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Mining Auctions and the Value of Geological Information: An Empirical Assessment for Mining Permissions in Brazil

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RESUMO

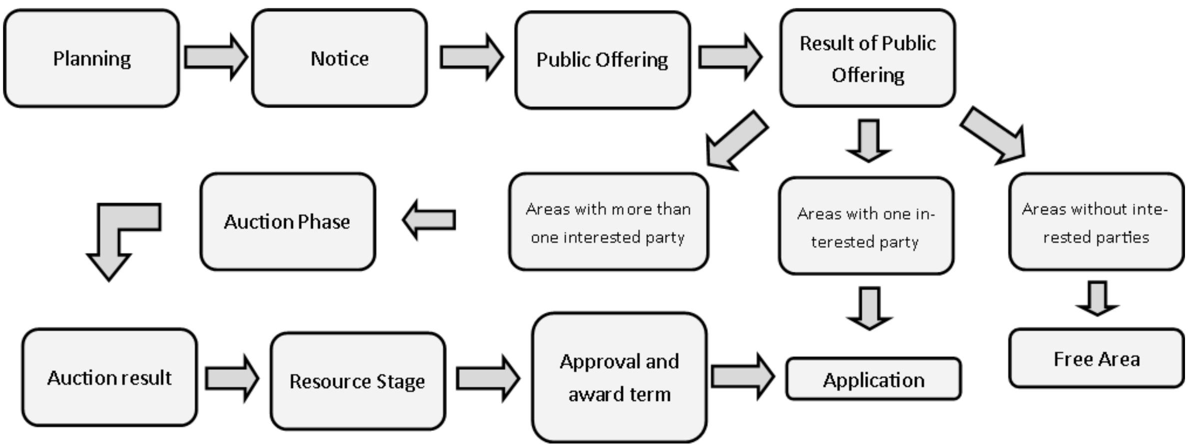
Since 2020, Brazil has revised the procedure for offering areas for mining that were previously owned by others. Before the new procedure, areas were offered based on the best technical project, a process considered slow and subjective. It has transitioned to a model of public offering and simplified auction. This article analyzes the first five rounds conducted since 2020, which offered 16,480 areas, with 9,643 areas awarded and 6,837 failing. The primary objective is to examine how geological knowledge affects the attractiveness of mining areas, considering the recognized challenges in valuing mining assets. Using logistic regression, the results show that areas with greater geological knowledge are 2.5 times more likely to be sold and that certain substances, such as gold and limestone, in addition to being more attractive, receive higher bids than others. The article contributes by providing a better understanding of the determinants of auctions, enabling the Public Administration to plan which areas will be offered in the next rounds, as well as supporting the decision to allocate public resources in search of greater geological knowledge in the Brazilian territory. For the private sector, the study can identify the most attractive areas, reduce information asymmetry, and support the calibration of bids, avoiding overestimation of the value of the area and the occurrence of the winner's curse.

1. Introduction

In 2018, the Brazilian government modified the rule to offer areas previously discarded or lost by former holders. The model chosen for the new availability was a simplified public offering, which takes place in two stages. First, investors express interest in the available areas. Second, an auction is held for areas with more than one expression of interest in the first phase.

The flowchart is presented in Figure 1, where three possible situations can be seen: 1) the area did not receive any expression of interest and remained vacant; 2) the area received only one expression of interest and was acquired by the only interested party; and 3) the area received more than one expression of interest and moves on to the second phase, the auction, where a new bidding period is opened and the highest bidder wins. The auction is a closed auction with the highest bid, where participants do not know how much is being offered by competitors.

Figure 1. Flowchart of the Public Offering at the Regulatory Agency.



Note: Prepared by the authors, in accordance with the procedure adopted by the regulatory authority.

This innovation allows many areas to be made available at once, as it simplifies the process of granting mining titles.

The first five rounds took place between 2020 and 2023, so the first round was more experimental, with few areas offered, and all for aggregates for civil construction (sand, clay, and gravel, mainly). The Agência Nacional de Mineração – ANM (the regulatory authority) carried out an ex-post analysis of the first five rounds (Brazil, 2022). This analysis demonstrated that the rounds, compared to the previous procedure: i) had a higher success rate; ii) the number of appeals and lawsuits was much lower; and iii) were more efficient, among other conclusions.

This article assesses which aspects and characteristics of the areas on offer explain the results of auctions promoted by the government, in relation to the level of prior geological knowledge of the areas. In addition, the empirical evaluation of auctions of mining areas will allow us to verify whether different substances generate different attractiveness (probability of being auctioned) and amounts paid.

We are not aware of any other study that has empirically analyzed the auctions of mining areas in Brazil. In addition to this primacy, this article is justified by the benefit provided to the public and private sectors by allowing a greater understanding of the determinants of the auctions, with the possibility of the Public Administration better planning which areas will be offered in the next rounds, as well as subsidizing the decision to allocate public resources in search of greater geological knowledge in the Brazilian territory, one of the countries with the largest mineral reserves in the world. For the private sector, the study can identify the most attractive areas, reduce information asymmetry, and support the calibration of bids, avoiding overestimation of the value of the area and the occurrence of the winner's curse (Thaler, 1988).

The importance of public offerings lies in the availability of a large number of areas, which can stimulate the sector in terms of job and income generation. According to the Declaration of Investments in Mineral Research, an annual declaration that companies holding research permits must make to the ANM (Brazil, 2022), the average amount that companies spend annually on mineral research is US$ 15,140. Thus, as the first five rounds of area offerings generated 5,351 research or mining requests, almost US$ 80.9 million would be invested in the contracting of services and equipment.

In addition to this Introduction, section 2 presents contextualization and theoretical framework, section 3 presents the methodology, section 4 the results, and section 5 the conclusions.

2. Contextualization and theoretical framework

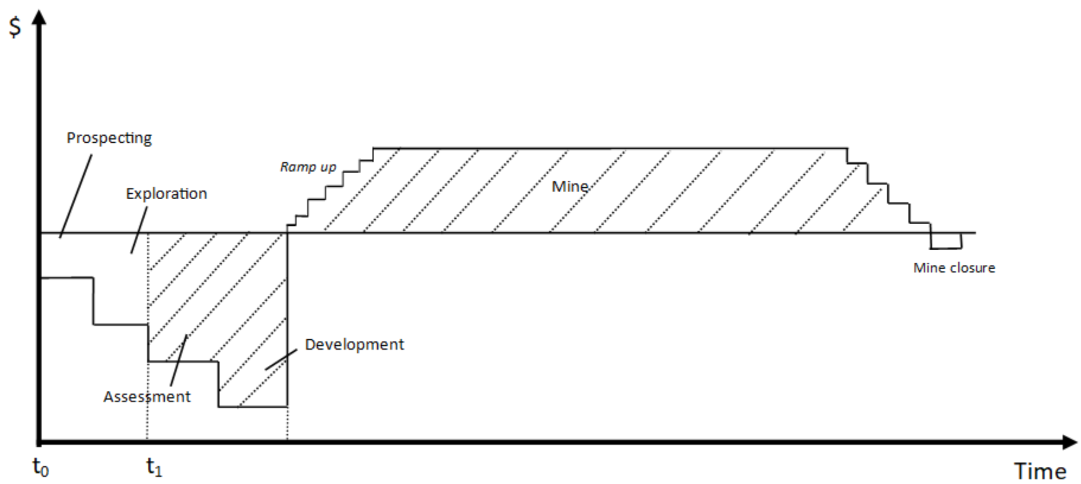
2.1. Contextualization

Mining has characteristics such as capital intensity, a long period until mining is obtained, high-risk activity, dealing with non-renewable resources, and environmental impacts that normally require compensation.

Before mining can be obtained, the prospecting, exploration, evaluation, and development phases are necessary, which are high-risk and have negative cash flow, as shown in Figure 2. The prospecting phase includes office studies that lead to the definition of a potential site to be explored, which is the next phase, in which samples are collected and analyzed. The positive result of this phase is the blocking of resources. After this, the mining process already has geological knowledge (hatched part in Figure 2).

In the evaluation stage, the results are already available, and a feasibility study of possible future mining is carried out. Following the mining process, an Economic Use Plan is presented, and the resources are transformed into reserves, which means that the holder has overcome stages of economic, social, environmental, and technical feasibility, among others.

Figure 2. Cash flow of mining activities, from prospecting to production.



Note: prepared by the authors, adapted from Nery (2001).

If the decision is to start mining, the development stage includes the construction of facilities, infrastructure, and the purchase of equipment for the future mine, and is therefore the most expensive. The average time for these four stages in

Brazil, from prospecting to mining, is 10 years, according to data available in the ANM Mining Registry System (Brazil, 2023a), but this depends on the substance to be extracted.

In the mining stage, the mine's useful life varies according to the reserves and the quantity mined. Finally, there is the mine closure stage, where the area is reconfigured, and environmental impacts are minimized, with negative cash flow.

A fundamental aspect of Figure 2 is that some of the areas offered, if auctioned, will have to start at t_0 (without any relevant geological knowledge), while other areas may already have studies and assessments available, i.e., they will be located as of t_1. This can substantially reduce the necessary investments, since a mineral deposit may already be defined. Thus, in areas located after t_1, greater attractiveness is expected, going into the auction phase with good competition and higher bids than those still at t_0.

The Brazilian mining sector is regulated by the Mining Code of 1967, which respects one of the fundamental principles of global mining law, which is the right of priority, i.e., first-come, first-served (Johnson and Ericsson, 2023).

When the Code was launched, areas were abundant, and the government sought to attract investment.

Carajás, a world-class and extremely powerful iron ore deposit, was only discovered in the 1970s. Marini (2016) shows that discoveries of large deposits in the world have been increasingly scarce and deeper, which causes companies to incur higher costs. He also shows that in Brazil, there is much to discover due to the history of low investment in mineral research. In the same work, the author reports that of every 1,000 preliminary targets (mineral occurrences), only 1 becomes a mine (Marini, 2016).

Therefore, greater interest in the available areas returned from former holders can be expected, especially those that already have research carried out. In 1999, an availability procedure was created to offer these areas through the publication of Notices, in which companies submitted envelopes with technical projects that had to be analyzed by Committees formed by three employees.

This procedure proved to be quite inefficient (Brazil, 2022), because, in addition to being complex, it required a lot of bureaucracy, which created a huge backlog of analysis of area requests (70,000 areas by the end of 2023). This procedure was suspended in 2017 by Ordinance No. 5, of January 27, 2017, which revoked all acts of availability procedures published as of January 1, 2016. There are no statistics or organized information in the competent Brazilian bodies on the interest in the areas made available in the previous procedure (based on the best technical project), which lasted until 2016.

Despite this, there are still processes with envelopes delivered but not opened, processes in which the envelopes were opened but have not yet been analyzed for qualification, and those in which qualifications have already been analyzed but have appeals pending analysis.

In both the old and new availability procedures, the winner is guaranteed the right of priority to request the area for research (the vast majority of areas) or mining, i.e., the auctioned areas do not necessarily represent an exploration right. In the case of the right to request the area for research, if the permit is received, the holder must hire a technical manager to carry out the research and pay the corresponding fees. The result is a final research report – FRP, which must be approved by the ANM if the deposit is found.

Once the FRP is approved, the holder has one year to apply for mining and present the Economic Use Plan, which must also be approved by the ANM. The definitive Mining Concession is granted not only with the approval of the ANM but also with the respective environmental operating license.

Using the Brazilian Mining Registry System, we divided the areas that were auctioned into: a) licensing; b) discarded; c) without geological knowledge; d) with approved final research report (FRP); and e) mining, as per Table 1.

Areas available for mining have geological knowledge but are presented separately in Table 1 because they represent a later stage. Likewise, the licensing, discarded, and unexplored areas are all unexplored and are also separated so that the attractiveness of each can be tested individually.

Table 1. Division of the types of areas that were offered to the public, their motivation and existing geological knowledge.

Area type	Reason	Geological knowledge
LICENSING	Regime for aggregates for civil construction, with areas of up to 50ha, in which there is no mineral research, but rather immediate mining. There are areas where the application was denied and areas that were mined, but this differentiation was not taken into account.	None or low
DISCARDED	Areas that were discarded for the following reasons: upon approval of the RFP in which the ANM required that the portion of the area that did not contain a deposit be discarded; partial withdrawal of the application; partial waiver of title; change of regime with reduction of area; or other reasons.	None or low
WITHOUT GEOLOGICAL KNOWLEDGE	Research permits in which the Annual Fee per Hectare – TAH was not paid and the permit expired, or presented a negative RFP, or other reasons.	None or low
WITH FINAL RESEARCH REPORT (RFP)	RFP positive and approved.	High
MINING	Positive and approved RFP, but which did not become a mining concession or even expired mining concessions.	High

Source: prepared by the author, based on events available in the ANM Mining Registry.

The National Mining Agency has two main ways of providing information on mining processes. The first is the Mining Registry System – SCM, which quickly provides information on the type of application, the current stage of the process, the name of the holder, the State and Municipality of the process, the substance(s) requested and the events that have occurred.

In the SCM, interested parties can already obtain some of the information shown in Table 1. The disadvantage of the SCM is that it only shows basic information and does not contain process documentation. Therefore, to obtain qualitative information, interested parties must access the physical or electronic process, with the electronic process being processed in the Electronic Information System (SEI). However, ANM began to adopt SEI for the final area only as of 2020, and only for new processes, with processes prior to 2020 being gradually digitized. Thus, for the first five rounds, agents interested in participating in the public offering had to go to the respective ANM Regional Management and request to view the processes to obtain information on the research plan or documents related to the mineral deposit, if they were interested in seeking more information.

The Mining Code (Brazil, 1967) does not define what a research work plan or research plan is, only that it is an instrument for the research application. Basically, it contains the substance to be researched, the budget and the schedule of activities to be carried out in the coming years, if the research is authorized by the ANM. The final research report, according to the Mining Code, must contain the results of the mineral research, with the definition of a deposit, as well as the Economic Use Plan (PAE), which contains the entire mining plan. Thus, if the process contains only the research application, the information obtained is no or low; however, if the process contains a positive research report and the PAE, the information is high.

To reduce this information asymmetry, the ANM made available files for each area with information from the Brazilian Geological Survey (Companhia de Pesquisa de Recursos Minerais – CPRM). These files locate the area in geological terms, making it easier to verify whether the region is suitable or not. In addition, the ANM makes available the shapes of the areas so that interested parties can plot them in geographic information programs (such as ArcGIS), so that they can be combined with other information (Brazil, 2023b).

In the first five rounds, the Government chose areas that had already been exempted for some time, as well as areas that were nominated. Nomination is a procedure created for the regulated entity to demonstrate interest in having an area placed in the Public Offering (Brazil, 2022). The nomination is not public, that is, it is not available to competitors which areas were nominated, as this would show ex-ante attractive areas of private information, which can be acquired in the Public Offering stage without going through the auction phase, which requires disbursement. For the first five rounds, no valuation of the areas was made, but minimum bids were placed, of R$971.63 in rounds 1 and 2, and of R$1,012.73 in rounds 3, 4 and 5.

Both areas without deposit information and those with deposit information are merely prospects, that is, they do not constitute the acquisition of a mine. Given that only a small number of prospects become mines, what is ultimately being offered is a probability, with the bid value being a fraction of the value of the deposit. Thus, this work does not aim to verify information income obtained by participants, nor does it consider mineral prices at the time of the offers, since the first five rounds were held in a very short space of time, some of which even overlapped. According to ARR Availability (Brazil, 2022), in August 2021 there were practically 4 rounds in progress.

Both the former DNPM and the ANM have a mineral economy sector that compiles data from holders of mining titles, which allows us to know the reserves and annual production of the main substances extracted in Brazil, the sector's trade balance, and new projects and expansions. In addition, data from the Mining Registry System and tax collection allow us to research the research permits granted, the annual fee per hectare collected in the research phase, and the royalties paid in the mining phase. Despite this information, as of the end of 2023, there are no statistics on the interest in the different types of areas and substances, nor how much the sector is willing to pay for each of them.

Negotiations between areas occur between the holders of mining rights and the buyers, with only one request for the transfer of the area being submitted to the ANM, which may be partial or full. Even so, the ANM does not compile data from these transactions. Therefore, the study conducted here is unprecedented and will have implications that go beyond the mere analysis of auction results, as it provides information that can assist in the management of mineral resources.

2.2. Theoretical framework

2.2.1. Auctions and information

McAfee and McMillan (1987) defines auctions as a market institution with an explicit set of rules that determine the allocation of resources and prices based on participants' proposals. Auctions have been studied in the field of microeconomics, mainly in modeling strategic behavior under asymmetric conditions.

There are several types of auctions and the choice of type, according to Pindyck and Rubinfeld (2013), can affect the seller's revenue. The four main auction formats are:

i. the ascending bid auction, or English, when bids are made in an increasing order. The characteristic of this auction is that bidders become aware of the current offer;
ii. the descending bid auction, or Dutch type, in which a maximum price is determined and the auctioneer announces lower prices;
iii. the sealed bid auction, in which each bidder submits only one bid and the winner is the one offering the highest bid, and where the bids of the other bidders are unknown; and
iv. the sealed bid and second price auction, the same as the previous one, but in which the winner pays the amount offered in the second highest bid, and is known as Vickrey.

The ANM adopts the highest bid and closed auction, and the dynamics occur on an electronic platform called SOPLE (Public Offer and Area Auction System), in which, after the Public Offer stage, the areas that had more than two interested parties are offered in a certain period of days, so that the bidder can make a bid and, if he changes his mind, can adjust it to another value as many times as he wants, until the closing deadline. The SOPLE platform contains the minutes of the first five rounds with the bids of all participants.

From a legal perspective, an auction is a price-setting tool that can be used by the government to purchase goods, in which case the winner is the one who offers the lowest price (reverse auction), or to sell assets and rights, in which case the winner is the one who offers the highest price. Mattos (2008) states that an auction is, above all, a mechanism for revealing information to the auctioneer, due to the asymmetry of information the auctioneer has regarding the value attributed by each potential buyer to the auctioned object. In other words, if the auctioneer knew exactly how much each potential buyer would be willing to give for the object, the auction would not be necessary.

Due to the way in which the ANM public offering was designed, and considering the enormous amount of areas to be offered and the difficulty in valuing them, in the first stage of the public offering it is already demonstrated which areas are interesting, with the uninteresting areas being those that do not receive any expression of interest, leaving them free for anyone to request at another time.

According to Pindyck and Rubinfeld (2013), auctions can be classified into private value auctions and common value auctions. Private value auctions are those in which each potential buyer knows what their individual assessment of the auctioned object is, and the assessments differ from one buyer to another, while in common value auctions the item to be auctioned has the same value for all potential buyers, but they do not know exactly what the value is and, therefore, their estimates vary.

Auctions may have elements of both private value and common value, which is the case of the areas offered by ANM, since some areas have approved reserves, available in physical processes, in which interested parties can obtain views, and from there define a bid value that varies according to other information. However, other areas do not have reserve information and each bidder will arbitrate a price and, in this case, an individual assessment may lead to very discrepant prices, evidencing the asymmetry of information.

According to Porter (1992), an auction is a market where information plays a crucial role, and is used by the seller when he is not sure of the price of the item to be sold. On the other hand, participants are uncertain about the evaluation of the good by other competitors, and the maximum value that an item can reach, especially when the information about the good is incomplete (information asymmetry). If a buyer has more information than the other competitors, he obtains an information income.

According to Brasil (2009), information income is the consumer surplus itself, that is, the difference between the reserve price of the auction winner and the bid he/she offered. This occurs in private value auctions, where it is more difficult to measure the individual assessment of each participant, and also in first-price closed auctions. The way to calculate information income is through a non-parametric estimation procedure, in which each private value can be expressed as a function of its respective bid, the distribution of observed bids and the probability density function corresponding to these bids. The ANM has the minutes with all the bids for each area, allowing information income to be calculated, but this is not the objective of this article. The conclusion of Brasil and Postali (2013), when analyzing the auctions held by the National Petroleum Agency – ANP, is that the greater the competition in the auction, the lower the winner's information income and, consequently, the greater the surplus extracted by the Government.

Still on the subject of types of auctions and information, Mattos (2008) highlights the difference between types of auctions, with first-price sealed auctions being more likely to attract a greater number of participants and potentially being more profitable, and that the most common problems found in the auction literature, the winner's curse and cartelization, have inverse effects: in first-price sealed auctions there are fewer concerns about possible cartelization, but the inability to review bids can favor the winner's curse, whereas in ascending oral auctions the opposite occurs.

The winner's curse is a situation that can occur mainly in common value and first-price sealed auctions where agents, unable to observe and learn from each other's bids, end up bidding in a low-information scenario, and the most optimistic (and not necessarily the most efficient) bidder may end up winning the auction. The problem is presented in Thaler (1988) in the form of an experiment using a jar full of coins: when auctioning this jar to a group of people, it is very likely that (i) the average bid will be significantly lower than the total value of the coins (bidders are risk averse) and (ii) the winning bid will exceed the total value of the coins, i.e., the winner will have paid more than it is worth ("the winner's curse").

The analysis of the occurrence of the winner's curse has already been carried out in the literature in very different markets, such as in mergers and acquisitions of firms (Roll, 1986; Boone and Mulherin, 2008), real estate sales (Ashenfelter and Genesove, 1992) and oil exploration areas (Capen et al., 1971). In Bazerman and Samuelson (1983), it is demonstrated through experiments that the occurrence and magnitude of the winner's curse is greater the greater the level of uncertainty regarding the value of the good for sale and the greater the number of bidding competitors.

2.2.2. Mineral resource auctions

For mineral resources, there are studies that provide a large amount of information about the auctions of oil areas that have taken place in the Gulf of Mexico by the United States Government since 1954. One of the seminal articles on the winner's curse (Capen et al., 1971), although they did not use the exact expression, evaluates auctions of oil areas. The authors demonstrate that the companies that win the auctions of oil areas in the Gulf systematically obtain very low returns.

According to Porter (1992), for the auctions held in the Gulf of Mexico areas, the following types of areas were offered: i) *wildcat* areas, whose geology is little known, in which companies were allowed to obtain seismic data, but not drilling; ii) "drainage" and "development sales", which are both adjacent areas of already discovered deposits, where seismic data were allowed to be obtained, but drilling was only allowed in adjacent areas, where concessionaires already had superior information. The difference between "drainage" and "development sales" is that the latter are areas that had already been offered previously, but the winners did not drill, or even areas of no interest, which were being re-offered. "Drainage" are, therefore, the most valuable areas, since they were being offered for the first time.

Hendricks and Porter (1999) showed that concessionaires in areas adjacent to the areas offered had superior information and bids were higher than those in *wildcat* areas, which, despite having seismic information, received lower bids. In this study, an ex-post evaluation of the information income obtained was carried out, which was higher in areas adjacent to the production areas.

Haile et al. (2009) summarized the information from 1954 to 1982, the year in which changes occurred in the auctions promoted by the US Government, and from 1983 onwards. Until 1982, there was a greater dispersion of bids in *wildcat* areas, that is, areas with less information and not previously explored (the dispersion considered was the percentage difference between the first highest bid and the second highest bid). Furthermore, until 1982, 50% of the areas were sold and of those that received bids, 64% had at least two bids, with an average of 3.2 bids per area. From 1983 to 2006, 7% of the areas were sold, and only 25% received at least two bids, and the average number of bids per area fell by more than half, to 1.3. This was explained by the fact that, after 1983, more deep-water *wildcat* areas were offered. In addition, until 1982 there was a process of nominating the areas that companies were interested in, which increased the attractiveness of the auction.

Following the opening of the oil sector in Brazil in the 1990s, the National Petroleum Agency (ANP) began to hold auctions. Monteiro (2015) showed that, in ANP auctions, the fact that Petrobras was knowledgeable about sedimentary basins, due to its long monopoly period, generated information asymmetries, and its success rate in auctions was quite high. The same study shows that, after the first auctions, with the entry of OGX, which incorporated Petrobras technicians, that is, bringing knowledge of the basins, the company also achieved success in some auctions, until its financial collapse.

2.2.3. Assessment of Mining Areas

Paione (1998) advocates that the economic value of a mineral deposit, which depends on the present value of the monetary benefits projected for the future resulting from the commercialization of the mineral, is a function of the following variables:

$$VE = f(n, R_n, D_n, i, I, p),$$

Where:

- n = life of the deposit, or number of years that must elapse until all the useful ore or mineral substance is exhausted. It is directly linked to the calculated mineral reserves.
- R_n = operating revenue resulting from the sale of ore.
- D_n = operational costs of ore extraction and processing.
- i = interest rate.

- I and p = investments, including working capital.

The above function is broken down into a Discounted Cash Flow, so the economic value of a deposit is the difference between the sum of the cash flow of net revenues and the sum of the investments applied to extract that deposit, discounted at a pre-established rate.

Therefore, the evaluation of mineral deposits requires, among other variables, mineral reserves. Thus, the vast majority of areas in the ANM's public offering simply cannot be evaluated for a minimum price. The few areas that could be evaluated, with a final approved research report (herein referred to as having geological knowledge) and those in mining, even if they are no longer prospects, still have a difficulty in evaluating because they represent a possibility of obtaining mining (it is not certain that the mining concession will be granted).

3. Methodology and database

As the work is focused on evaluating determinants of the attractiveness of auctions, especially in relation to the value of information on the economic potential of areas and substances, we sought to separate the areas by their origin and the substances by their quantity, since there were several different types of substances offered.

For the areas, five large groups were identified:

- areas that belonged to the licensing regime, a type of regime for aggregates for civil construction (Lic);
- discarded areas (Desc);
- areas without geological knowledge (Semgeo);
- areas with geological knowledge (RFP);
- mining areas (Mining): despite being areas with geological knowledge, it is important to separate them to verify their attractiveness in relation to the areas from the previous phase, which have geological knowledge, but which have not yet obtained the concession (mining application areas can also be made available).

The second separation was in relation to the substances. Although the Brazilian mineral sector has over 50 mineral substances mined, the 10 with the largest quantities in the first five rounds were chosen: sand; clay; sand and clay; limestone; granite; copper ore; iron ore; gold ore; manganese ore; and quartzite.

Many areas are required for more than one substance, causing some difficulty in analyzing the data. One of the reasons for requesting another substance is the size of the area, since substances used as aggregates for civil construction have a maximum limit of 50 ha, so it is quite common to request sand and gold, for example. The ANM is only certain that the process is really for a certain substance after the final research report – RFP is approved.

Since these areas represent only 6.5% of the areas that were offered, and to minimize possible errors in determining the substance of areas without geological knowledge, areas with only one substance, for example, copper, were chosen. If the request was for copper and nickel, this area was not used in the statistics. Thus, the only substances that appeared together in the top 10 were sand and clay (as well as individually), which were considered in this study, since both are used as aggregates for civil construction. In any case, if an area was requested for the substance sand, for example, this certainly did not represent an intention to mine manganese, and this separation, in itself, is already valid from the point of view of differentiating substances for civil construction aggregates (sand and clay), industrial aggregates (limestone), ornamental rocks (quartzite and granite) and metallic aggregates (copper, iron, manganese and gold).

To measure whether the size of the area impacted both the probability of auction and the amount paid, the Hectares regressor was used, which can reach up to 10,000 hectares, depending on the substance group and location (areas located in the Legal Amazon and substances other than aggregates for civil construction can have up to 10,000 hectares).

It is important to highlight that the five rounds were considered in a single period of time, since all rounds were carried out practically within a period of two years; therefore, the model was structured in cross-section. As demonstrated in ARR – Availability (Brazil, 2022), the rounds were, in many periods, overlapped with others, so it is difficult to even consider that there was a learning curve in the sector between one round and another, which could lead to a change in the behavior of the agents.

Another extremely important factor to be considered is that many participants purchased an area but did not request it, i.e., they did not proceed with obtaining the mining title, and this will be addressed in this study, since the requested areas represent the areas in which there was proven interest. For those who did not proceed, i.e., did not request the areas, sanctions such as fines and the inability to participate in new public offerings are foreseen.

3.1. Determinants of the probability of success in a public offering

To perform the empirical assessment of the probability of success of the public offering, a logistic regression is performed, according to the formula below:

$$\begin{aligned} Y_i = \beta_0 &+ \beta_1 \text{Lic}_i + \beta_2 \text{Desc}_i + \beta_3 \text{Semgeo}_i + \beta_4 \text{RFP}_i + \beta_5 \text{Mining}_i \\ &+ \beta_6 \text{Sand}_i + \beta_7 \text{Clay}_i + \beta_8 \text{SandClay}_i + \beta_9 \text{Limestone}_i + \beta_{10} \text{Copper}_i \\ &+ \beta_{11} \text{Granite}_i + \beta_{12} \text{Iron}_i + \beta_{13} \text{Manganese}_i + \beta_{14} \text{Gold}_i + \beta_{15} \text{Quartzite}_i + \theta\, \text{Hectare}_i \end{aligned} \tag{Equation 1}$$

Where:

- $Y_i = \log\left(\frac{p}{1-p}\right)_i$ is the probability of success (auction of area i);

- $\beta_1, \beta_2, \beta_3, \beta_4$ and β_5 are the model coefficients related to the evaluation of the effect of information (geological knowledge) on the area;
- Lic, Desc, Semgeo, RFP and Lavra are the predictor variables, related to the types of areas listed in Table 1, that is, to the level of information available on the economic potential of the area. In this sense, RFP and Lavra can be considered high information, and the others low information. Each variable consists of a dummy, with a value of 1, if it is of the type of area in question (Lic, for example), or zero if it is not of the type in question;
- β_6 to β_{12} are the model coefficients related to the substance offered;
- The Hectare variable consists of the size of the area put up for bidding, which can affect the market's interest in bidding.

The substances Sand, Sand and Clay, Clay, Limestone, Copper, Granite, Iron Ore (from here on only Iron), Gold Ore (from here on only Gold), Manganese Ore (from here on only Manganese) and Quartzite consist of the main substances in terms of quantity placed on offer by the ANM. Each variable consists of a dummy, with a value of 1, if it is of the substance in question, or zero if it is not of the substance in question.

3.2. Determinants of the value of the public offering

To perform the empirical assessment of the effect on the value of the public offering, a multiple regression using ordinary least squares is performed, according to the formula below:

$$
\begin{aligned}
\text{Value}_i = {} & \beta_0 + \beta_1 \text{Lic}_i + \beta_2 \text{Desc}_i + \beta_3 \text{Semgeo}_i + \beta_4 \text{RFP}_i + \beta_5 \text{Mining}_i \\
& + \beta_6 \text{Sand}_i + \beta_7 \text{Clay}_i + \beta_8 \text{SandClay}_i + \beta_9 \text{Limestone}_i + \beta_{10} \text{Copper}_i \\
& + \beta_{11} \text{Granite}_i + \beta_{12} \text{Iron}_i + \beta_{13} \text{Manganese}_i + \beta_{14} \text{Gold}_i + \beta_{15} \text{Quartzite}_i + \theta\, \text{Hectare}_i
\end{aligned} \qquad \text{(Equation 2)}
$$

Where:

- Value_i: amount paid, in reais, to the government as a result of the offer presented by the interested party for each area i, being zero if the area has not received any proposal. Therefore, the values are greater than zero if there is more than one proposal.

The other coefficients are the same as those described in Equation 1.

3.3. Database

The first five rounds offered 16,480 areas, of which 9,643 were auctioned and 6,837 were failed. Areas that were auctioned are understood to be those that were auctioned: i) in the public offering stage (3,916 areas), with only one offer received; and ii) that went to the auction stage (5,727 areas), i.e., that had more than one proposal in the public offering stage. This division shows the number of areas that had interested parties (sold), but it is important to emphasize that both the areas auctioned in the public offering and in the auction stage may, in fact, have failed later because they were not requested, i.e., the agent, despite having won the area, did not proceed with its request. The areas actually requested total 5,295 areas.

Table 2 summarizes the data from the five rounds. It shows that Round 1 had the largest number of failed areas, 64.5%, and the smallest number of areas sold in the public offering, 20.1%.

The other rounds show similar amounts of failed, sold and auctioned areas, but round 4 had a slightly higher amount of areas for auction, 41.7%, compared to the average of 34.7%. In terms of average bid value, round 2 had the lowest average, at just R$13,595. In this round, the rule was tested that if the first-place bidder did not honor the bid, the area would be offered to the second-place bidder who, if they also did not honor the bid, would be offered to the third-place bidder. However, according to the ARR of Availability (Brazil, 2022), this modification was discarded to avoid collusion.

Table 2. General round data.

Round	Areas offered	Failed	%	Sold in offer	%	For auction	%	Avg. bid (R$)
1	502	320	64	99	20	82	16	30,349
2	7,027	2,751	39	1,711	24	2,416	34	82,983
3	2,762	1,090	39	571	21	1,092	40	75,334
4	1,658	569	34	389	23	696	42	71,952
5	4,500	1,918	43	1,123	25	1,459	32	79,005
Total	16,449	6,648	40	3,893	24	5,745	35	67,925

Source: SOPLE.

Table 3 shows the quantities of area by origin made available in the first 5 rounds, where it can be seen that the areas without geological knowledge were the vast majority, with 70.2%, while the areas with geological knowledge, together with those of mining, total only 6.5%. Areas under the extraction regime, a specific regime for public agencies, are not shown in the table, as they were not used in the study, and which totaled only 4 areas.

Table 3. Number of areas by origin.

Area type	Amount	%	Geological knowledge
Licensing	1,475	8.9	None or low
Discarded	2,355	14.3	None or low
Without Geological Knowledge	11,575	70.2	None or low
Final Research Report Approved	643	3.9	High
Mine	428	2.6	High
Total	16,480	100	

Source: prepared by the author based on data from SOPLE and the Mining Registry System.

4. Results

The success of the public offering took into account the expression of interest in the first stage, in which the areas were designated as "sold" when they had only one expression of interest; or "awaiting auction" when they received two or more expressions of interest. Thus, both the areas sold and the areas awaiting auction were considered sold.

When they did not receive any expressions of interest, they were considered to have failed, leaving them open to new interested parties.

It is important to highlight that even areas that were auctioned or awaiting auction may have failed later due to: i) those that were auctioned, because they were not requested by interested parties; ii) those in the auction, because they did not receive bids, or even because they received bids but were not paid or, lastly, the area was not requested.

Before carrying out the logistic regression, the probability of the general auction of the areas was verified, which consists of 58.5% for those auctioned at the public offering stage, as explained above, and 32% for those actually requested.

The first logistic regression considered as successful the areas that received expressions of interest in the first stage of the public offering. The results can be seen in Table 4 and show that the licensed areas, discarded areas and areas without geological knowledge have a decrease in the probability of being auctioned, and the areas resulting from the licensing regime were the only ones that came close to statistical significance.

Areas with a positive final research report, which will now be referred to only as RFP +, and mining areas show an increased probability of auction, with mining areas being statistically significant. In this model, these mining areas have a 3.3% greater chance of auction than the others. Gold areas have a 2.8% greater chance of auction.

Still regarding the substances that remained statistically significant, copper has a 33.2% higher probability of auction and sand and clay, 20.3%. The two substances sand and clay, in isolation, have a decrease in the chances of auction. Granite, quartzite and iron did not have statistical significance in this model, as well as the licensed areas, discarded areas, areas without geological knowledge and RFP +. The variable Hectares has no effect on the chances of auction.

Table 4. Logistic regression results for auctioned areas.

Coefficients	Estimate (β)	Std. Error	z value	Pr($>|z|$)	Exp(β)	(exp(β)-1)$\times$100
(Intercept)	0.288	0.293	0.985	0.325	1.338	33.8
Licensing	-0.582	0.297	-1.955	0.052 .	0.550	-44.3
Discarded	-0.184	0.294	-0.627	0.530	0.829	-17.1
Semgeo	-0.041	0.293	-0.141	0.887	0.956	-4.4
RFP +	0.281	0.303	0.929	0.352	1.321	32.1
Mine	1.193	0.316	3.773	0.000 ***	3.302	230.3
Sand	-0.155	0.068	-2.276	0.023 *	0.856	-14.4
Clay	-0.312	0.061	-5.087	0.000 ***	0.732	-26.8
Sand and Clay	0.184	0.078	2.344	0.019 *	1.202	20.3
Limestone	0.435	0.083	5.221	0.000 ***	1.545	54.5
Copper	0.287	0.101	2.844	0.004 **	1.331	33.2
Granite	-0.041	0.059	-0.694	0.488	0.959	-4.0
Iron	0.112	0.066	1.689	0.091 .	1.118	11.8
Manganese	0.639	0.107	6.195	0.000 ***	1.942	94.2
Gold	1.035	0.072	14.426	0.000 ***	2.814	181.4
Quartzite	-0.036	0.098	-0.369	0.712	0.964	-3.5
Hectares	0.000	0.000	3.259	0.001 **	1.000	0.0

Notes: Signif. codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1. Dispersion parameter for binomial family taken to be 1. Null deviance: 22366 on 16479 degrees of freedom. Residual deviance: 21615 on 16463 degrees of freedom. AIC: 21649. Number of Fisher Scoring iterations: 4. Dependent variable is the probability of auctioning the areas.

Table 5 shows the results for the same probabilistic regression; however, instead of success being the expression of interest, this became the areas that were actually requested. This is considered a better scenario than the expression of interest, since the subsequent request demonstrates that the agent was really interested in the area. This is because many agents may have expressed interest in the first phase of the public offering to see if they could win the areas without greater competition. This behavior can be identified in the minutes of the public offering available on the SOPLE platform, where there are agents participating in the first phase, but who are later not present in the auction phase, that is, they did not bid.

In this scenario of effectively requested areas, the Akaike information criterion – AIC was lower than that of auctioned areas, showing the best fit of the model. This new scenario showed that the licensing, discarded and unexplored areas continued to have a decrease in the auction probabilities, while those with RFP + and mining increased, so that RFP + increased significantly (32.1% to 53.3%). However, the results of RFP + in both scenarios were not statistically relevant.

Regarding the substances, sand, clay and granite showed a decrease in the probability of auction, with sand being close to statistical significance. Considering that the probability of auctioning the areas actually requested is lower than that of the auctioned areas, it is expected that all areas and substances had a decrease in the probability of auctioning in the requested model.

In this model of areas actually required, therefore, mining areas increase the probability of auction by 140.9%, gold by 120.6%, manganese by 64.6%, limestone by 64.1%, sand and clay by 31.8% and copper by 6.3%, all with statistical significance. Here, again, the variable Hectares does not impact the probability of auction.

Table 5. Results of logistic regression for the origin of the areas that were requested.

Coefficients	Estimate (β)	Std. Error	z value	Pr($>|z|$)	Exp(β)	(exp(β)-1)$\times$100
(Intercept)	-0.610	0.314	-1.944	0.052	0.543	-45.7
Licensing	-0.837	0.320	-2.611	0.009 **	0.432	-56.7
Discarded	-0.392	0.315	-1.244	0.214	0.675	-32.4
Semgeo	-0.193	0.314	-0.615	0.538	0.824	-17.6
RFP +	0.427	0.322	1.326	0.185	1.532	53.3
Mine	0.879	0.326	2.699	0.007 **	2.408	140.9
Sand	-0.135	0.078	-1.738	0.082 .	0.873	-12.6
Clay	-0.194	0.069	-2.809	0.005 **	0.823	-17.6
Sand and Clay	0.276	0.081	3.398	0.000 ***	1.317	31.8
Limestone	0.495	0.080	6.155	0.000 ***	1.640	64.1
Copper	0.061	0.104	0.590	0.555	1.063	6.3
Granite	-0.239	0.066	-3.602	0.000 ***	0.787	-21.2
Iron	0.043	0.069	0.609	0.542	1.043	4.3
Manganese	0.498	0.098	5.074	0.000 ***	1.646	64.6
Gold	0.791	0.061	12.926	0.000 ***	2.206	120.6
Quartzite	0.168	0.102	1.645	0.099	1.182	18.3
Hectares	-0.000	0.000	-1.614	0.010	0.999	0.0

Notes: Signif. codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1. Dispersion parameter for binomial family taken to be 1. Null deviance: 20694 on 16479 degrees of freedom. Residual deviance: 20084 on 16463 degrees of freedom. AIC: 20116. Number of Fisher Scoring iterations: 4. Dependent variable is the probability of auctioning the areas.

Finally, other models were run, one of them after a test was carried out to detect multicollinearity where the variables licensing, discarded, semgeo and RFP + presented high VIF (variance inflation factor).

In this sense, a model was presented that simplifies the difference in knowledge between the areas and allows for improved interpretation of the coefficient, so that we have a single dummy of geological knowledge (here called "GeoKnowledge") that aggregates the mining areas and the RFP + areas. Thus, the following equation was estimated:

$$\begin{aligned} Y_i = \beta_0 &+ \beta_1 \text{GeoKnowledge}_i + \beta_6 \text{Sand}_i + \beta_7 \text{Clay}_i + \beta_8 \text{SandClay}_i + \beta_9 \text{Limestone}_i \\ &+ \beta_{10} \text{Copper}_i + \beta_{11} \text{Granite}_i + \beta_{12} \text{Iron}_i + \beta_{13} \text{Manganese}_i + \beta_{14} \text{Gold}_i \\ &+ \beta_{15} \text{Quartzite}_i + \theta\, \text{Hectare}_i \end{aligned} \qquad \text{(Equation 3)}$$

In which the GeoKnowledge variable was constructed according to Table 6 below.

Table 6. Model with only one geological knowledge variable (GeoKnowledge).

Area type	Geological knowledge	Dummy
LICENSING	None or low	0
DISCARDED	None or low	0
WITHOUT GEOLOGICAL KNOWLEDGE	None or low	0
GeoKnowledge (Mining and RFP+)	High	1

The results for the model considering the variable GeoKnowledge, instead of the previous variables related to geological knowledge are presented in Table 7 below. Being the area with geological knowledge increases by 110.3%. Gold, manganese, limestone and copper also contribute significantly to the attractiveness of the area.

Table 7. Results of logistic regression for the auctioned areas and the GeoKnowledge variable.

Coefficients	Estimate (β)	Std. Error	z value	Pr(> |z|)	Exp(β)	(exp(β)-1)×100
(Intercept)	0.152	0.027	5.653	0.000 ***	1.164	16.4
GeoKnowledge	0.743	0.070	10.548	0.000 ***	2.103	110.3
Sand	-0.287	0.065	-4.381	0.000 ***	0.750	-24.9
Clay	-0.377	0.060	-6.239	0.000 ***	0.685	-31.4
Sand and Clay	0.194	0.078	2.479	0.013 *	1.214	21.4
Limestone	0.480	0.083	5.784	0.000 ***	1.617	61.7
Copper	0.354	0.100	3.533	0.000 ***	1.425	42.5
Granite	0.010	0.059	0.172	0.863	1.010	1.0
Iron	0.170	0.065	2.601	0.009 **	1.186	18.6
Manganese	0.724	0.107	6.777	0.000 ***	2.063	106.3
Gold	1.094	0.071	15.368	0.000 ***	2.985	198.5
Quartzite	0.018	0.097	0.189	0.850	1.018	1.8
Hectares	0.000	0.000	4.682	0.000 ***	1.000	0.0

Notes: Significance codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1. Dispersion parameter for binomial family taken to be 1. Null deviance: 22366 on 16479 degrees of freedom. Residual deviance: 21739 on 16467 degrees of freedom. AIC: 21765. Number of Fisher Scoring iterations: 4.

The model with the probability of auctioning the areas that were actually requested is shown in Table 8, which presented an AIC of 20210 against 21765 of the auctioned areas, so, again, this is considered the best model. Here, the substances iron and copper did not present statistical significance. In this model, the geological knowledge areas present an odds ratio of 2.456 of auction, which means a 145.6% increase in the probability of auction. The substance gold presents a 136.1% increase in the probability of auction, while manganese and limestone 76.3% and 71.9%, respectively.

Table 8. Results of logistic regression for the required areas and variable GeoKnowledge.

Coefficients	Estimate (β)	Std. Error	z value	Pr(> |z|)	Exp(β)	(exp(β)-1)×100
(Intercept)	-0.910	0.029	-31.545	0.000 ***	0.402	-59.9
GeoKnowledge	0.899	0.065	13.868	0.000 ***	2.456	145.6
Sand	-0.280	0.075	-3.733	0.000 ***	0.755	-24.4
Clay	-0.263	0.068	-3.844	0.000 ***	0.769	-23.1
Sand and Clay	0.279	0.087	3.462	0.000 ***	1.322	32.2
Limestone	0.542	0.080	6.758	0.000 ***	1.719	71.9
Copper	0.140	0.103	1.359	0.174	1.151	15.1
Granite	-0.187	0.066	-2.839	0.004 **	0.829	-17.0
Iron	0.113	0.069	1.631	0.103	1.119	11.9
Manganese	0.567	0.097	5.790	0.000 ***	1.762	76.3
Gold	0.859	0.060	14.180	0.000 ***	2.361	136.1
Quartzite	0.233	0.102	2.296	0.022 *	1.263	26.3
Hectares	-0.000	0.000	-0.273	0.785	0.999	-0.0

Notes: Significance codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1. Dispersion parameter for binomial family taken to be 1. Null deviance: 20694 on 16479 degrees of freedom. Residual deviance: 20184 on 16467 degrees of freedom. AIC: 20210. Number of Fisher Scoring iterations: 4.

Although this is the best model, Tables 4 and 5 were maintained because they show the interest in the different types of areas, mainly between the two types of areas with geological knowledge, those with RFP + and those for mining, with the latter having a higher odds ratio of auction, therefore showing the potential of the areas offered for mining, as shown in Figure 2.

The various models used were used to capture the effects of the areas and substances. Although the initial objective was to show and measure the probability of the different areas in such a way that areas with geological knowledge have a higher probability of auction, it was also possible to measure the effect of the ten largest substances (in quantity), in such a way that areas with geological knowledge have a very high probability of auction, as well as the substances gold, limestone and manganese.

4.1. Determinants of the value of the auction stage

For the auction stage, bids in the five rounds totaled R$347 million, but R$276 million were actually paid. For the chosen substances, statistics show that those used in civil construction, such as sand and clay, had the lowest average bids, of R$18,801 and R$24,550 respectively. For the substance granite, the average bid was higher, at R$35,190, and there is no distinction, in the ANM data, between granite used for gravel, which has a lower added value, and granite used as ornamental rock. This is also the case for limestone, which can be used for cement, lime and corrective, and which had an average bid of R$52,517.

The highest bidder was gold ore, with R$85 million, and an average bid of R$132,349. The highest average was iron ore, with R$197,444, and a bid of R$74 million. However, only one area for iron ore had a bid of R$50 million, which influenced this variable. Thus, iron ore and gold ore totaled R$159 million, or 45% of the bids in the five rounds. The sum of the bids and the averages are shown in Table 9.

Table 9. Sum of total bids and bids by substance.

Total bids (R$)			346,698,628
Total effectively paid (R$)			275,625,962
Substance	**Amount**	**Sum of Bids (R$)**	**Average bid (R$)**
Sand	1,126	3,179,790	18,380.29
Clay	1,353	5,913,227	28,845.01
Sand and Clay	762	6,138,046	29,845.01
Limestone	727	15,203,491	58,250.93
Copper	464	18,680,707	137,358.14
Granite	1,427	10,348,239	34,725.63
Iron Ore	1,157	73,844,174	197,444.31
Manganese Ore	466	10,777,460	58,256.54
Gold ore	1,391	88,321,825	130,076.33
Quartzite	462	4,983,039	39,547.93

Source: SOPLE/ANM.

A regression using ordinary least squares was performed to analyze the value of the offer. Only the variable iron showed statistical significance, as shown in Table 10.

Table 10. Ordinary least squares multiple regression for dependent variable bid value.

Coefficients	**Estimate**	**Std. Error**	**t value**	**Pr(> |z|)**
(Intercept)	57,296	24,404.6	2.348	0.019 *
GeoKnowledge	37,306	45,441	0.821	0.412
Sand	-44,581	71,868	-0.620	0.535
Clay	-36,988	66,331	-0.558	0.577
Sand and Clay	-31,713	66,161	-0.479	0.632
Limestone	-4,808	59,743	-0.080	0.936
Copper	75,532	79,915	0.945	0.345
Granite	-29,282	56,455	-0.519	0.604
Iron	135,933	56,456	2.643	0.008 **
Manganese	-4,345	69,515	-0.063	0.950
Gold	67,347	41,342	1.629	0.103
Quartzite	-24,736	82,672	-0.299	0.765
Hectares	1	6	0.266	0.790

Notes: Significance codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1. Residual standard error: 893500 on 4324 degrees of freedom. Multiple R-squared: 0.003186, Adjusted R-squared: 0.0004196. F-statistic: 1.152 on 12 and 4324 DF, p-value: 0.3127.

Thus, some hypotheses were sought to explain the significance for iron ore alone. When analyzing the spreadsheets, the existence of outliers was verified, such as an area of iron ore for which Mineração Usiminas paid R$50 million, or an agent who paid R$8.5 million in an area for the substance marble. Such values deviate from the averages, possibly because the agents aim to ensure the continuation of their mining operations. In summary, we have the following explanations for very different bids:

- Diversity of areas and substances: aggregate substances for civil construction (sand and clay) have much lower values than metallic substances. Areas of geological knowledge should probably receive higher bids, as hypothesized in Figure 2. Thus, there is a mixture of different areas and different substances.
- Privately valued areas may receive much higher bids due to information asymmetry. Agents with nearby areas who want to continue their business or even protect their market from new competitors may bid much higher, as already exemplified in the case of the two areas above.

Thus, quantile regression was applied in an attempt to capture the effects of areas and substances in the different quantiles of values, and also to control for the possible effect of outliers, according to the following formula:

$$\begin{aligned} Q_\tau(\text{Value} \mid \text{Areas, Substances}) = {} & \beta_0(\tau) + \beta_5(\tau)\text{GeoKnowledge}_i + \beta_6(\tau)\text{Sand}_i + \beta_7(\tau)\text{Clay}_i \\ & + \beta_8(\tau)\text{SandClay}_i + \beta_9(\tau)\text{Limestone}_i + \beta_{10}(\tau)\text{Copper}_i \\ & + \beta_{11}(\tau)\text{Granite}_i + \beta_{12}(\tau)\text{Iron}_i + \beta_{13}(\tau)\text{Manganese}_i \\ & + \beta_{14}(\tau)\text{Gold}_i + \beta_{15}(\tau)\text{Quartzite}_i + \theta(\tau)\text{Hectare}_i \\ & \text{for } \tau = 0.25;\ 0.50;\ 0.75;\ 0.90 \end{aligned} \qquad \text{(Equation 4)}$$

Where:

- Value_i: amount paid, in reais, to the government as a result of the bid submitted by the interested party for each area i, being zero if the area has not received any proposal or has received only one proposal (situation in which it will not be auctioned). Therefore, the values are greater than zero if there is more than one proposal.

The other coefficients are the same as those described in Equation 1.

The results are shown in Table 11.

Table 11. Quantile regression results for the dependent variable offer value.

Coefficients	$\tau = 0.25$	$\tau = 0.5$	$\tau = 0.75$	$\tau = 0.9$
Intercept	2,778.1***	8,185.6***	28,432.2***	81,741.2***
GeoKnowledge	389.0	4,393.5**	20,181.6***	59,638.5*
Sand	219.4	-103.2	-7,488.2*	-39,323.8***
Clay	218.7	-2,394.9 .	-7,919.2 .	-30,045.3**
Sand and Clay	117.3	-2,508.1**	-9,448.8*	-25,038.4
Limestone	2,324.8***	11,800.2**	20,986.2***	49,759.8
Copper	125.5	1,202.2	51,926.1***	333,954.1
Granite	67.2	-246.6	-6,707.9	-21,369.2
Iron	-319.5	-2,830.1*	-2,560.9	38,468.9
Manganese	-764.4**	-1,405.1	1,276.9	26,505.5
Gold	2,169.0***	12,636.7***	23,589.7***	115,439.6***
Quartzite	-776.0 .	-3,053.6*	-10,421.2**	18,601.5
Hectares	0 *	0.4 .	2.1***	-0.8
No. observations	1,084	2,168	3,253	3,903

Note: Significance codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1. Quantile 0.1 only had 434 observations and was therefore excluded, while quantiles 0.75 and 0.9 have the largest number of observations, 3,253 and 3,903, respectively. Quantile regression shows a larger number of variables with statistical significance, in relation to the ordinary multiple squares model. Initially, there is an increase in the intercept values in the upper quantiles and this growth is accompanied by areas with geological knowledge and by the substances limestone and gold, with gold showing statistical significance in all quantiles, going from R$2,169.0 in quantile 0.25 to R$115,439.6 in quantile 0.9. An important result consists of the geological knowledge variable: an area classified in this way leads to a result of R$4,000 (quantile 0.5) to R$60,000 (quantile 0.9) more than the value offered for auction. The areas of sand, clay, sand and clay, iron, manganese and quartzite, when they presented statistical significance, had negative contribution values to the regression values.

The hectares variable has no influence on the values, and also as it did not change the odds ratio, it does not impact the public offer, that is, the size of the area does not change the probability of auction or the value offered.

5. Conclusions

This study analyzed the first five rounds of public offerings carried out by ANM between 2020 and 2022. The first round was more experimental in nature, with few areas, to test the SOPLE platform, built specifically for the new availability model. The empirical analyses were in relation to the probability of auction and offer values, depending on the variables of level of geological knowledge about the areas and substances.

Regarding the probability of success, the regression showed that areas with geological knowledge, including areas with approved final research reports and mining areas, have a higher probability of being auctioned. Regarding the substances, gold areas presented a high probability of being auctioned, followed by manganese and limestone areas.

The areas with geological knowledge and the substances limestone, copper and gold presented a significantly higher bid value compared to the areas and substances that do not have these characteristics. Thus, the hypothesis that the areas with geological knowledge in Figure 2 would have a greater probability of being auctioned and would have higher values was confirmed.

The combination of the two regressions and other information obtained provides an interesting overview for the Federal Government, showing areas and substances that have a higher probability of auction and collection. There may therefore be a combination of these variables aiming at greater success in the bid and collection by the Government. Therefore, areas with geological knowledge and for the substances limestone, copper and gold form a scenario of high probability of auction and higher collection value. In addition, one of the results may be the forecast of collection for the next auctions, considering the probability of auction and the values of the bids. For example: auction with certain areas (types of areas) and substances (some of the 10 largest substances) can be inserted into Equation 4 to forecast collection.

In addition, other issues may arise, for example: according to the ANM Mining Registry System, at the end of 2023 there were more than 23 thousand areas in the mining application phase, which requires the Government to set deadlines for these areas to become productive mining concessions, generating employment and income. Otherwise, they must be made available to other interested parties.

There are also mining concessions that have been suspended, which can also be inspected with requirements to determine whether the holder is still interested. If not, such areas can be terminated and offered to new agents via public offering. In other words, the Government can act to make currently unproductive areas productive, obtaining revenue from the auction and also from the economic movement of the sector (hiring of labor and services to carry out research and mining work).

Another scenario that can be seen with the five public offers is the possible shortage in the market of certain substances, such as limestone, and the Government may give priority to their inclusion in future competitions.

For the private sector, which seeks to generate financial returns, research into information on mining processes can indicate areas and substances with a greater probability of being auctioned, significantly reducing initial expenditure on mineral research. It is therefore suggested that the ANM make as much information available as possible to interested parties, aiming to increase the attractiveness of public offers.

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