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Gemstone mining as a development cluster: A study of Brazil's emerald mines

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ABSTRACT

For many centuries, emeralds have bejeweled the rich and famous all over the world. Emeralds have also made many millionaires overnight, sometimes by chance, as in some of the cases reported in this study. On the other hand, even though emerald mining has brought some economic benefits, many of these have remained at the top of the production chain. In many cases mining activities have caused a number of negative social and environmental impacts locally. Working conditions in small mines are very poor in general: with bad ventilation, high temperatures, long working hours, lack of safety, informal working contracts and no health or life insurance. Environmental impacts can be significant, such as widespread deforestation, erosion of abandoned mines, and soil and water pollution in streams. The economic and social public benefits can be minimal. Even when taxes on gem mining are relatively low, much of the mining local activity is informal and the high value-added formal activities take place outside the mining regions. This study aims to understand the dynamics of emerald mining and its impact on local development using the concept of clusters. The research analyzes three case studies in Brazil: Campos Verdes/Santa Terezinha (Goias state), Nova Era/Itabira (Minas Gerais state) and Carnaiba/Campo Formoso (Bahia state). Emerald mining regions attract many migrants, increasing the demand for public services (infrastructure, health, education, etc.), but local governments are unable to provide for them because the activity produces little tax revenue. In the end, there is a growing mismatch between demand and supply of public services, leading to a series of social and environmental problems. However, working with the concept of cluster can help to shed light on policies to improve the local benefits of gem mining, by organizing the miners and their supporting organizations to allow investments that bring long term benefits locally.

Introduction

Gem production generally contributes little to miners and local development[2] (Cartier, 2009), but it does generate jobs and income (Hilson, 2009). Given the growth of the jewelry market worldwide, the economic impact and economic and social potential related to emerald mining are immense. However, little is understood about social, economic and environmental impacts on the localities where emeralds are produced in Brazil and other developing countries. There is some knowledge on the technical part of emerald production (e.g. gemology, see Giuliani et al., 1998; Giuliani, 1997), but very few studies exist about the social, economic and environmental aspects of gem production. Our aim is to empirically understand the dynamics of emerald production in Brazil through case studies in the three most significant emerald producing regions in the country by using the concept of "clusters".[3]

This article considers how small-scale gemstone mining may potentially create conducive conditions for longer-term development by acting as a catalyst sector. We aim to understand how good local governance in the cluster could bring together small mining related producers to join forces with the help of the public sector to overcome many of those institutional obstacles.

This paper considers how gem miners, businesses, Non-Governmental Organizations (NGOs) and governments can play an important role in improving the predicament of many emerald producing

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[2] Some specialists estimate that less than 5% of the retail price of a good cut emerald stays at local level, and much less again is available to be invested in public goods (we estimate less than 0.1% in the case of local government). The 5% includes the private remuneration of miners, even though they may spend very little locally.

[3] In this paper, we will utilize the expression "cluster" to refer to an agglomeration of mineral related activities, though other expressions are found in the literature. There are a few other concepts similar to clusters, such as the Local Productive Arrangement (Arranjos Produtivos Locais—APLs in Portuguese), industrial districts and local innovation systems.

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regions by promoting initiatives that lead to more effective local development. Based on this analysis, we propose some recommendations for improvement in the sector. The promotion of gem related small scale activities as a clusters can build institutional capacity to overcome obstacles by formalizing mining related activities, attracting investment and bringing a balance between social demands and provision of social services.

Mining and clusters

We use the concept of clusters and social upgrading to analyze the case of emerald mining. Although there are many definitions of clusters, we define them as small agglomerations of economic agents working in one specific sector in one region. There may be some interaction or potential for interaction among the economic agents, and between them and supporting organizations, such as governments, Non-Governmental Organizations (NGOs) and universities. Even though the focus of clusters is the dynamics of small economic agents, we also consider as clusters agglomerations with a presence of medium and large economic agents. We could borrow the concept of clusters for mining areas, as mining firms, independent miners and others in the mineral production chain (cutting, commerce, etc.) both in the formal and informal sector could be considered economic agents in the same (mining) sector. Academia and the business community have used the idea of clusters widely in recent decades. The literature on the subject has grown rapidly, along with public policies that try to create and develop clusters.[4] A cluster as a unit of analysis can also serve as an interesting concept in thinking about local development, as do other units of analysis of economic organizations, such as firms, sectors or production chains, lack the territorial boundaries that delimit local development, and includes non-economic actors (governments, training organizations and units).

Using clusters as a conceptual framework to work with mining activities is especially useful when dealing with small-scale mining. Generally, a mining region develops as a resource cluster over time because it naturally becomes an agglomeration of economic actors in the mining sector. Minerals attract miners and mining companies, as well as organizations that work closely with them, such as specialized training organizations, trade unions, dealers and jewelers. Those actors interact with each other to a certain extent to explore, exploit, comercialize or add value to minerals. Miners can work alone or in small groups, and could be considered small or micro-enterprises. The relationships among different organizations and individuals are affected by the amount of trust existing among the social actors, which in turn is shaped by cultural local values. These relationships influence the way the actors cooperate as well as the cluster's innovative capacity, which in the end determines the spill over effects on local development.

The dynamics of the interactions among the different actors in the cluster can bring positive effects for the economic agents (firms or individuals). These effects could be divided into two kinds. First there are the external economies documented by Alfred Marshall in the 19th century (Marshall, 1890). They are the positive or negative unpaid, extra-market side-effects (externalities) of the activity of one economic agent on other agents. There is also a second effect, collective efficiency, which is the advantage to be gained by local external economies and joint action (Schmitz, 1995). This is a deliberate conscious act resulting from the collective action of different actors in the cluster (both economic agents and supporting organizations). Those effects are important in explaining cluster upgrading as collective action is necessary to help firms to overcome certain obstacles to upgrading.

The concept of the cluster was particularly important in providing conceptual support to policies in small scale gem mining in Brazil, as gem mining is developed mostly through formal and informal mining organizations, generally at a small scale. In clusters, small economic actors are able to overcome some of the hidrances they usually face when working in isolation, such as lack of scale, lack of specialized skills, difficulty in obtaining modern technologies and inputs and services, problems in reaching markets and good distribution channels, and access to information, credit and services.

Clusters can also help small scale mining firms and individual miners to socially upgrade. Social upgrading is the improvement of social, environmental, labor and economic (formalization) standards and local and/or regional development.

The good governance of clusters can help small producers to overcome the obstacles to social upgrading, bringing the advantages of scale and collective efficiency:

- Scale in finding individual solutions for many. For example, one low-cost individual sediment tank for reducing water pollution.
- Collective joint solutons, such as common schist washing tanks.
- Development of specialized skills helping to improve the productivity and income of miners.
- Potential for innovation in technology and the spread of information and learning, as there are more people and organizations developing their ideas.
- Potential for development of external services (consultancy, maintenance).
- Scale in the organization of social movements (environmental, labor) and law enforcement.

However, being in a cluster may also have some limiting effects on social upgrading, as clusters may lead to difficulties in scaling-up because of the number of actors and high total costs involved and due to political resistance from social actors that benefit from the disorganization of the cluster.

The literature in Brazil has exposed several examples of clusters in different sectors and regions[5] (Amorim, 1998; Lasters et al., 2003; Cassiolato and Lastres, 2003), including the analysis of social and environmental improvement (Puppim de Oliveira, 2009). In the mining sector, some practical interventions in the clusters in the mining sector have taken place to improve environmental quality, as for example, in the cluster relating to ornamental stones in Santo Antonio da Padua in the state of Rio de Janeiro (Langsch et al., 2009; Peiter et al., 2000).

Emerald production in Brazil

Mining of different minerals has going on in Brazil for centuries (Machado and Figueiroa, 2001), but emeralds were not found until recently. The Brazilian explorers (called Bandeirantes) of the seventeenth century trailed the interior of the country several times to try to find emeralds without success (Sauer, 1982, 1992).[6] Only in the 1960s, were emeralds found in the state of Bahia by chance. Since then, emeralds have been found in several places in Brazil in the states of Minas Gerais, Goias, Tocantins, Bahia and Ceara. The history of appearance of Emeralds in Brazil is shown in Fig. 1.

[4] See the work of Schmitz (1995), Schmitz and Navi (1999) and Altemburg and Eckhardt (2006).

[5] See the extensive work of REDESIST (www.redesist.ie.ufrj.br).

[6] In the attempts to find a legendary "emerald mountain" in the middle of Brazil, the "bandeirante" Fernao Dias Paes Leme found gold in the region of Vila Rica (today's Ouro Preto). This led to the gold rush and boom of the gold cycle in Brazil, which was fundamental to the development of the country in the seventeenth and eighteen centuries.

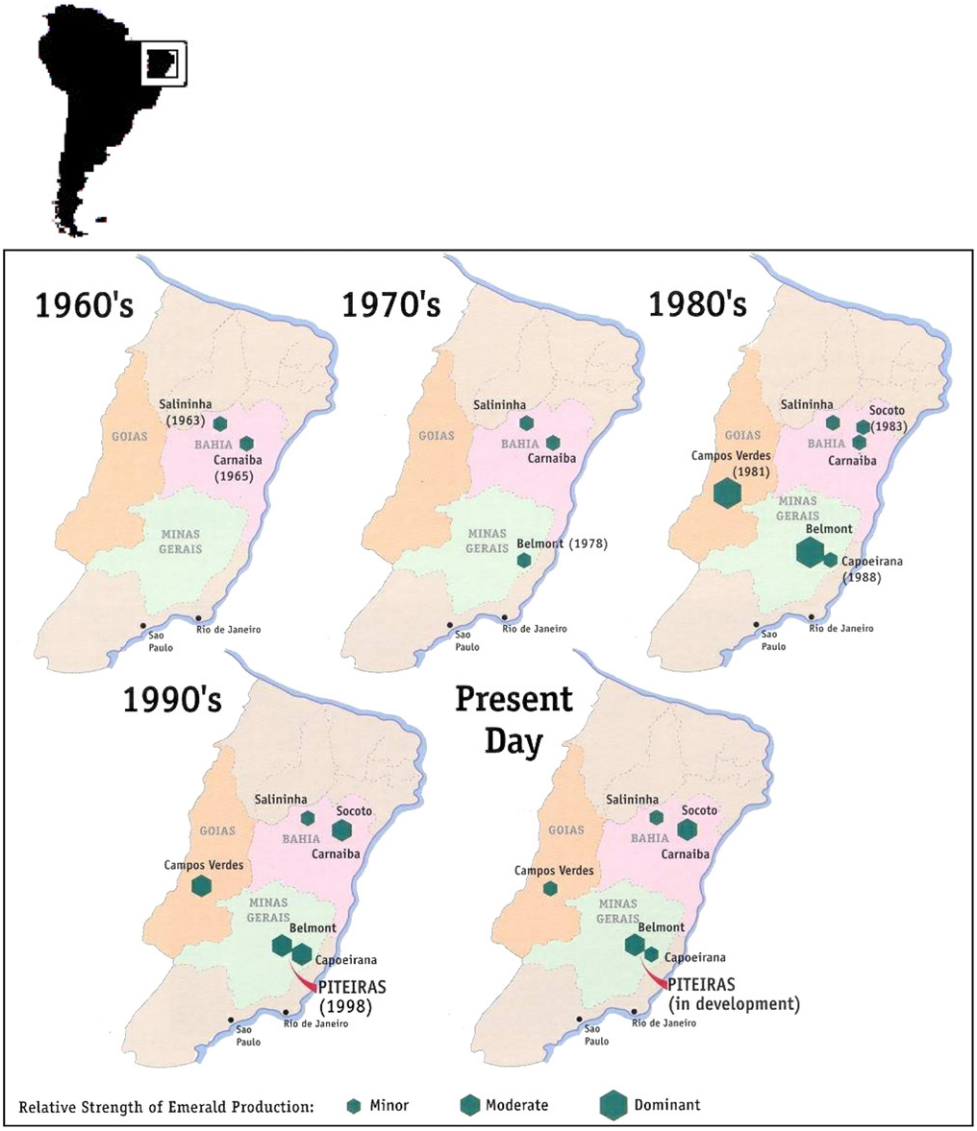

Fig. 1. Occurrence of emeralds in Brazil over time (the maps show the Northeastern part of the country).
Source: Castañeda et al. (2001).

This research analyzes the three most important emerald producing regions or clusters in Brazil[7]: Campos Verdes/Santa Terezinha (Goias state), Nova Era/Itabira (Minas Gerais state) and Carnaiba/Campo Formoso (Bahia state). These three regions produce more than 95% of the Brazilian emeralds and those of the best quality. Analysis of these cases can help in the understanding of the dynamics of local development in an emerald producing region. The production always started with an unexpected discovery, then a rush of "garimpeiros",[8] consolidation in small or large mines, and eventually some decline. Table 1 summarizes the three cases.

The methodology used was that of a case study (Yin, 1994), which is qualitative in nature based on collection of documentation, formal and informal interviews with more than 40 individuals and physical observations. The cases focused on comprehension of the functioning of the emerald mining related activities, including the production and distribution chains and surrounding social, economic and natural environments as well as the behavior and values of miners and other important social actors. The case was developed through field visits to all sites between 2005 and 2008, a workshop with policy makers in December of 2008 and follow-up email and phone conversations in 2009. The case study methodology is used not to generalize to all mining cases, but garner some key lessons for the understanding of what kind of policies could help to upgrade emerald clusters to lead to greater local development.

We found no conclusive relation between emerald production and development indices in the municipalities that produce emeralds.

Out of the three cases, the mining in Itabira (Minas Gerais state) is the only one where gem production is not the main economic activity of the region. Even though Itabira (MG) is the largest producer of emeralds in Brazil in 2008, emerald mining is just a

[7] Nowadays, emeralds are constantly produced in the states of Bahia, Goias and Minas Gerais, and recently in Tocantins (Fig. 1). The state of Bahia does not produce in large economic scale anymore. Ceara had some occurrence in the past, but no production has occurred recently. The cities with the greatest economic dependency on emeralds are Campos Verdes, followed to a lesser extent by Sta. Terezinha (GO) and Nova Era (MG). *Source*: Interview with Dr. Jurgen Schnellrath of the CETEM.

[8] Garimpeiro is a Brazilian word for an independent miner, often working informally.

Table 1
Information about the three cases on emerald production in Brazil.

Place (State)	Year emerald was found	Who discovered the site?	Number of miners (garimpeiros)	Kind of production	Economic activities	Production numbers[a]	Emerald related activities
Campo Formoso (BA)	1965	A peasant found a green stone, and the landowner later found it was an emerald	Had 6000 now around 500	Only garimpeiros	Gem mining is the main activity, within it emeralds are important	10.39 kg (1993)	Some cutting and commerce
Itabira and Nova Era (MG)	1978	A truck driver, who inherited a plot of land, was digging a pool for his cows when he found some green stones. Later he founded his own firm	Had around 3000, now only 600	Large firms and garimpeiros	Iron mining and industrial activities predominate. Emerald mining is secondary.	One large company produces 60–80 kg of rough gems per month, 10 kg of good quality	Only mining
Sta Terezinha, now Campos Verdes (GO)	1981	A farmer was building a road on his farm when he found green stones. Local people say that farmer later filled a truck with emeralds and disappeared, after selling the land to a more experienced emerald miner from Bahia	Reached 50,000 at its peak, now around 500	Mostly garimpeiros, some medium scale firms	Emerald related activities are the main economic driver	44,567 kg of emeralds in 2003, generating R$ 2.6 million in commercialization	Little cutting and commerce

Obs: The acronyms of the states. BA=Bahia, GO=Goias, MG=Minas Gerais.

[a] These are rough estimates from the interviews or sources, but they are not reliable, as much of the emeralds are produced informally.

secondary economic activity, as iron-ore mining and industrial activities are the dominant economic drivers.[9] Another characteristic of the Itabira case is that almost no gem processing takes place locally, nor do local markets exist to commercialize the gems. Basically, gems are sold to be cut outside the region.

In contrast to Itabira, the economies of the other two regions (Campos Verdes and Campo Formoso) revolve around gem production, especially emeralds. In Campos Verdes (GO), emerald production is the only significant economic activity at present. In Campo Formoso (Bahia), emerald production is one of the main economic activities, but other gems are produced besides emeralds. In these two regions, there are active markets for gems and some gem cutting and jewelry production. Open-air markets exist in both regions, where one can buy gems directly from miners and middlemen. These bring people from different regions of the country and foreigners to buy gems. Also, both places do some gem cutting and jewelry production, but those activities seem to be small in scale compared to the emerald production, and they use only low quality gems. Most of the good quality gems end up in other regions of the country or abroad.

Regarding development indicators, the Itabira (MG) region does much better than the other two regions (BA and GO), according to Table 3. Itabira and Nova Era rank among the state's top 10% according to the municipal Human Development Index (HDI). On the other hand, the emerald producing municipalities in Goias and Bahia rank in the bottom half of their respective states in terms of HDI (see Table 2). Campos Verdes, for example, is among the worst 10% of municipalities in Goias. Itabira and Nova Era (MG) rank better on the HDI than Campos Verdes and Santa Terezinha (GO), even though Minas Gerais ranks below Goias in the average state HDI (Tables 2 and 3).

In sum, emerald production is not the only, or even the main, factor in explaining the differences in development among the regions. Moreover, the information above shows that gem production does not necessarily lead to better social or economic performance. From the field work and interviews, we found that most miners are under employed and do not benefit much from emerald production as compared to other livelihoods unless they find a particularly valuable gem. In the two cases where emerald production is the main activity, HDI and economic indicators are worse than in the case where emerald is not the most important activity. However, we cannot infer whether the municipalities would be better off, or worse off, without the emeralds.

Emeralds, like some other gems, are formed where there is a layer of contact between a mass of biotite schist and a mass of granite gneiss that melted together millions of years ago. The concentration of emeralds in these gem pockets varies in each different vein, even though the process of natural emerald production is the same. In some veins, the emeralds are very concentrated in small pockets, like in the case of Bahia. It means that you can only find emeralds next to the pocket. It can take a long time to find a pocket, but when one reaches it a large volume of gems are found. In others, the gems are less concentrated as they are spread over a large area where the schist and granite gneiss are in contact, as is the case with Goias and Minas Gerais. When miners feel they are in an area with a good probability of finding an emerald, they remove a large volume of schist to wash carefully as a gem could be hidden somewhere in the middle of the schist.

There is a high probability of finding gems when a special part of the layer schist/granite is reached. The schist mixed with soil, granite and other rocks (here we call it "schist mixture") have to be washed in order to spot the emeralds, which are generally encrusted in the

[9] Emerald was not even mentioned on the Itabira city home-page www.itabira.mg.gov.br (accessed on 09/09/2007).

Table 2
Human Development Indexes (HDI) for Brazilian States.
Source: IBGE, 2007.

State	HDI-M (1991)	HDI-M (2000)	Change HDI (1991–2000)	RANKING (1991)	RANKING (2000)	Change in the rank (1991–2000)
Brasilia (best)	0.798	0.844	0.047	1	1	0
Goias (GO)	0.707	0.770	0.062	9	7	+2
Minas Gerais (MG)	0.698	0.766	0.068	11	11	0
Bahia (BA)	0.601	0.693	0.092	22	20	+2
Alagoas (worst)	0.535	0.633	0.098	27	27	0

Table 3
Development Indices for the municipalities where emerald production has an impact.
Source: IBGE, 2007.

Municipality	State	Life expectancy at birth	Adult literacy rate	Rate of school attendance	Per capita income/ Month (R$)	Human development index (HDIM)	Ranking per state	National Ranking (out of 5500 municipalities)
Itabira	MG	72,798	0.903	0.876	264,521	0.798	45 of 853	599
Nova Era	MG	73,618	0.904	0.879	217,531	0.792	66 of 853	743
Santa Terezinha de Goiás	GO	67,630	0.809	0.884	158,745	0.721	171 of 256	2607
Campos Verdes	GO	63,332	0.792	0.940	143,043	0.694	215 of 256	3098
Campo Formoso	BA	60,856	0.668	0.809	91,236	0.613	245 of 415	4429
Pindobaçu	BA	59,361	0.684	0.771	78,294	0.595	319 of 415	4744

rocks. The task of washing can be done in the mine itself, by the miners or by the community. Some mines, especially those run by large mining companies, control the whole process. They take the schist mixture from the mines, wash the schist to try to find the emeralds and separate the gems by quality. This work can be done manually, or completely or partially by machines.

The relationship between the mine owners and the miners and the community depends on how gem pockets are formed in a given emerald producing region. In Goias, as the emeralds are not concentrated, mines sell the schist mixture, as they do not have the capacity to wash all the schist. People are willing to buy it because there is some likelihood that they can find good emeralds. Miners make good money selling schist. Sometimes this money is to finance the mining process. If mine owners feel that the mixture is good, they hold it for themselves. A similar process happens in Nova Era (MG), where garimpeiros buy schist from mine owners or exchange mixture for work in the mines.

The large mines have a well-developed system for mine production. They use geological surveys to guide the mining process. Belmont also has a sophisticated system of automatic sorting of the gems by their quality and color. The system was designed by a German company, and according to Belmont's president, it is the only one of its kind in the world. Belmont also praises itself for its environmental management initiatives, such as tree planting on mined terrain and recycling of water used for washing and also replenishing some of the natural water reserves in the soil. The company's environmental management has even been mentioned by the federal government.[10]

However, the investments in emerald mines can be high, especially as shallow deposits are depleted and deeper shafts need to be dug, so it is not easy to become a mine owner. Registration and geological studies can be expensive, as well as operational costs. Experienced miners say that one needs at least R$20,000 (~US$10,000) upfront to start activity. The running of a mine also requires working capital for electricity, salaries, machinery, etc., which can run from R$5000.00 to R$10,000.00 (~US$2500–5000) a month for a typical small mine. Miners have to keep spending money to maintain the mine until they find a precious vein, which can take several months or years. Returns can be good though. A family in Campos Verdes who owns a mine had a revenue of R$50,000 (US$25,000) a month only from the green stones (low quality gems that are used in construction and decoration) from the mines after two years of operation, but they spend around R$5000 a month just on electricity.[11]

The assessment of the value of a rough emerald gem is one of the greatest barriers to increase the added-value of emeralds in the hands of small miners. Even for specialists, estimating the value of a gem is very difficult before it is cut for several reasons. Emerald gems always have impurities, which are difficult to assess fully beforehand. One apparently good gem could contain a lot of impurities or break up when one tries to cut it, making it worthless. This is why the large Brazilian jewelry companies (H. Stern, Amsterdam Sauer) mostly buy cut emeralds in order to avoid these risks. Small miners, who generally live next to the mines, have little knowledge and power in the market of rough emeralds, leading them to their getting low prices for their gems in most cases. The Brazilian Department of Mineral Production (DNPM) and the Brazilian Institute of Gems and Precious Metal (IBGM) have developed several methodologies and criteria for assessing emerald quality and price, but this is still out of the reach of many small miners.

Emerald production and local development: main problems

This section presents analysis of the main problems in the emerald mining area and considers ways by which local dynamics can be changed through better governance of the cluster, so emeralds can be a source of lasting development. As the mining activities are mostly carried out informally by small firms or individuals with little coordinated efforts, the local social and environmental conditions tend to be very low both at the mines and in the areas around it.

[10] Personal communication with the local branch of IBAMA, Brazilian Federal Environmental Agency, 2007.

[11] However, much of the earnings go unaccounted because the accounting does not include what they call 'good gems' ('pedra boa'). The owner confesses that he can get 1 kg of good stones when they find a vein sometimes. The market value can reach R$ 12,000 (US$6000) per gram depending on the quality.

Informal small scale mining is also associated with low educational levels, and low levels of investment and technological capacity. A lack of governance in the cluster impedes most collective solutions as well. However, a change in governance could improve collective efficiency and upgrade those conditions taking advantage of solutions which are difficult for miners or small firms to implement individually, but are viable collectively.

Mismatch between local demand and capacity to supply public services due to large informality

In general, the population growth that comes with the rush of miners to new mining areas is not generally matched by a proportional increase in municipal revenues, as gems do not generate much local tax revenue because of the large degree of informality. Thus, the mining towns have a mismatch between the growth in population and the local economy on one side, and a lack of resources to provide adequate public services and infrastructure to the increasing population on the other side.

As valuable gems are found, the local economy tends to grow, as flows of miners and fortune seekers come, even though the growth is in the informal economy. As the economy grows, social problems also tend to increase, such as a lack of adequate housing and public health, and increases in prostitution, drugs, alcoholism and crime. For example, in the municipality of Monte Santo, the first reaction of the mayor when emeralds were found in 1997 was to increase the number of policemen from two to twenty (Hollanda, 1997). As new veins are found, new flows of people come and go. As the mines become exhausted, part of the population tends to move to other mining regions, and the mining town becomes a "ghost" town. However, often many miners settle down locally working in mines or moving to other activities.

Very little tax is paid on gem production, as this activity takes place mostly informally, and the formal activity is low end (production of rough gems) and hence local public benefits are minimal.[12] For example, the emerald revenue from CFEM (financial contribution on mineral production), the main direct tax on mining, was only R$ 7461.26 (around US$4100) for the whole country in 2009 (DNPM, 2010). In the same year, the CFEM revenue Campos Verdes was R$365.85 (around US$ 200), and R$ 109 (around US$ 60) for the whole state of Bahia. Out of the little that is paid, just a part stays for local governments. Thus, there is no incentive for governments to control (formalize) or help emerald production, seeing as almost no revenue remains locally. Regarding private benefits, much of the added value from emeralds goes into the hands of companies and individuals from outside the region of production, especially at the end of the production chain (jewelry sellers and cutting of gems for high end markets).

The lack of organization of the cluster makes formalization and proper payment of taxes difficult. There is a kind of a cycle that keeps a large part of the small mining activities informal. Local governments have little interest in formalizing and educating miners and providing adequate services to mining regions because mining does not pay much tax. Moreover, enforcing tax rules would not bring many resources (as tax on emeralds is just 0.2%) and could be politically disastrous (Tendler, 2002). On the other hand, informal miners do not expect much from governments as they do not pay taxes and many are from outside the region (they do not expect to spend much time in the region). Therefore, they remain informal and have little access to formal finance markets and investment, which keeps the activity at a low level of technology and low level of productivity, as well as producing little tax.

Bad conditions for the workers due to labor informality and lack of proper technology

Low socio-economic conditions of the emerald miners

Even though stories of people getting rich finding emeralds overnight occur, these are exceptions. The economic and social conditions of a large number of emerald miners are precarious, as most of them work informally. Sometimes, they are organized in cooperatives, usually with the help of government agencies or unions. These cooperatives include independent garimpeiros, who work for themselves and can hire others to help them out. Others work for mine owners informally. Some of the mine owners have legal rights over mines and others have only informal rights. Finally, there are few formal medium and large companies like the Belmont in Itabira.

As most of the activities are informal, most miners work under informal contract arrangements, leaving them without any fringe benefits like social security or retirement plans. Health and life insurance is almost unheard of in small mines. Moreover, the low level technology used in informal mining is an impediment to increases in productivity and incomes, especially when the alluvial and shallow deposits are exhausted and deeper tunnels are needed to extract the emeralds. Moreover, informality limits the credit lines and benefits from governmental agencies. The lack of organization among miners and the rest of the production chain in the cluster hinder their capacity to overcome the obstacles to getting organized and formalizing their activities, which could increase their productivity through technological improvements.

There are no formal estimates of the number of small scale miners (garimpeiros) in Brazil, much less of emerald miners. Officials of the mining agency of Goias estimate that there are around 80,000 garimpeiros in the state (DNPM, 2005a, b). The number of people working in the rest of the production and distribution chain (stoning, sales, jewelry, services, etc.) is also unknown. Almost all people working in the mines are men. Typically, they are between 25 and 30 years of age, single, with a low level of education (many illiterate or with less than four years of schooling). Women work in services like cooking or laundry.

Another feature that makes difficult an estimate of the number of garimpeiros is that many of them work only part time in mining. Many are also small scale farmers or work in services or commerce in a nearby town. In their spare time, they go to "garimpo" in the field or buy some schist for washing in the hope that they will find emeralds in the waste rock. The population dynamics are also seasonal and changeable. In some places, people move out during the rainy seasons or when the mines have periods of low production.

In the small formal and informal companies, the range of salaries is low (US$ 100–200 per month), or sometimes workers have no fixed salary and just receive a commission on what they find. The rudimentary technology used by most of the informal and small mining keeps the incomes low, besides increasing the risk of accidents. Miners have little survey data to inform them of the best direction to build tunnels (miners follow their intuition) and the tools used make mining slow, time consuming and expensive.

Besides mining, other kinds of activities grow in the regions where emeralds are found, such as commerce, services and construction. These can offer miners job opportunities outside the informal mining

[12] When someone wants to explore for minerals, they should follow a process of legalization. Mining companies and miners should apply for registration for their fields (called 'lavra') from the DNPM. There are two alternative regimes to formalize emerald production (and gems in general). The first is the regime to authorize exploration and the concession to exploitation, in cases where the area has production potential. In general, medium and large companies apply under this regime as it requires a lot of investment in research and surveys. The second regime is the permission for "Lavra Garimpeira" ("garimpeiro plot"), which requires less investment and is used to formalize the areas with garimpeiros (individually or in cooperatives). However, enforcement is difficult because there are several informal sites and DNPM capacity is limited.

sector and increase their incomes. Also, there are some developments in the rest of the emerald production chain, such as commercialization of rough gems and jewelry production. In Carnaiba/Campo Formoso (BA), the local market for beryl is intense, and buyers come from everywhere including some foreigners from as far as India and China. In Campos Verdes (GO), there is an incipient cutting and jewelry industry, which adds value to some of the rough gems.

The mine owners claim that formalization is difficult because there is a high turnover of workers as mobility is high among garimpeiros. Many garimpeiros move to other regions when they hear that valuable minerals have been found there. Moreover, the bureaucracy involved in formalizing economic activities in Brazil is huge. However, even though small scale mining is still very little formalized and coordinated in Brazil, organizing miners in clusters of small mining firms or cooperatives could facilitate the process and give them the opportunity to formalize their activities and get access to formal lines of credit or governmental programs to help them to upgrade their technology,[13] and consequently their social and economic situation.

High safety and health risks of emerald mining

Working conditions in small-scale emerald mining operations are terrible in general. Many miners work under extreme risk with little protection and no health or life insurance. In Campos Verdes (GO) garimpeiros are hired to work in mines of up to 425 m in depth and with temperatures of 50 °C (122 F). They receive R$ 200 (~US$ 100) per month. Garimpeiros sometimes work with their feet in water and their clothes are always wet because of the high humidity and temperatures. The worst job is that of the 'quebradores' (rock pickers). They spend from 8 to 18 h inside the mines fracturing rocks in a suffocating climate with considerable air pollution. Sometimes they have no drinking water or food. Some mine owners try to rotate the workers inside the mines to avoid accidents.

The risk of accidents is also high. Water flows into the mines and has to be pumped out to avoid draining or the collapse of the mine. If a tunnel reaches an abandoned mine full of drained water, the water can drown the miners inside the tunnel (or even electrocute them).[14]

There is also the risk of the collapse of the mines because most of the mining structures are precarious. Some structures are made of wood and are not maintained regularly. Moreover, workers can fall when traveling up or down the mines.[15] Officials from the Ministry of Labor check the conditions and enforce labor laws once in a while. In Campos Verdes (GO), the regional office of the Ministry of Labor (Delegacia Regional do Trabalho) closed down the largest six mines because of a lack of safety for the workers in the early 2000s. The mine owners say that it is too expensive to abide by the law and that the risk of being caught is low; ''no one has ever died in my mines'', was the claim of a former Congress representative who owns mines.

The lack of organization of the miners in the cluster is the underlying cause of the health and safety problems. They have no strong labor union to fight for their rights and working conditions when they are employed. The mines are mostly informal and have little enforcement of labor laws. The informality is also an obstacle to new investments in technology, which could improve the health and safety conditions.

Improvements in mining methods have happened in some places, especially where there has been investment. In Socoto-Carnaiba/Campo Formoso (BA) mines are made with shafts of up to 120 m. In some garimpos, investors have come and injected capital and created partnerships for improving exploitation. In the 1990s, the manual lifts were substituted with electric lifts in many emerald mines. This has allowed garimpeiros to exploit deeper mines, and increase the production in some places, as well as improving safety and labor conditions. However, some problems continue, such as in safety in the galleries and improper working conditions.

Negative environmental impacts of emerald mining due to lack of environmental control and proper technology

There are a series of potential negative environmental impacts of emerald mining, such as soil erosion, deforestation, and soil and water pollution. Because emerald mining does not require any toxic materials or chemicals (like mercury in gold mining), the environmental impacts are relatively simple to control, but there is a need for effective coordination to scale up solutions and search for collective alternatives. However, the cluster synergy is still very incipient in leading to collective efficiency.

As miners are dispersed and tend to work informally, the state has little control over their activities, including the closure of the mines. Deforestation happens when mines are located in forested areas. Miners have to cut down or burn the forest to gain access to the gems. Erosion is the most common problem in emerald mining. Mining starts in open pit mines, which become huge holes overtime due to natural processes (rain). This can lead to uncontrolled erosion, as mines are abandoned. In Campos Verdes (GO), a hole of 50 m in diameter and 30 m in depth was left in the place where some of the first gems had been found. Abandoned mines also cause the risk of accidents, as people and animals can fall in some of the holes.

Soil and water pollution is the most noticeable and widespread environmental problem in emerald mining. Debris from the mines and waste from the washed schist ends up contaminating the soil and streams, which can kill the vegetation and wildlife. This problem was common in all three sites of this research (Goias, Minas Gerais and Bahia), especially because of schist washing. The sites for schist washing are located next to streams, where water is available. The waste water from the process runs back into the streams, contaminating the water.

Environmental and mining authorities are trying to control those problems in several formal ways, but with limited success. There is no national policy for environmental licensing of mining of gems, like emeralds. Each state in Brazil has its own legislation on environmental licensing of emerald mining.[16] DNPM officials argue that they have limited capacity to control and need support from the states, especially the environmental agencies.

There is also an apparent difference in environmental performance among the regions because of the kind of mine production and

[13] For example, SEBRAE (Center for Support of Small and Micro Firms, a quasi-public organization organized nationally) has a program to support clusters of mineral activities. This includes low interest loans or grants to upgrade their activities, as well as free advising, consulting and training.

[14] Just before one of the field visits to Campos Verdes, two miners were trapped inside a mine full of water that drained suddenly from another mine. Pumps from a third mine had to be used to pump out the water over the course of two days. Luckily, the two miners were rescued safely because they were kept alive in an air bubble at the end of a tunnel.

[15] One example is the Santa Terezinha mine in Campos Verdes (GO). It has 1.2 km of tunnels and only one entrance. Workers move up and down in precarious elevators called 'cages' (gaiolas). The tunnels are not straight, so the cages bang on the walls of the tunnels. Many mines have no routine for the regular changing of cables (cables are changed only when there are clear signs that they are worn out).

[16] DNPM tried to control the situation by, for example, stipulating a maximum depth of 50 m for the mines, but in Goias (Campos Verdes), there were mines of 300 m deep already, formed by tunnels of 100 m long with no control or geological studies. One of the restrictions established by the federal government is the number of holes opened. The idea is to avoid the excessive use of explosive and transform the mining places in huge craters as the case of the gold mining in the (in)famous Serra Pelada mines in Para state.

capacity of the state environmental agency. In Minas, because of the tradition of large mines for iron ore (such as operations from Vale), the state environmental agency has more experience in dealing with the mining sector. The enforcement capacity seems to be less in Goias and in Bahia, as those regions produce gems and gold only on a small scale.

Environmental agencies have tried to enforce environmental laws against miners. Agencies have certain enforcement capacity against larger mining companies, like Belmont in Itabira (MG), because such firms are few in number and have the technical capacity and resources to implement legal requirements. Environmental agencies find it more difficult to enforce the law against small scale mines. They are much more numerous, are more widespread and mobile, most of them are not informed about environmental procedures and law, are working informally and do not have the technical capacity or resources needed to comply with the law. However, environmental agencies have cracked down on mining regions regularly. In all three sites discussed in this research (Campos Verdes, Nova Era/Itabira and Socoto/Campo Formoso), miners reported the regular presence of officials from the environmental agency in the region. In Nova Era (MG), small mines were not operating during one of our field research visits (December, 2005) because the environmental agency required them to clean up the debris and solve the problem of pollution due to schist washing.

Compared to small scale miners, large emerald mining companies display different behavior regarding environmental management in several regards. First, large scale miners have a broader local impact as they use machines and the scale of production is larger (so they move more soil), but they also have greater technical and financial capacity to control those impacts. Belmont, for example, has an automatic system for sorting the gems, which results in a lesser need to wash the schist, as well as a system for waste water management. On the other hand, individually, small scale miners have a smaller local impact, but in general they are concentrated in large number in the same place, so the overall impact can be larger. The washing of the schist is also done to a large extent by third parties, out of the control of the miners. Second, even though enforcement of environmental regulations is weak in general (but growing stronger) in Brazil, the environmental agencies tend to focus their enforcement work on the large companies because this allows their work to have a larger and more visible impact.

Government agencies and NGOs have also implemented some initiatives to help mining regions to solve their environmental problems. In Campos Verdes, the municipality and state government created a series of common washing sites for schist buyers. Before, schist washing was done next to rivers and streams without any control. Now, there is a washing area with tanks that avoid run off of waste water and debris. In the same region, there is an environmental NGO that works on environmental education for small scale miners and others in the production chain.

Small scale informal mining lacks the proper technology to manage the environmental impacts of mining activities. Some technologies are simple and could be adopted on a large scale with little cost if miners worked together to develop the solutions. On the other hand, agencies in charge of environmental control focus most of their limited capacity on large scale mining companies. Informal mining is difficult to control as it is generally dispersed and miners do not have the means to comply with the technological, management and administrative requirements to operate formally. Dealing with the mining activities as a cluster could achieve the minimum scales to make the enforcement of environmental regulation more effective. At the same time, clustering would help the miners to minimally formalize their activities and get support to adopt technologies to comply with the environmental regulations.

Social upgrading of emerald clusters

Recent literature has developed some explanations of the ways that economic agents can socially upgrade: upgrading through markets, through ethical concerns and through regulation (Puppim de Oliveira, 2008). First, upgrading can be undertaken through markets, for example by linking with outside investors, distribution chains and markets, which generally are more demanding in terms of quality. This would provide motivation and technical and financial resources to lead firms to upgrade (Humphrey, 2003; Humphrey and Schimtz, 2002), including the upgrading of non-economic standards. The Kimberley process for "blood" diamonds is an example in the mining industry. Second, social upgrading can come with the adoption of voluntary ethical and social principles, what is called Corporate Social Responsibility (CSR) (Vives, 2006). Third is social upgrading through regulation. Many developing countries have strict social, labor, tax and environmental regulations, but they are not enforced.

Clusters of emerald related activities lead to a series of problems, but they have a large potential for local development if their governance is improved. The experiences in this study can shed light on under what conditions the production of emeralds could bring more social and economic benefits to local communities and miners, as well as having its negative social and environmental impacts controlled. The emerald clusters are still not living up to their full potential to provide for interaction among the different actors and economies of scale to upgrade their economic, social and environmental conditions, and bring all the benefits possible within a more organized agglomeration of economic agents or clusters. In the following parts, some recommendations are made to potentially improve governance and to help clusters of emerald production to have more positive impacts on local development.

Improve the conditions for partnership between small mines owners and investors

Low capital requirements and rudimentary techniques can be sufficient for emerald production when mines are shallow. However, as mines become deeper, working capital increases, as each meter of tunnel becomes more expensive to produce. Also, geological studies and more sophisticated techniques (both in equipment and organization) are necessary for safer and more cost-effective production. Therefore, capital and technical expertise are required for continuation of mining activity in the medium and long term. Many owners of small mines do not have the capital or expertise to upgrade production. Local and external investors can be an alternative to improve the production of mines, especially deeper mines. Some investors can bring both capital and expertise, or at least capital to get access to better techniques. Moreover, investors can invest in safer and better working conditions for miners, providing better equipment and formalizing work contracts, as they do not want to risk their investments on mines that can be closed down for breaking labor laws.

One of the problems in increasing the number of partnerships between investors and mine owners is the insecure environment for investments due to the informality of the mines and lack of knowledge of the mining potential. Many investors cannot stay in the mines throughout the period of production (they just come once in a while) or they do not fully understand the mining process. During the field visits, cases of successful partnerships, which led to improvements in production were observed, but there were also cases where investors were scammed by unscrupulous mine owners, and to a lesser extent mine owners that lost their mines to investors. There is a need to make easy arrangements for partnerships and get both mine owners and investors more informed about contracts of partnership, even given the limited educational level of many mine owners.

The organization of miners in cooperatives or any other associational organization can bring economies of scale to solve common problems and attract investment from the public sector. For example, the ornamental rock cluster in Santo Antonio da Padua was able to reduce water pollution significantly through a partnership between the miners and CETEM (The Center of Mineral Technology) using a simple technology with tanks for residue sedimentation (Langsch et al., 2009; Peiter et al., 2000).

Increase the public benefits (tax) for local governments in mining regions

After their establishment, mining regions experience a boom in population and demand for public services, but local governments are unable to increase service supply adequately because tax revenues do not increase proportionally to the demand. Even though economic activity increases, most of it is unaccountable because mining activities and commercialization are mostly informal. Moreover, governments are not very politically or administratively accountable to the miners because they do not pay taxes, even though direct taxes on emerald mining are relatively low,[17] as many of them plan to stay for a short period. Increasing taxes could make local governments more effective in providing public services, as well as making them more accountable to the local population.

The way to increase tax revenue is to formalize production and commercialization activities and increase the proportion of gem taxes going to local governments. Most local governments do not have the institutional capacity to crack down on informality (and many do not want to do that because it would be politically disastrous). State or federal government (DNPM) would have to be the main responsible parties in increasing formality. Finally, a larger part of the CFEM tax could be made available to municipal governments, seeing as they bear most of the negative impacts of emerald production.

Many regions that do not produce gems receive taxes because gems are commercialized there. A change in the tax law would also be desirable to be fair to local governments where mining takes place. Gems should be taxed were they are extracted, not where they are commercialized, or at least part of the taxes should stay where production takes place.

Formalize mining activities by strengthening education, labor unions and cooperatives

Many miners have terrible working conditions and none of the benefits of a formal work contract, such as social security, health and life insurance. Improving enforcement of labor laws in mining regions would certainly do some good, but would not solve the problem fully. Besides the bureaucracy and high costs of Brazilian labor laws, informality in mining happens because the profession of "garimpeiro" is not fully recognized by law. Also, as there is a high turnover of miners, mine owners do not want to formalize their working conditions.

Temporary contracts in mining could boost formalization of work contracts in emerald mining. As miners move to other regions, the contracts could be ceased and re-activated wherever they moved to. Moreover, labor unions could play an important role in the formalization of work, if they were better organized and strengthened in the mining regions. The labor unions in mining are generally controlled by large scale miners who employ miners informally themselves. A similar problem happens with the cooperatives. Many of them are led by mine owners or gem traders, who have little interest in the formalization of work. Strengthening labor unions and cooperatives by enforcing the laws on labor union organization and cooperatives or giving training or incentives for the proper organization of these institutions could boost the formalization of mining.

The low educational level of the miners hinders their ability to get through the bureaucracy and to get informed about their rights and benefits. Thus, general educational initiatives for adults could also lead to more formalization, as there is a strong link between formalization and education (Ferreira and de Barros, 2000), as a more educated labor force tends to be engaged in more formal work. Labor unions and cooperatives could be catalysts for educational activities, if they were strengthened.

Incentives for voluntary amelioration of production activities.

Incentives from governments and national and international organizations could help to control some of the environmental effects of emerald production. Many of the environmental impacts of gem production can be reduced through simple methods of environmental control, allied with a better enforcement of environmental law. The field research highlighted some cases where inexpensive projects led to improvements in environmental quality, such as the installation of common pools for the community to wash schist in Campos Verdes.

The rehabilitation of abandoned sites could be boosted. The environmental NGOs in Campos Verdes implemented a program of environmental education and reforestation with very few resources. Cooperatives, or labor or trade unions could also lead the projects in some of the producing regions, which do not have an organized civil society or NGOs.

Trade unions and the CETEM (The Center of Mineral Technology from the Ministry of Science and Technology—MCT) could play an important role in designing solutions to the environmental problems caused by emerald production. For example, CETEM has experience from helping the cluster for ornamental stone production in Santo Antonio da Padua to re-use the stone residue and reduce pollution, as well as from the establishment of the quarry school in another cluster of ornamental stones in Bahia. Those solutions could be adapted to the local conditions, such as by designing systems with low maintenance and operational costs and easy installation. CETEM has helped to design and promote solutions for mercury poisoning in gold mining, so it could also help in gem production.

Upgrade the production chain for emeralds within the mining regions

The regions that produce emeralds have few activities at the high end of the production chain, where most of the added value of emeralds is generated (jewelry production). Out of the three case studies, only Campos Verdes (GO) presented some intensity in activities related to emeralds besides mining, such as handicrafts, sculpture and jewelry production, but these were still insignificant relative to the quantity of emerald produced in the municipality. Most of the emerald gems leave their regions of production rough and unprocessed.

Local governments have not been very successful in trying to increase derivative activities from emerald mining. Even though the municipalities in the three regions mentioned their intention to increase added value, they could not do much due to a lack of political support, interest or technical capacity. Itabira had almost no post-mining activity locally, but had plans to create a school of gemology in a local technical school and university, but still needs funding. Local authorities were unsuccessfully trying to convince the Belmont company to bring some of its cutting activities, which are done in Sao Paulo, to the city. Campos Verdes had a program for

[17] CFEM (financial contribution on mineral production) is the main direct tax on mining activities. For emeralds it is just 0.2%. CFEM revenues are divided among the three levels of government. The municipality gets 65% of its value. It could be used to mitigate the impacts of mining, but in general its use is not targeted at mining. There are also several other taxes on mineral related activities and their production and distribution chain, such as sales taxes (ICMS, PIS and CONFINS) and tax on profits or incomes (IRPJ and CSLL). Moreover, there are taxes and other contributions related to labor (such as income tax).

upgrading the production chain for emeralds, and even won a prize, but the program seems to have been discontinued after a change in government. The present government had good intentions but little knowledge of how to implement the program.

There is a need for professional training in the cutting and even the evaluation of gems, as well as for capital for creating business. Much help could come from the state trade unions and SEBRAE (Center for Support of Small and Micro Firms, a quasi-public organization organized nationally). State and municipal governments could offer economic incentives and political support to bringing outside companies to mining regions and providing training, such as through the establishment of more training camps in sustainable mining, management, gemology, cutting, gem valuation, jewel production and commerce. Moreover, better education and cooperation among the different local government and non-governmental actors in the mineral sector could facilitate the creation of trust among them, efforts to formalize economic activities and develop collective initiatives. The development of a formal plan to carry out more coordinated action among different actors in the gem sector in certain areas could also improve the local benefits from mineral related activities and bring about public and private investment.

Concluding remarks

Emerald mining has harnessed only a small portion of the potential benefits this activity could bring in terms of local development. The full potential of the sector for improving local development could only be realized if mines followed tax, labor, health and safety and environmental legislation. However, there are a lot of obstacles to changing the current situation, especially because of the local political and economic dynamics. Policy makers and responsible firms could try to create initiatives to increase formalization in the sector in order to keep a larger part of the benefits of the gem production chain locally, and reduce its negative local environmental and social impacts. Focusing on an effective implementation strategy using the cluster concept and its many manifestations in other business settings could pave the way for making emeralds a catalyst for development in Brazil and elsewhere.

There are several hindrances to gemstone mining becoming a more powerful tool in local development. Firstly, most of the activity is informal, so governments collect minimal tax revenues. Secondly, most of the taxes on formal activity are paid where the gems are commercialized, not in the regions of production. Thirdly, local governments get very little from the tax collected, as much of the revenue stream remains with higher levels of governments (state and federal). Finally, many of the activities with high added-value, like cutting and jewelry making are done outside the regions of production.

Thus, most of the benefits of emerald production stay at the top of the production chain, generally outside the mining region, and the social and environmental costs stay at the local level, where they are extracted. When emeralds are found somewhere, there is a huge increase in the demand for public services as miners and mining companies rush to the region, but local governments have little capacity to respond to those demands because there is not a proportional increase in revenues and institutional capacity. Also, since much of the activity is informal, miners have distressing working conditions, such as high temperature and humidity, long working hours, lack of safety and informal contracts.

Better cluster governance could harness the benefits of scale and collective efficiency to overcome the main obstacles to social upgrading by using the three frameworks mentioned in Section 5: upgrading through markets, through ethical concerns and through regulation (Puppim de Oliveira, 2008). There is a large room for locally driven solutions that could drive changes. If miners and their supporting organizations were more organized, they could more easily get access to formalized working conditions, credit, new markets and technical support, as well as adopt collective solutions to follow the law. There are a series of policies and measures that could improve catalyze those local initiatives governance, such as allocation of more mining revenues to local miners and governments in the regions of production (so locals would have a larger stake in the activity and be more responsible for their success or failure), strengthening of the cooperatives and labor unions and promotion of the development of activities throughout the production chain in the mining region.

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