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The Global Production Network for iron ore: materiality, corporate strategies, and social contestation in Brazil

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ABSTRACT

The purpose of this article is to make explicit the iterative relationship between economic and social agents in the Global Production Network (GPN) for iron ore. Focusing on the Brazilian node of this GPN, it argues that the structure of economic actors and their corporate strategies influence the organization of social actors, whose contestation practices impact the modes of action of economic actors. This iterative model of economic and social agency is reliant upon the integration of the GPN approach to ecological economics and political ecology to explain both the material dimension and ecological distributional conflicts associated with economic activities. Once the conceptual nexus of these domains is established, the Brazilian node of the GPN for iron ore is described and the materiality of this network related to the appropriation of value through commodification of natural goods and dispossession of common goods. Furthermore, the paper identifies how this process drives the reactions of different social actors that emulate practices and strategies of economic actors in developing contesting practices, which can be relevant for conditioning corporate behavior.

1. Introduction

The aim of this paper is to integrate key approaches associated with the Global Production Network (GPN), ecological economics, and political ecology. Many researchers borrow theoretical and methodological ideas from these fields in an attempt to understand transnational production systems and the environmental disputes associated with them. It is argued that the structure of economic actors and their corporate strategies influence the organization of social actors, whose contestation practices impact the former's modes of action. The article is based on an appraisal of the iron ore industry.

The current study is based on a literature review and participant observation. It follows Denzin (1989), who defines participant observation as a research strategy that combines document examination, interviews, and direct observation, as well as Flick (2009), who argues that it allows researchers to observe their surroundings from the actors' points of view. For the case reported here, one of the authors has attended meetings and debates on the Brazilian Network for Environmental Justice since 2006, witnessing, inter alia, the evolution and eventual establishment of the Coalition on Mining and Steelmaking Working Group. Additionally, in 2010, this author attended the first workshops organized by the International Network of People Affected by Vale. Both authors have also followed the activities of the National Committee for the Defense of Territories against Mining, have taken part in policy debates, and carried out workshops for the Committee's members.

This paper comprises two main sections in addition to the introduction and final remarks. Following the introduction, the first substantive section examines the main theoretical and methodological approaches mentioned above. The GPN is considered a fruitful model for exploring and analyzing the relationships between globalization, production systems and economic development. In turn, it is assumed that ecological economics and political ecology bring to light the material dimension of economic relations, integrating their natural and social components in order to demonstrate the centrality of natural resources in shaping limits and possibilities for the economic 'success' of diverse actors. The second section is divided into two parts. The first focuses on economic actors in the GPN for iron ore and highlights the Brazilian node of the network. The second stresses the importance of social actors in shaping the GPN. It is also argued that the contestable character of private conversion of common goods makes economic actors the targets for strategies of social contestation. Such

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strategies are understood as modes of economically relevant agency, and influence the conditions for the exercise of corporate power.

The final section of the paper discusses the main results of the research. Most notably, it describes the pivotal role of controlling and replacing mineral reserves as a component of competition strategies in the market. It also addresses the importance of transportation systems in achieving corporate power in the network, as well as the mimetic capacity of contestation actors. Finally, it evaluates this approach in relation to other possible strategies for analyzing similar data.

2. Global Production Networks (GPNs) and the extractive industries

This section of the paper describes the two main conceptual aspects of the article. First, it presents a brief description of the GPN concept and its main analytical categories. It then introduces ideas from political ecology and ecological economics. Putting these aspects together is considered necessary for better understanding social contestation against extractive industries, as much of the emerging socio-environmental conflicts are not related to value capture, but to the use of common goods, a notion that is not fully debated within the GPN literature.

2.1. GPNs and economically-relevant action

Henderson et al. (2002) proposed the GPN approach as a theoretical and methodological framework for globally organized economic activities. New transnational production systems represent sets of economic activities that are functionally integrated and territorially dispersed (Coe et al., 2008), and they constitute the most representative example of increasing global interconnection (Dicken, 2011). Despite the availability of other theoretical models (e.g., the Value Chain, Global Commodity Chain, and Global Value Chain), this independent conceptualization has helped researchers map and track the growing complexity of the processes of extraction, production, distribution, consumption, and disposal of goods and services. The concept of "network" calls into question the linearity and unidirectionality of the "chain" approaches, which suggest rigid, inter-firm structures. In addition, the use of the term "production" instead of "commodity" is a reference to the social processes (especially labor) inherent to the variety of goods and services created and traded in such systems. Finally, the qualifier "global" rejects implicit state-centric concepts in favor of territorial processes through interwoven analytical scales (Santos, 2010). In this sense, a GPN is defined as 'the nexus of interconnected functions and operations through which goods and services are produced, distributed and consumed' (Henderson et al., 2002).

The firm in a GPN remains central in the model, expanding its scope of agency in its search for specific economic purposes (Weber, 1978). These include cost reduction, sales revenue, and market share to maximize short-run profits. Advocates of the GPN view design and control as exclusive properties of the economic actor. These two aspects constitute the primary means through which firms transform common goods into value.

Along with power and embeddedness, value is a key conceptual category in the GPN perspective. According to Marx's (2004) Theory of Value, labor is the connecting of the energo-physical conversion and incorporation processes that yield a good. The realization of the good, however, is nonetheless contingent upon complementary circulation activities. In short, the commodity – understood as the synthesis of extraction, transformation, and distribution processes – remains bound to a 'sole source of value' (Böhm et al., 2012) without being confined to it. Accordingly, processes related to incorporating 'technologies of branding, advertising, and marketing that build consumer sentiments' (Weller, 2008) align with the activities performed by extraction and logistics systems. This, in turn, strengthens the link between consumption and appreciation. Given this, an understanding of a GPN's inherent materiality can be advanced by discussing the dimensions of (a) value appropriation through processes of accumulation by dispossession[1] (Harvey, 2003); and (b) value enhancement by material and energy incorporation from large-scale logistics systems.

The introduction of power (both collective and institutional) exercised by different social actors further illustrates the decentralization of agency in the GPN framework. Henderson et al. (2002) extend the power exercise to non-governmental organizations, trade unions, governments, business associations and international agencies. Nonetheless, it is argued this analytical perspective should be fully implemented with the aim of developing a multicentric approach. In this sense, economic actors serve as a pathway to the GPN analytical unit (i.e., the "network"), setting structures and processes around which a myriad of embedded actors orbit. Therefore, in order to advance the proposed approach, it is necessary to recognize the importance of social agency in conditioning economic activity. Thus far, social agency has been largely ignored in the literature on transnational production systems (refer to Wilson, 2013; for example.).

The GPN framework also highlights the capacities of actors in their development of different forms of association, which both influence and are influenced by social relations (Santos, 2011). In addition, it is critical to consider both social (Hess, 2004a) and territorial (Henderson et al., 2002) embeddedness. Thus, in shaping economic activities, the sociocultural history and institutional structures surrounding the economic actor can influence behaviors within the actor's home or host countries (Hess, 2004a).

The analytical use of the GPN approach in this regard addresses the problem of economically-relevant agency (Weber, 2011). It also allows researchers to understand the formation and operation of GPNs as complex and all-encompassing phenomena that have multiple sources of autonomous and influential agency.

2.2. The materiality of extractive industries

This section addresses an issue that has gone understudied in research related to transnational production systems. Past work on GPNs has focused most primarily on industry and the consumer goods sector (Coe and Hess, 2013), while overlooking the extraction and primary processing of raw materials (Bridge, 2008; Wilson, 2013). As part of broader 'dispersed functional networks', natural goods and raw materials are intrinsic to all production processes (Ciccantell and Smith, 2009). More importantly, according to Dicken (2011, '"the race for resources" has been a central component of the development of a global economy for centuries.' Therefore, comprehensive strategies for ensuring consistent, safe, and growing access to minerals (Bunker and Ciccantell, 2005) have become increasingly important. This is particularly true with respect to corporate tactics related to the creation and control of transnational production systems and opportunities for national economic development (Wilson, 2013).

In turn, transnational primary economic activities give rise to globally-integrated, locally-disarticulated economic structures (Ciccantell and Smith, 2009). Therefore, the integration between the primary goods sector and the consumer goods sector becomes

[1] Harvey (2003, p. 145) defines 'accumulation by dispossession' as the 'continuation and proliferation' of the primitive accumulation by various processes, including the commodification of land, the conversion of various forms of collective property and the suppression of alternative forms of production.

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a key element in shaping both these systems and the territories in which they are embedded. Thus, the centrality of natural resources in the process of capital accumulation establishes territory as a formative and influential material dimension of GPNs (Bridge, 2008; Ciccantell and Smith, 2009; Wilson, 2013).

Networks centered on natural resources are especially dependent on territory-specific processes, and are influenced by 'geology, topography, hydrology, indigenous populations, conflicts over resource access, (and) efforts to capture the benefits of extraction for local populations' (Ciccantell and Smith, 2009). They also represent relevant examples to the understanding of social agency at the local level. In this sense, natural resource-centered GPNs or global extraction networks connect patterns of temporality (not renewability), spatiality (immobility) and sociability (embeddedness) (Dicken, 2011) among territories as well as different degrees of social contestation (Hommel and Godard, 2005).

Accordingly, shifting the focus to extractive sectors brings new challenges and perspectives to debates over GPNs. On the one hand, it requires a deeper analysis of logistics services, particularly in relation to bulk products and their role in enhancing or capturing value. However, it defies the notion of value that is traditionally referenced within the GPN literature once natural resources are considered common goods. When this occurs, natural resources should not be valued monetarily.

With regard to logistics, when extractive GPNs are evaluated, processes related to value enhancement have become increasingly dependent on the 'key role of transportation systems that move these often heavy, bulky materials from remote agricultural and mining locales to urban and metropolitan places where manufacturing and consumption take place' (Ciccantell and Smith, 2009). Transnational transportation systems have expanded dramatically, and this expansion has created mobile (e.g., oil tankers and ore carriers) and fixed infrastructure (e.g., pipelines, railways, and ports). Most importantly, though, this large-scale infrastructure is 'extremely vulnerable to disruption' (Ciccantell and Smith, 2009). The relative immobility of transportation systems inherent to GPNs allows for the identification of social agency modes capable of changing prevailing knowledge regarding the relations between corporate, institutional, and collective power (Henderson et al., 2002) built around economic activities.

In addition, extractive industries have become more intensive in their use of energy, water and matter, and have engaged in processes that contribute to environmental degradation. These outcomes are occurring in more remote areas to an increasing degree. In these areas, natural resources are not necessarily valued and traded monetarily. Given this, perspectives underpinning disciplines such as political ecology and ecological economics may be useful.

As a conceptual framework, political ecology is useful for comprehending the thermodynamics principle at the institutional and social levels (M'Gonigle, 1999). It addresses conflicts involving environmental resources and services (Martinez-Alier, 2002), as well as the problems that arise because of inequalities in power, property and income (Gerber et al., 2009; Kallis et al., 2013).

Ecological economics offers a strategy for providing a systemic view of environment and economy; it defines the economy as a subsystem of a finite physical ecosystem. In this way, ecological economists criticize initiatives that value environmental services and losses. In the same vein, one of its main concerns is the development of new indicators and metrics for measuring (un) sustainability (Martinez-Alier, 2002). In other words, ecological economics seeks to ground economic thinking in biophysical and moral constraints (Daly and Farley, 2004).

Based on these theoretical traditions, it could be argued that the use of monetary value in the evaluation of extractive GPNs is restrictive. When debating the limitations of monetary valuation of natural resources, Kallis et al. (2013) argue that (1) value cannot compress all the complexity of ecosystems into a single metric; (2) there are methods of valuation other than monetary; (3) the respective values of environmental goods depend on the distributional context; and (4) people's preferences differ as a function of their institutional environments. It follows that systems based on monetary value or price are likely to externalize the associated environmental and social costs (Roberts and Parks, 2009).

Thus, the analysis of material flow may offer more appropriate methods for registering withdrawals of natural resources (Rice, 2009). Moreover, developing metrics other than monetary

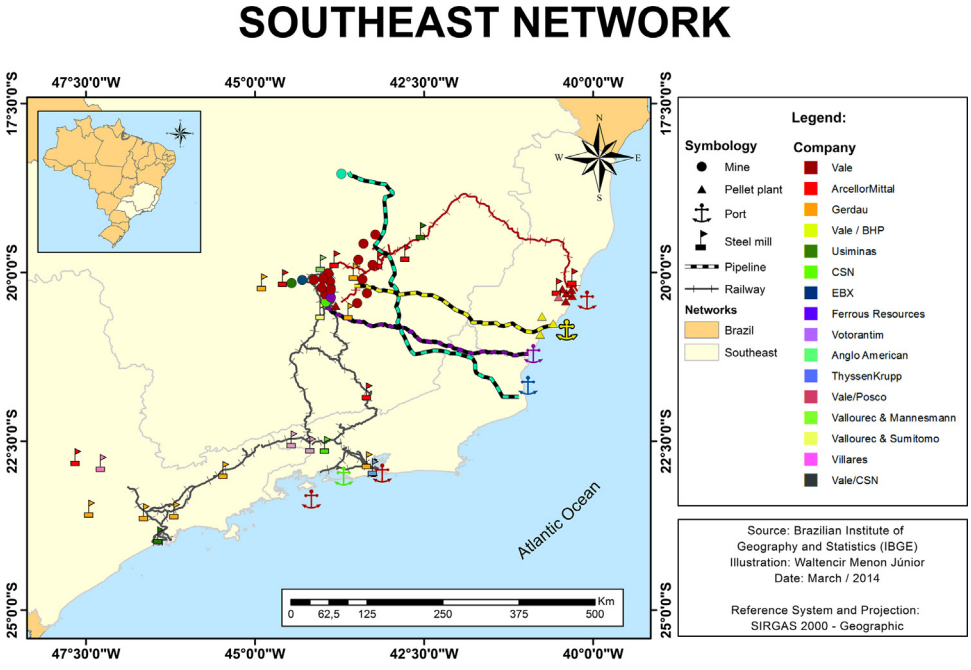

Fig. 1. GPN for iron ore—the southeast network.

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valuation is important when debating social contestation to extractive GPNs. Consider that when traditional communities oppose particular projects they often do not disagree with the value of the resources, but with the commoditization of natural goods. The evaluation of these conflicts brings to light new perspectives that may be usefully incorporated into the GPN paradigm.

Given the above, strategies for accessing stocks of natural goods from different territories become crucial. The implementation of these strategies place contemporary processes of accumulation by dispossession at the center of the expanded reproduction of capital (Altvater, 2010; Harvey, 2003). In some cases, these strategies are framed and implemented in ways that are widely supported by diverse economic, political, and social actors. These strategies can be described as "consensual." A typical case of this trend addresses the formation and evolution of the resource network for steel in the Asia Pacific. This case was particularly geared towards describing the resource network in relation to economic-political coalitions in Japan (1950s) and China (2000s). Both countries developed strategies to access and control sources of coal and iron ore in Australia, Brazil and Canada, as a condition to create and nourish their respective steel industries and industrialization processes (Wilson, 2013).

3. The Production Network for iron ore in Brazil

This section presents two different dimensions of the GPN for iron ore in Brazil. The first part describes the economic aspects of the GPN, focusing on the network structure and its organization. The second part looks at the contestation networks and evaluates to what extent they influence and are influenced by the strategies of economic actors.

3.1. The economic dimension

3.1.1. General aspects

As discussed in the previous section, mining is a good proxy for an integrated approach of the network setting and the materiality of economic activities. On the one hand, it is the base of most industrial sectors, from automobile to information technology; on the other hand, it is explicitly intense in the consumption of natural resources and environmental impacts.

Moreover, discussions related to the Brazilian node of the GPN for iron ore have substantial empirical relevance, both in terms of the Brazilian economy and the GPN in which it operates. In 2011, Brazil had the second-largest estimated reserves of iron ore in the world, allowing it to produce the third-most amount of iron. This, in turn, helped Brazil to become the world's second-largest exporter of iron (DNPM, 2012; International Trade Center, 2015). Within Brazil, the exploitation of iron ore is geographically concentrated in the states of Minas Gerais and Pará; this influences the spatial distribution of iron production and logistics infrastructure (see Figs. 1 and 2).

According to Brazil's Constitution, mineral deposits belong to the Union (Brasil, 1988). All of its mining activity is regulated by two main governmental sectors: the Ministry of the Environment – in association with federal and state environmental agencies – and the Ministry of Energy and Mining (MME).

Holders of mining leases are expected to obtain an environmental permit prior to exploitation and, depending on the circumstances, exploration. Environmental permits usually are issued by state environmental agencies; nevertheless, in specific situations, such as when environmental impacts affect more than one state, the federal environmental agency may be responsible for assessing the environmental impacts (Brasil, 2011).

The Mining Code (Decree-law no. 227 of February 28, 1967) is the cornerstone of Brazil's mining legislation. It is enforced by the National Department of Mineral Production (DNPM), the agency responsible for granting exploration licenses and supervising the mining production. DNPM operates under MME, which issues development concessions (Brasil, 1967).

The mining legislation and, even the federal constitution, have undergone amendments in recent years. Among these, in 1996, changes allowed foreign investment in the sector (Chaparro, 2002; KPMG, 2012). In 2009, the federal government proposed reviewing the Mining Code, in an attempt to stimulate activity in Brazil and, particularly, enhance the participation of the state in the mining rent. The Bill underwent important changes in the House of

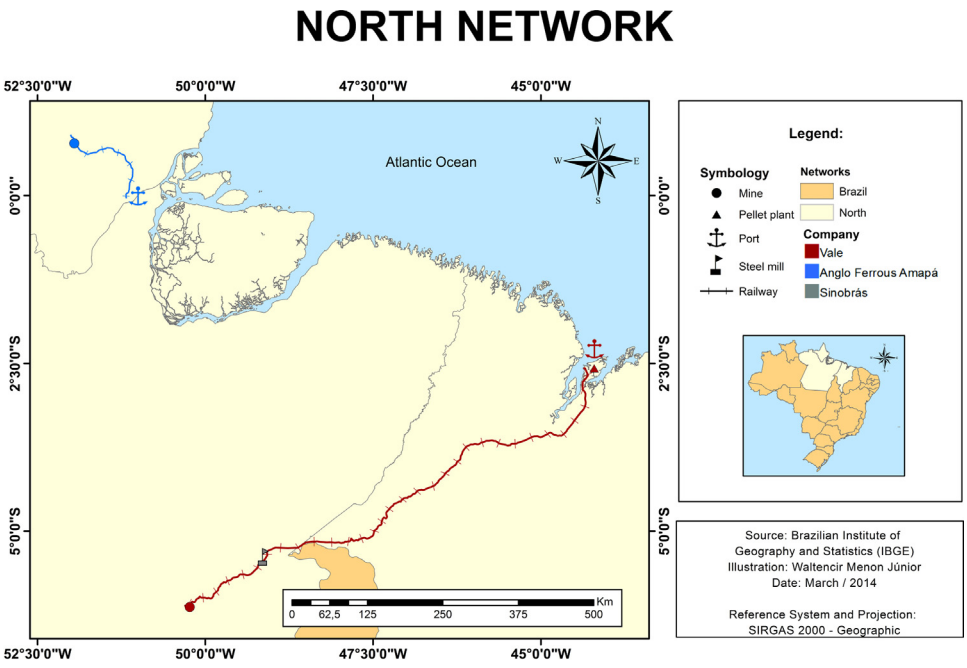

Fig. 2. GPN for iron ore—the north network.

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Deputies, especially because of deputies' refusal to accept government initiative to substitute the priority right system for a concession system (Gurmendi, 2014; Milanez and Santos, 2013). The priority right system is associated with companies' interests. The House of Deputies' decision has been explained as a consequence of the fact that various deputies that took part in the special committee had their electoral campaigns funded by mining companies (Oliveira, 2013). Financing electoral campaigns is a common strategy in Brazil to increase corporate power over institutional actors.

There are other forms of exerting corporate power as described below. The remainder of the section focuses on the structure of economic agents and is based on the work of Singh and Hoyt (2007).

3.1.2. Exploration

The exploration process involves varying degrees of uncertainty. Geology companies are responsible for geological mapping, prospecting campaigns, surveys, and computer modeling as a means to identify, measure, and characterize mineral deposits. Exploration involves high sunk costs as a result of its inherent nature, and the productive and logistics infrastructure associated with it.

The Geological Survey of Brazil (CPRM, Serviço Geológico do Brasil) is the primary public actor responsible for performing research and mineral exploration. However, the CPRM has historically experienced periods of low funding and understaffing (MME, 2011). To overcome these problems, small firms have engaged in consulting activities with larger mining companies, and the latter have developed their own exploration capacities.

3.1.3. Extraction

Extraction is typically carried out in open pit mines and comprises drilling, blasting, loading, and transportation. Table 1 lists and summarizes the major companies that engage in iron ore extraction in Brazil. These data indicate that Vale S.A. (Vale) has significant corporate power within the Brazilian market, accounting for more than 80% of iron ore production in 2012. The importance of Vale is a consequence of its embeddedness and origin as a state-owned company. Its two main iron ore reserves, Itabira (Minas Gerais state) and Carajás (Pará state), were expropriated, respectively, in 1942 and 1969, and transferred to the company by the federal government (Silva, 2004).

In addition to market concentration, data also illustrate the significant increase in industry production expectations. In total, firms predicted growth of over 70% between 2012 and 2016. As a necessity to reduce fixed costs, and increase value capture, iron ore mining has relied mainly in mega mines. As a result, mining companies are usually the main employers in mining towns, particularly in rural areas in the Amazon region. This condition is a key element to understanding the high level of corporate power of mining companies at the local level.

3.1.4. Processing

Processing iron ore involves crushing, screening, concentration and in some cases, pelletizing. Except for the latter, all activities typically occur near the mines to avoid waste transportation and thereby reduce operating costs. Screening activities involve sorting the ore particles according to their dimensions. This results in multiple categories of ore, including pellet-feed (<0.15 mm), sinter feed (0.15–6.00 mm) and lump ore (6.00–31.00 mm). Usually, steel mills transform sinter-feed into sinter.

Pellet-feed is similarly used in the production of pellets (8.00–18.00 mm), which are more suitable for oversea transportation. Pellet plants are typically located away from extractive sites and receive pellet-feed from different mines (Mourão, 2008). Pelleting is not common in Brazil; only about 17% of the ore that is extracted is pelleted (DNPM, 2010). The process is mostly implemented by Vale in partnerships with international steel mills from Australia, Italy, Japan, South Korea, and Spain in a process of network embeddedness (cf. Hess, 2004b). In 2009, the output capacity of pellets in Brazil was 56 Mt, 79% of which was produced in Espírito Santo state, 12% in Maranhão state and 9% in Minas Gerais state (Quaresma, 2009).

3.1.5. Logistics

The chief purpose of transportation infrastructure in the iron ore industry is to connect the mine to consumers or pellet plants, and from these to consumers. Coupled with its high density, the large volume of iron ore traded makes it imperative to increase economies of scale and reduce fixed costs. Thus, domestic consumers are usually supplied by railways or pipelines, and international consumers are supplied by ore carriers. In 2012, iron ore and coal accounted for 76% of total cargo carried by train in Brazil (Vilaça, 2013). According to ANTT (2012), large portions of Brazilian railroads have been conceded to companies in the mining sector, including Estrada de Ferro Carajás (892 km; Vale S.A.),

Table 1
Major iron ore mining companies in Brazil.

Company	Main shareholders (common shares)	Market share[a]	Iron ore production (thousand metric tons)[a]		Change
		2012	2012	2016	2012–2016
Vale	Previ (20%), BNDESPar (13%), Bradespar (11%), Mitsui (10 %), FUNCEF (3%), Petros (2%)	76%	360,000	425,000	18%
CSN/Namisa	Dorothéa Steinbruch (33%), Clarice Steinbruch (6%), Leo Steinbruch (6%), Estate of Fabio Steinbruch (6%), BNDESPar (2%)	8%	38,000	89,000	134%
MMX	Eike Batista (42%), Wisco (10%), SK Networks (9%)	3%	13,000	42,500	227%
Ferrous Resources do Brasil	Not available	1%	3,000	40,000	1.233%
Anglo American	Anglo American Plc.	1%	5,500	35,000	536%
Samarco	Vale (50%), BHP Billiton (50%)	5%	24,000	30,500	27%
Mineração Usiminas	Sumitomo Corporation (30%), Nippon Steel Corporation (14%), Ternium Investments S.àr.l (11%), CSN (8%), Previ (7%)	3%	12,000	29,000	142%
Others	–	3%	15,300	118,000	671%
Total			470,800	809,000	72%

[a] According to IBRAM estimates.
Sources: Econoinfo (2015), IBRAM (2012), Brasil Mineral (2012).

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Estrada de Ferro Vitória-Minas (905 km; Vale S.A.) and MRS Logística (1674 km; CSN, Vale S.A and Usiminas). In both Carajás and Vitória-Minas the mining companies are also responsible for passenger transportation, a special source of corporate power, particularly in distant rural areas in Pará and Maranhão states.

Pipelines serve as a secondary means of iron ore transportation, though few companies utilize them. The primary pipeline system in Brazil is owned by Samarco and crosses almost 400 km and 25 municipalities. In 2014, Anglo American finished a 525 km pipeline (AGB, 2011). At the same time, Ferrous Resources was building a 480 km pipeline (AGB, 2012), Manabi had a 511 km project (Gontijo, 2014) and Sul Americana de Metais was developing a 482 km duct (Notícias de Mineração Brasil, 2014). The increasing use of pipelines has resulted in various conflicts concerning water use between local communities and mining companies, particularly in the Minas Gerais state (Pasini et al., 2013).

Global trade is conducted exclusively by sea, making access to ports greatly important. Seaborne transportation represents the major cost item in the formation of iron ore prices. This reiterates the significance of economies of scale. Accordingly, ore terminals are cargo-specific and many of the ports that export iron ore are privately-owned or operated by mining companies. A list of the main ports is presented in Table 2.

3.1.6. Consumption

The steel industry is the primary consumer of iron ore. In 2011, of the 398 Mt of iron ore that were traded, only 30% was consumed by the domestic market; the rest was exported. In that same year, of 62 Mt of pellets sold, only 10% were used domestically (DNPM, 2012). Within the Brazilian domestic market, steel production is rather concentrated. The five major groups (ArcelorMittal, Gerdau, Usiminas/Nippon Steel Corporation, Companhia Siderúrgica Nacional, ThyssenKrupp Steel/Vale) are responsible for 94% of the crude steel produced in Brazil. Four of these conglomerates are highly internationalized, and only CSN has its activities centered in Brazil (Econoinfo, 2015). As shown in Table 1, Usiminas and CSN have their own iron ore reserves as a strategy to reduce dependence on mining companies; similarly, ThyssenKrupp Steel created a joint-venture with Vale in an attempt to improve conditions and access to high-quality ore. The iron ore can also be purchased by merchant pig iron producers, which sell it to mini-mills. The pig iron market is more fragmented, consisting of 85 companies and 154 blast furnaces (SINDIFER, 2007). Nonetheless, international consumers are critical in the GPN for iron ore. In 2012, China consumed 52% of the iron ore and pellets that Brazil exported, followed by Japan, 10%; South Korea, 5%; and the Netherlands, 4% (MDIC, 2013).

3.2. The contestation dimension

This section describes and analyzes the role of social actors and some of their strategies. It also addresses issues that are seldom empirically debated in the GPN approach, though are often described in their theoretical and methodological formulations.

The national node of the GPN for iron ore highlights direct and indirect conflicts around both natural (e.g., air, water, and land) and common (e.g., historical and cultural heritage) goods. Accordingly, a pattern of conflicting social relations (Ramalho et al., 2013) established in the GPN for iron ore illustrates the extent to which social actors are relevant in forging territory as a space for power relations (De Sardan, 2005).

Specifically, material and symbolic interests shape strategies and tactics that should be understood as modes of economically-relevant action (Weber, 2011). These interests influence economic activities and (in some cases) actions taken by economic actors. For example, opposition groups in São Luís (Maranhão state) prevented the building of a steel mill there by ThyssenKrup/Vale, thereby leading to its relocation to Rio de Janeiro state (Porto et al., 2011).

Given the agency of these actors, preliminary thoughts on the role of economically-relevant action based on three cases of anti-mining contestation networks are presented. The discussion illustrates this type of action based on the concept of social contestation. Hommel and Godard (2005) present a firm-focused evolutionary concept that links alerts and assumptions of risk to explanatory discourses and mechanisms of corporate accountability. Further, they describe how iterative patterns of action and reaction establish and influence conflicting arenas.

However, for social actors, embracing the evolutionary dimension of social contestation implies a recognition of the potential for contentious politics (Tarrow, 2011). Therefore, it is argued that contentious actions, routines and performances reveal the collection and mobilization of strategic and tactical resources by social actors (Tilly and Tarrow, 2007).

There are multiple types of social actors involved in the GPN for iron ore, including labor unions, neighborhood organizations, and ethnic groups. This section, however, focuses on the networks composed by these actors. By adopting the GPN framework, the section not only evaluates the economic actors, but also indicates how the actions of different groups of actors influence each other. In this sense, it is assumed that the structure of economic actors influences the organization of social actors, whose contestation strategies, in turn, affect economic actors' decision-making. Given that the establishment of contestation networks is a response to production networks, the networks themselves represent the units of analysis for the study.

There is a number of extant studies on networks of social movements that oppose the negative effects of mining industries (Horowitz, 2011; Kraemer et al., 2013; Owen and Kemp, 2014). Although many of these studies have linked corporate behavior with environmental and social conflicts (McDonell, 2015), they rarely focus on the reciprocal nature of these influences. In this way, with a few exceptions (Bebbington, 2009), they have failed to effectively theorize about the interdependence of production and

Table 2
Major iron ore ports and terminals in Brazil.

Port/terminal	Owner/operator	Region	2012		2013		2014	
			Amount (Mt)	(%)	Amount (Mt)	(%)	Amount (Mt)	(%)
Ponta da Madeira	Vale	Northeast	104	31	106	32	111	32
Tubarão	Vale	Southeast	103	31	102	31	101	29
Itaguaí	Vale, CSN	Southeast	49	15	51	15	57	16
Guaíba Island	Vale	Southeast	40	12	40	12	41	12
Ubu	Samarco	Southeast	23	7	22	7	26	8
Others	Usiminas, Anglo American, Zanin Amapá	–	13	4	9	3	10	3
Total	–	–	332	100	330	100	346	100

Notes: Figures for Itaguaí include Itaguaí Terminal (Vale) and Dry Bulk Terminal (CSN).
Mt—million metric tons.
Source: ANTAQ (2015).

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contestation networks. This section redresses this oversight by adopting an integrated approach to discuss the activities that influence the decisions and actions of mining companies.

Since the mid-2000s, contestation movements against mining companies have grown in size and popularity within Brazil. At that time, many new projects were proposed and developed, stimulating an increase in mining and metallurgy activities. In response to this increase, organizations in different territories began to resist the proposed projects.

In 2007, the Brazilian Network for Environmental Justice (Rede Brasileira de Justiça Ambiental (RBJA)) proposed a nationwide network encompassing these resistance movements, the Coalition on Mining and Steelmaking Working Group (Grupo de Trabalho Articulação Mineração-Siderurgia (GTAMS)). This Working Group encompassed movements from 10 different states and sought to address disputes related to the implementation or expansion of mining and steelmaking projects. In addition, GTAMS sought to promote the political empowerment of social movements involved in such conflicts (GTAMS, 2008).

Another important network was the International Network of People Affected by Vale (Articulação Internacional dos Atingidos pela Vale (AIAV)). Established on the basis of a strong intersection with GTAMS, this network is simultaneously narrower and wider. On the one hand, it has a more restricted scope, since it concerns the effects of a single company. On the other hand, its geographical reach comprises social movements in different countries, including Argentina, Canada, Chile, Indonesia, New Caledonia, Mozambique and Peru (AIAV, 2010).

A third network is the National Committee for the Defense of Territories against Mining (Comitê Nacional em Defesa dos Territórios frente à Mineração (CNDTM)). It was established in 2013, in response to the proposal for a new mining bill. Although CNDTM was founded to focus on legal issues, it involved many actors, including traditional peoples and non-governmental organizations. In total, the CNDTM encompassed nearly 50 organizations and social movements (CNDTM, 2013b).

The establishment of contestation networks aims at facing the decentralized transactions of large corporations, which operate in different territories simultaneously. These construction plans are based on the search for greater flexibility in terms of information exchange, the political empowerment of local organizations, and the sharing of contestation strategies (AIAV, 2010; GTAMS, 2008). These strategies can be classified according to their direct and indirect effects, as described below.

One of the more traditional direct strategies is the disruption of operating activities. In the case of the GPN for iron ore, some contestation networks perceive firms' logistics systems as their most vulnerable node (Ciccantell and Smith, 2009), making the interruption of these systems a common tactic. In the case of the Carajás Railroad (Estrada de Ferro Carajás (EFC)), railroad blockages by communities are not unusual as a means to force Vale to either engage in negotiation or respect previous agreements. For example, in 2012, the EFC works were shut down by residents of nearby communities to call public attention to the fact that the company had not fulfilled the conditions stated in the agreement related to the environmental licensing of its expansion (Santini and Glass, 2012).

In response to these disruption strategies, some firms develop counter-strategies to block resistance initiatives. For example, in response to the closing of the EFC, Vale has obtained a judicial prohibitory injunction against AIAV members. By making use of a legal device that allows for the prosecution of individuals if they take part in demonstrations near the EFC, the company has anticipated and constrained social contestation (FiDH, 2012).

Another direct impact strategy used by contestation networks is participating in shareholders' meetings. These initiatives result from the understanding that shareholders, rating agencies, and banks exert significant influence on firms. Organizations linked to the AIAV have most commonly adopted this strategy. Since 2010, they have purchased Vale shares and taken part in the meetings as critical shareholders. At these meetings, they describe the negative environmental impact of the company's activities to other shareholders, demand changes in corporate practices, and seek to embarrass the Board of Directors (Glass, 2012).

In addition to these direct-effect strategies, other initiatives seek to indirectly influence companies' actions. Among these, one of the most popular is to influence public opinion and motivate others to act against the firms. One such strategy involves the preparation of Unsustainability Reports and the giving of "awards" to companies to highlight their negative aspects. As an example of the former, some networks have developed so-called "Shadow Reports" to dispute official Sustainability and Social Responsibility reports. In 2012 and 2015, the AIAV prepared the "Vale's Unsustainability Report", which made explicit mention of the contradictions between Vale's reports and its practices (AIAV, 2012, 2015). As an example of the latter strategy, in 2012, Vale was nominated for the Public Eye Award, a "name and shame" prize given to corporations for violating human rights. The firm immediately questioned the "prize" and sought to delegitimize the claims as baseless and misleading (Vale, 2012). This response exemplifies a reactive pattern of denial to social contestation (Santos, 2012).

Contestation actors also engage in actions intended to use institutional power against firms. Some of these initiatives include questioning environmental licensing procedures in courts and lobbying the Congress. Although licensing procedures require public hearings, these offer few opportunities to affect change in mining projects (Zhouri, 2008). Nevertheless, the debates initiated in these hearings have evolved into complaints to the Public Prosecutor Office, and served as the foundation for lawsuits against firms. For example, after a complaint by AIAV in 2012, the courts ordered Vale to halt their expansion of EFC due to irregularities in the licensing process (Folha Online, 2012).

With the goal of affecting more structural changes, contestation networks have also sought to influence mining legislation. The creation of CNDTM illustrates how social movements seek to shape regulation in the country. In this sense, CNDTM has cultivated a nationwide campaign geared towards pressuring Congress on issues related to mining activities (CNDTM, 2013a).

The analysis of strategies and practices employed by contestation actors demonstrates their role in the GPN for iron ore. Data suggest that contestation networks emulate corporate structure and allow social actors to engage in contestation activities in various places simultaneously. Moreover, these actors develop tactics and strategies that either directly or indirectly impact different nodes of the GPN. Regardless of the degree to which these strategies are effective, their mere existence indicates how social actors seek to influence the activities of economic actors.

4. Final remarks

This paper articulated different concepts and provided the debate on the organization of economic and social actors related to the GPN for iron ore. Initially, it sketched the GPN framework and considered a robust approach for assessing the relations between different actors in the network. Additionally, it incorporated elements of political ecology and ecological economics to explain the material importance of economic activity, which has gone relatively unexplored in the literature on GPNs. Moreover, it linked the physical dimension to the ecological distribution of conflicts, which in turn, serve as the foundation for contestation strategies against economic actors. Besides this, the paper has described the

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GPN for iron ore, analyzed its structure on a national scale, and evaluated strategies employed by economic and social actors (as well as the influence that these groups have on each other). In sum, it presented two main general contributions to the GPN theory: the relevance of physical elements and the influence of social actors over economic ones.

First, the incorporation of the material component of GPNs was essential for a better understanding of the modes of contestation associated with the mining industry. This is a resource intensive sector and the incorporation of this material perspective exposed the conflicts related to the distribution of ecological resources. In this sense, it went beyond the traditional perspective of economic distribution conflicts.

The example of iron ore used here is useful because it illustrates the private appropriation of common goods, which is at the basis of any GPN. Accordingly, accumulation by dispossession is a necessary condition of all economic phenomena stricto sensu (Weber, 2011). Once it becomes a material and symbolic dispute (Hornborg, 2009; Martinez-Alier, 2001), this competition is the primary driving force of environmental conflicts (Acselrad, 2004). In this way, social contestation and contentious politics are essentially forms of conflicting social relations between economic and social actors in the GPN for iron ore, and in the mining and the extractive industries at large.

Given that in the iron ore industry, 'the logic of rent capture exerts a strong influence (. . .), where it arises as a function of the confrontation between natural production and social production' (Bridge, 2008), economic action adds a value process to the original typology of the GPNs model (i.e., creation, enhancement and capture). The materiality of this GPN indicates that a key dimension of value appropriation is "commodification" of natural goods (i.e., the conversion of nature into mineral resources via political institution of property rights). According to Bridge (2008, p. 403), because the mining industry is based on the exploitation of non-renewable resources, companies 'confront a "resource imperative" intensely such that the cornerstone of their competitive strategies relate to the replacement and expansion of reserves.

Successful companies in the GPN for iron ore guide their economic actions in accordance with a physical-material rationale, seeking to access and control the quantity and quality of main reserves. It follows that there exists an intense territorial embeddedness of firms in relation to exploration and extraction, both of which are central to value processes. More importantly, Böhm et al. (2012, p. 3) connect such a material, economic rationale to 'new (and ongoing) rounds of enclosure, privatization and appropriation' of natural and common goods.

Therefore, when bringing along the relevance of physical elements and incorporating elements of political ecology and ecological economics, this research proposes new challenges to the GPN framework, which might be developed in future research. First, it requires a more comprehensive understanding of value. Most of the GPN literature understands value as surplus value or economic rent; ideas borrowed from ecological economics underscore the need to include non-monetary value, when assessing conflicts among various actors. Second, ecological economics also has a strong element of ecological cost of opportunity: in order to create manmade capital, it is necessary to transform/destroy natural capital (Daly and Farley, 2004). This proposal can be associated with the notion of capital destruction, which has already been proposed by Dicken (2011), but not fully incorporated in GPN studies. Finally, physical elements also pose constraints to the firms' decisions, such as location, logistics infrastructure and even production processes. The Commodity Chain approach seems to give strong relevance to this element (Bunker and Ciccantell, 2005; Ciccantell, 1999); nevertheless it still seems absent from the GPN debate.

The second general contribution relates to the influence of social actors over economic ones. In addition to evaluating the interaction between the mining industry and social contestation movements, the study indicates that economic actors' behaviors influence and are influenced by the economically relevant actions of contestation actors. The description of economic actors in the national node identified a very short production network in which companies seek to gain corporate power through forward vertical integration. In this sense, logistic infrastructure becomes central in the GPN for iron ore. Within the iron ore industry, the drive to reduce transportation-related costs and increasing market concentration and centralization largely explain the process of vertical integration following the privatization of state-owned mining companies and steel mills in the 1990s. Given this, the quasi-monopolistic dominance of these actors in segments of the national railway system, as well as the considerable degree to which they control some major ports and private terminals in Brazil, become understandable.

It is argued that the GPN for iron ore operates in an environment in which worldwide reserves are depleting, both in terms of quality and quantity. In this context, if one assumes the logistic processes that form the GPN as key factors in reducing costs, it follows that the processes of value creation in the primary processing stage represent a relatively minor component of revenue generation. Therefore, competitive advantage can be obtained through processes geared towards time-space compression (Harvey, 1990). Thus, capital accumulation in resource intensive sectors would result mainly from value enhancement and capture rather than from value creation.

This dependence on value enhancement via logistics establishes a primary focus of economically-relevant action that can be implemented by contestation networks. The repeated use of blocking and occupation tactics on the EFC, which transforms social contestation into contentious politics (Tarrow, 2011), motivated comprehensive reactive actions from Vale. Based on the prohibitory injunction, these reactions suggest that hegemonic economic actors have influence over institutional actors.

Another characteristic of economic actors that is reflected in the organization of their contestation counterparts concerns Vale's market dominance. The company not only has an overriding share of the country's ore reserves – as a double function of its institutional history (social embeddedness, cf. Hess, 2004a) as a monopoly in the form of a public company and its new status as a "national champion" (Bossi et al., 2009) – but is also the main target of social movements. For these reasons, Vale is the only company with an exclusive contestation network that is also the target of global campaigns.

From a GPN-based perspective, it is possible to identify two dimensions related to the organization of contestation movements. First, there are local/regional movements that respond to the effects that various companies have on their territories. Some of these movements may even evolve into campaigns against these companies. Second, there is a corporate dimension that unites movements in different territories; these movements then come to challenge the same company. Therefore, it could be argued that the geographical structure of the firms influences the spatial organization of the contestation networks.

In spite of the focus on the Brazilian node of the GPN for iron ore, some of these findings apply to other contestation movements against mining in various countries. For example, Bloomfield (2014) evaluates to what extent the "No Dirty Gold" campaign questioned unwanted industry activities and pressure firms to change specific practices. Mutti et al. (2012) study social stakeholder networks and evaluate their belief systems, although fail to debate their strategies and actions. Along these lines, Hoogesteger and Verzijl (2015) use the concept of "grassroots scalar politics" to understand how local

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groups navigate between different scales (from local to national). Such elements of contestation networks should also be included on the GPN framework.

In summary, the article still assumes that firms are at the core of the GPN analysis. Nevertheless, it suggests that looking at their sole decisions or their relationships with institutional actors, as a significant part of the GPN research does, might undermine other important elements. Therefore, it proposes that bringing along the influence of physical elements and contestation networks on firms' actions might conceptually improve research on the GPN related in the context of extractive industries.

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