalyptus forest is for firewood, for energy production" (INTERVIEWEE A).

Forestry plantations for producing firewood sold on the market have low physical specificity, as they do not require much care when planted or specific characteristics when harvested. It also has low brand specificity, as it is not produced for a specific buyer, and time specificity does not require a minimum number of years for harvesting. Producers choose to trade the forest via the market, given the low specificity of firewood. The relationship between low asset specificity and the choice of market transactions is also found in food production chains, as demonstrated by Viana *et al.* (2012) and Vinholis *et al.* (2014).

The results in Table 6 indicate that price, payment and type of commercial partner involve the highest levels of uncertainty for producers who sell their forest via the market. Due to this uncertainty, Interviewee B reports that he only sells the product of his forest for cash:

"Sometimes things like this happen; for example, the thick logs I explained to you are something you can only sell for cash. Even other wood for large factories, you can sell with a 30-day deadline to receive it, and they all pay for it, but logs are like cattle; you can only sell them for cash because otherwise, you will not get paid. If you do not sell for cash, you risk not getting paid" (INTERVIEWEE B).

On the other hand, in contract negotiations, transactions are formally guaranteed in the form of contracts, which are used by medium and large producers, with clauses stipulated for both parties, resulting in greater legal certainty and a guarantee of payment. Williamson (1985) addresses the behaviour of agents in two dimensions: limited rationality and opportunism. These two dimensions play a crucial role in commercial dynamics in the transactions of the producers surveyed. The limited rationality of agents, who deal with information that is often incomplete, and opportunism, which can arise when individual interests override collective interests, shape the structure of negotiations. The results in Tables 7 and 8 indicate that producers moderately perceive opportunism in commercial relations, recognising the possibility of unfair commercial practices or a lack of transparency in negotiations. Corroborating this, Skulska *et al.* (2021), in an analysis of the evolution of Portuguese community forests, stated that land governance problems were caused by their owners' low efficiency and inadequate behaviour.

In studies on opportunism, Eyaa *et al.* (2021) argue that environmental uncertainty increases opportunism in the agricultural sector, while power asymmetry increases opportunism in the non-agricultural sector. In the viticulture sector, Lopes and Augusto (2023) observed that bounded rationality is evident in transactions, providing a favourable environment for opportunistic behaviour between the parties. In turn, Sánchez-Navarro *et al.* (2024) found that cooperative-oriented behaviour reduces opportunism.

The logistic regression analysis (Table 9) indicates that asset specificity and uncertainty significantly impact determining whether the type of transaction is via contract or the market. This result is in line with the findings of Mondelli and Zylbersztajn (2008), Vinholis *et al.* (2014) and dos Santos *et al.* (2021), who point to asset specificity as the main variable influencing the type of governance structure adopted in the transaction.

Conclusions

The analysis of the governance of forest producers' transactions in southern Brazil in the light of Transaction Cost Economics involved a detailed investigation into how these producers coordinate and manage their commercial interactions. The research highlighted the importance of governance structures in the forestry production chain, including its forms of organisation (market and contract). We identified the characteristics of the transactions and the behavioural

assumptions of the forest producers, measuring their degree of prevalence in each governance. We also assessed the determinants of the choices of different governance structures, seeking to understand the motives and factors that influence producers' decisions.

Transactions take place via the market or contract. The largest eucalyptus production areas in southern Brazil are used for cellulose, which is negotiated via contracts with the industry. The smallest areas are used to produce firewood via the market, mostly directly to the end consumer.

Regarding asset specificity, the time the forest has been growing and the time dedicated to production directly influence producers' governance strategies. Uncertainty, especially about price and management, affects commercial transactions to a greater extent via the market. Forest producers perceive moderate opportunism, with a greater perception of market transactions. In the logistic estimation results, asset specificity and uncertainty emerge as significant variables in explaining the type of transaction to be adopted (via the market or contract).

Finally, future research on this topic could explore other areas, such as the consequences of climate change, which can directly affect biodiversity and forest growth. It could also be applied to analyse changes in the market for forest products such as wood and cellulose. Future research in forest management could investigate technological innovation, the supply chain, sustainability, risk management, operational efficiency and public governance. Another gap that can be investigated more deeply is the role of opportunism in governance structures. Overall, this field of research aims to improve management skills, leverage the sustainable use of forest resources, add new technologies, improve the supply chain, reduce risk and inform public policies to ensure equitable economic development and environmental preservation.

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