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Rethinking Global Commodity Chains

Integrating Extraction, Transport, and Manufacturing

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Abstract

The global commodity chains (GCCs) approach is an insightful way to understand issues of ‘development’ and production and consumption differentials across space. It potentially offers insight into the issue of ‘ecologically unequal exchange’. However, we propose *three* revisions to conventional GCC analysis. First, many of the GCC studies tend to focus on only part of the commodity chain – and we need, in effect, to ‘lengthen’ the chains. Stephen Bunker (1984) emphasized that ‘commodities can emerge only from locally based extractive and productive systems’ (p. 1017). Beginning GCC analysis with these primary products forces the examination of various modes, techniques and technologies of extractive regimes, as well as the key roles of transportation and communications systems. Second, focusing on this ‘longer chain’ requires analysis of spatially based disarticulations and contestations. Mineral deposits and agricultural economies tend to be tied to specific ‘natural’ geographies – thus, ‘enclave economies’ frequently develop that are globally integrated but locally disarticulated. Transportation systems (especially of bulk products) are extremely vulnerable to disruption and change dramatically over time. Third, we explicitly focus on tightly integrated social and natural processes across a range of industries. The goal is to focus on the relationship between long-term changes in the world economy and the natural environment, as well as on research in environmental studies that examines ‘ecologically unequal exchange’ and points to prospects for sustainable development.

Key words: ecologically unequal exchange • global commodity chains • globalization • raw materials • transport

1. LENGTHENING THE CHAIN: EXTRACTION AND ECOLOGY

The global commodity chains (GCCs) approach is an insightful way to understand issues of ‘development’ and how processes of production and consumption vary

across physical and social space. The key questions that this perspective prompts are inherently both sociological and geographic, integrating social and natural processes. It provides a useful framework for analyzing ‘ecologically unequal exchange’ in the world-system. Acknowledging the analytical usefulness of the GCCs framework, we propose rethinking it in *three* basic ways.

First, many studies associated with GCCs research tend to focus on only part of the commodity chain; we need to, in effect, lengthen the chains. Despite an initial view that was more comprehensive (see Hopkins and Wallerstein, 1982), most recent research using the GCCs approach focuses on manufactured goods and ignores the ‘beginning’ of the chain. We propose using a theme developed by Stephen Bunker (1984) to remedy this problem: ‘Commodities can emerge only from locally based extractive and productive systems’ (p. 1017). The modern world-economy is dependent on a wide array of key raw materials. Indeed, these are integral to *all* commodity chains and production processes, including those for the sort of light manufacturing that is often the focus of GCC analysis but also for a wide array of other essential end products, including basic infrastructure, buildings and housing, heavy equipment, etc. First, a GCC analysis with these primary products forces the examination of various modes, techniques and technologies of extractive regimes, as well as of 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. Such an analysis, literally, opens up broad new vistas that narrower industrial case studies might have missed.¹ This provides us with new insights into contemporary globalization, the rise of a ‘new international division of labor’, and economic restructuring, as well as better understanding of concomitant unequal processes of ecological change and degradation. As Bunker and Ciccantell (2005, 2007) demonstrate, the local profoundly shapes the global in raw materials GCCs, with factors such as local geology, topography, hydrology, indigenous populations, conflicts over resource access, efforts to capture the benefits of extraction for local populations, and a variety of other location-specific characteristics and processes shaping the strategies of global firms and national states to utilize these resources. In contrast to a ‘flat world’ (Friedman, 2006) and ‘footloose’ global firms, lengthened GCCs incorporating the theoretical insights of new historical materialism (Bunker and Ciccantell, 2005, 2007) brings the spatiality and location-specific processes that constitute the capitalist world-economy to the center of the analysis. It is impossible to pretend that raw materials deposits, mines, railroads, and steel mills are footloose; their fixity in space and the contestations over these locations firmly ground our analysis.

Second, focusing on this ‘longer chain’ raises new questions about spatially based disarticulations and contestations over the shape of the future of the capitalist world-economy. Mineral deposits and agricultural economies tend to be tied to specific ‘natural’ geographies – thus, ‘enclave economies’ develop that

are often globally integrated but locally disarticulated. Indigenous populations define and use natural resources in very different ways from global mining firms, and these different definitions and uses are creating an increasing number of conflicts in many remote regions that are rich in raw materials, setting the stage for ecological degradation (see, for example, Bunker, 1984; Gedicks, 2001; Kaup, 2008). Transportation systems (especially of bulk products) are extremely vulnerable to disruption and have changed dramatically over time (for instance, the dramatic increase in the size of oil tankers and bulk carriers and the concomitant growth of massive port infrastructures). Thus, starting at the beginning of commodity chains not only provides a more comprehensive and complete story of contested transformation sequences, but it also reveals new ways in which geographic and spatial disarticulations and ecological inequalities are integral to the global economy.

Third, we explicitly focus on tightly integrated social and natural processes across a wide range of industries. The goal is to build on existing work in the world-systems tradition that focuses on the relationship between long-term changes in the world economy and the natural environment, as well as on research in environmental sociology and in environmental history that has long examined the relationship between society and nature, particularly in natural resource-based industries. In the world-systems tradition, a number of researchers have examined various dimensions of the relationship between socioeconomic change and the natural environment during recent decades, the last 500 years of the capitalist world-economy, and the last several thousand years. Global climate change (Burns et al., 1997; Roberts and Grimes, 1999; Roberts and Parks, 2007), the export of hazardous industries (Frey, 2006), and other environmental issues that are now garnering a great deal of public interest can be more fully understood within the broader context of the evolution of the capitalist world-economy in recent decades. The expansion of the capitalist world-economy to incorporate more and more of the earth's surface over the past five centuries reshaped and restructured social and natural systems globally (Bartley and Bergesen, 1997; Bunker and Ciccantell, 2005; Chew, 1992, 1997). In an even longer-term perspective, Chase-Dunn and Hall (1997a, 1997b), Chase-Dunn et al. (2007), Friedman (2007), Hall and Turchin (2007) and Hornberg (1997) examine how the growth of a variety of world-systems and processes of exchange between social groups changed local and regional environments. In a manner often parallel to global commodity chains research and new historical materialism, environmental sociology often focuses on the relationship between society and nature as observable in particular industries (e.g. Freudenburg and Gramling, 1994; Freudenburg et al., 1995), as have many environmental historians (e.g. Cronon, 1991; McNeill, 2001; Merchant, 2007).

Our revised version of GCC analysis allows us to make comparisons across industries and over decades and even centuries in our effort to understand the relationship between society and nature. These comparisons will be used to

develop a theoretical model bringing together new historical materialism and the emerging body of integrative systems theory in the natural sciences (Liu et al., 2007; Palmer et al., 2005; Pickett et al., 2005; Schlesinger, 2006) in order to better understand and help address the profound socioenvironmental challenges that now confront us (Millennium Ecosystem Assessment, 2003; NRC, 2001; Steffen et al., 2004).

2. ADVANTAGES OF STARTING AT THE BEGINNING OF THE CHAINS

The intellectual payoffs from our three revisions to GCC analysis include: a) using GCC as part of a world-systemic method of comparative analysis for nested and over time comparisons; b) examining how and why economies and polities change over time as the result of the creation, maintenance, and eventual decline of critical institutional patterns linked to extraction and raw material transport (in addition to those tied to changing industrial and/or financial regimes); and c) bringing the GCC approach, world-systems theory more generally, and the environmental sociology and environmental history literatures into more direct dialogue about the processes of unequal ecological exchange and degradation.

The GCC approach is typically used as a heuristic device for research that highlights some stage or stages of extraction, production and consumption in a particular industry. These analyses are placed within a context of a globally connected system, but there is often little explicit attention to the underlying theoretical model of world-systems analysis and the long-term historical processes that shape the creation and evolution of these GCCs. Similarly, developments in different nodes in one GCC are sometimes compared, but comparisons over the long term or across GCCs are not a major focus. Our effort to ‘lengthen the chains’ focuses on these theoretical issues in creating a fully world-systemic analytic method for making comparisons nested within an evolving global system, à la Arrighi (1994), Bunker and Ciccantell (2005) and others. These comparisons will take a variety of forms, such as analyzing change in one industry over time, comparing two or more industries over time, comparing two industries at one point in time, comparing two countries involved in the same industry at different points in time, etc. By insisting on taking a ‘long view’ on GCCs, this comparative analysis always focuses on how creating and maintaining these chains simultaneously link social and natural processes, are shaped by global processes, affect particular locations, and shape the long-term evolution of the world-system.

More fundamentally, lengthening the chains allows us to use comparative analysis to examine a foundational issue: how and why do economies and polities change over time as the result of the creation, maintenance, and eventual decline of critical institutional patterns? Overly broad generalizations about long-term changes in social and natural processes (industrialization, imperialism, colonialism, neo-colonialism, globalization, etc.) typically conceal as much as

they explain. Even the fairly specific concept of ‘late 19th and early 20th century British imperialism’ meant very different things for the how and why of creating new states after the Second World War in India and Nigeria, as Kohli (2004) demonstrated. Local natural resource bases, existing uses of land that were often incompatible with imperial plans, local topography and infrastructure, longstanding local political conflicts, and a variety of other location-specific characteristics and processes shaped British imperialism in this period and, more generally, efforts by core states and firms to access essential raw materials around the world and over time (Bunker and Ciccantell, 2005). Our approach allows us to highlight how the local has shaped global commodity chains and the process of globalization itself. A lengthened GCC-based approach focused on particular industries, technologies, transport systems, and geographies allows the construction of a comparative analysis that can explain how and why political and economic institutional patterns were created and endure, based on the foundations of raw materials extraction, processing, transport, and consumption. We are also able to construct a methodological approach that lets us look at very different industries, times, and places and make meaningful comparisons that can then serve as the basis for state and non-state actors to build a more socioeconomically and ecologically sustainable future. This new approach deepens world-systems theory and will allow us to move past three key conundrums that confront many efforts to understand the relationship between nature and society in both the natural and social science literatures.

First, ‘dematerialization’ that some analysts see as a positive step for increased sustainability in the late 20th and early 21st centuries in the wealthy countries of the core (for various perspectives on this debate, see e.g. Ausubel and Waggoner, 2008; Ayres and van den Bergh, 2005; Cleveland and Ruth, 1998; Ruth, 1998; Sun and Meristo, 1999; van der Voet et al., 2005; Wernick et al., 1996) is simply an illusion. Although some products use less material as measured by volume or weight (e.g. lighter, smaller cars in 2009 in comparison to cars of the 1950s) and the amount of material used per dollar of economic output in core countries has decreased, more iron ore and coal are being mined than ever before and transformed into steel, more oil is being extracted and consumed than ever before, and, in fact, the extraction and processing of raw materials continues to increase rapidly.

Table 1 Mine production of three major raw materials millions of metric tons

	Bauxite	Copper	Iron ore
1964	33.2	4.2	568.9
1970	59.5	6.4	773.9
1980	93.1	7.7	917.9
1990	114.8	9.0	980.6
2000	138.9	13.3	959.7
2007	191.4	15.6	1655.5

However, this extraction, processing, and much of the resulting consumption and environmental degradation take place in areas that are increasingly remote from the core countries of the United States and Europe, most notably in extractive peripheries like the Brazilian Amazon and Western Australia and in rapidly industrializing nations like China and India (Bunker and Ciccantell, 2005, 2007). Analysts and residents in the core may see less of the materiality of the world economy, but global economic growth remain firmly grounded on increasing use of raw materials.

Second, natural and social scientists have long sought some sort of common metric that allows us to integrate social and natural processes in order to examine the relationship between nature and society. The use of the idea of ‘ecological footprints’ is one such attempt (Wackernagel, 1994) that has generated a great deal of useful research (for instance, Jorgenson, 2003). Energy is another particularly appealing metric (Adams, 1982; Martinez-Alier and Schlupmann, 1987; Prigogine and Stengers, 1984). However, without unlimited and costless energy, the form, place and time of a particular type of matter cannot be reduced to any energy metric. A cubic yard of iron ore cannot be transformed into a cubic yard of coal, aluminum, fertile topsoil, or any of the myriad forms of matter on which human society depends for its survival. Similarly, whether that cubic yard of iron ore is in a Brazilian rainforest, the Australian desert outback, or a northern Minnesota forest makes a tremendous difference in its economic, political, transport, and environmental availability for human use. So situating extraction on longer, geo-coded commodity chains is critically important.

Third, as a result, ‘matter matters’ (Bunker and Ciccantell, 2005, 2007) for understanding the relationship between society and nature, just as do space, time, technologies, socioeconomic and political structures, and a variety of other intertwined natural and social characteristics that must be taken into account in efforts to understand this relationship and the potential for future sustainability in the capitalist world-economy. This may not be so obvious when we examine the latter half of the commodity chains for some consumer goods (for example, garments, athletic shoes, or even computers and electronic equipment). But it is a major and unavoidable element of any analysis that considers iron ore or petroleum. One of our larger goals is to develop an analytical approach that allows us to identify the key elements of this complexity and provide a better understanding of this relationship.

3. LENGTHENING GCCS VIA ‘NEW HISTORICAL MATERIALISM’

Global Commodity Chains

In the foundational work on global commodity chains in world-systems literature, they are defined as ‘a network of labor and production processes whose end result is a finished commodity’ (Hopkins and Wallerstein, 1982: 159). In its initial formulation, this analytic approach sought to link mining, logging,

agriculture, and other forms of raw materials extraction from nature, typically in the periphery, to the industrial processing and consumption of these materials, most commonly in the core, in order to understand the mechanisms that created and reproduced systematic inequalities in the capitalist world-economy. A model of the shipbuilding commodity chain in the 18th century, for example, brought together the extraction and processing of trees, iron ore, flax and hemp into the timbers, tar, pitch, tools, nails, rope, and sails that were utilized to build and operate the world's best cargo ships during the period of Dutch hegemony, and linked this shipbuilding commodity chain to the shipping, naval power, and business organizations that depended on this chain for their world-leading positions (Hopkins and Wallerstein, 1982). This approach brought together analysis of the impoverishment of extractive peripheries and their economic and political connections to the core that enriched the core; it also incorporated an explicit focus on consumption, particularly of final consumer goods, into world-systems analysis.

Not surprisingly, scholars studying agricultural rural sociology and farming also developed ideas about rather similar chains. Perhaps the most influential work in this area came out of 'the new political economy of food and agriculture' in the 1980s. In particular, William Friedland (1984) outlines 'commodity systems analysis' as a framework for studying farming and agribusiness in the United States (with a particular focus on the production and marketing of lettuce). Despite obvious similarities, this work was independent of Hopkins and Wallerstein (Jackson et al., 2006; for a detailed discussion of the intellectual genealogy of commodity chain research – and all its 'mutations' – see Bair, 2008). While the commodity systems analysis approach did start with extraction (growing of produce on farms) it was much less interested in the environmental context or the biophysical properties of raw materials than the new historical materialism (Bunker and Ciccantell, 2005).

The main variant of sociological and comparative development studies of commodity chains was initially grounded in the world-system perspective and the essay by Hopkins and Wallerstein. Building on that work, Gereffi et al. (1994) defined a global commodity chain as 'sets of interorganizational networks clustered around one commodity or product, linking households, enterprises and states to one another within the world-economy . . . (it is) the sequential stages of input acquisition, manufacturing, distribution, marketing and consumption' (1994: 2). Their work and that of others who used this global commodity chains (GCC) approach examined key processes of change in the capitalist world-economy in the late 20th century, including how and where surplus or profit accrue in various points where the commodity chain touches down. They also explored whether 'industrial upgrading', a popular policy prescription in the periphery and semiperiphery, was possible at different nodes in the chain. This 'upgrading' was important because it was assumed that it could raise the value of local transformation, capture more of the surplus/profits from the chain,

and ultimately promote economic development. Many studies in this tradition (Appelbaum et al., 1994; Bair and Gereffi, 2001; Gereffi, 1994; Gereffi and Memdovic, 2003; O’Riain, 2004; Schrank, 2004) focused on the efforts of non-core nations to industrialize based on textiles, electronics, and other consumer goods manufacturing for sale in core markets.² This research yielded valuable insights into contemporary globalization, development policies, firm strategies, and the evolution of the world economy in the late 20th century.

The GCC model provides an excellent tool for examining ‘development’ and how production and consumption vary across natural and social space. How and where do GCCs ‘touch down’ around the world? How do GCCs affect local people and places? The fundamental insight of GCC analysis, that industries should be analyzed as a linked set of activities that often cross multiple national boundaries in a globalized economy, has become an integral part of international management standards such as the ISO 14001 standards, life-cycle assessment models, and supply chain management (Barbutti et al., 2008; Frees, 2008; Frischknecht, 2007; Guinee, 2002; IISI, n.d.; ISO, 2006; Lindner and Babbitt, 2008; SAIC, 2006; Woolridge et al., 2005). The prevailing focus on consumer goods industries meant, however, that analysis of the upstream end of the chain in raw materials extraction and processing received much less attention.

New Historical Materialism

In contrast to the GCC approach, new historical materialism (Bunker and Ciccantell, 2005, 2007) focuses attention on the upstream end of the commodity chain, highlighting the critical role of raw materials extraction, processing and transport in shaping the evolution of the capitalist world-economy. In any rising economy, strategies for economic ascent must respond to and take advantage of contemporary technological, geopolitical, environmental, and market conditions in the rest of the world and of the nation’s position and location within that particular global economy. They must also coordinate the physical characteristics and location in space and in topography of the various raw material resources actually or potentially available with the rest of the national territory. The beginnings of economic ascent require successful coordination of domestic technological advances, particularly in heavy industry and transport, with the external solution of access to cheap and steady sources of the raw materials used for heavy industry. The raw materials used in greatest volume present the severest challenge and best opportunity for economies of scale. These economies of scale, however, drive a contradictory increase in transport cost, as the closest reserves of raw materials are depleted more rapidly as the scale of their industrial transformation increases (see Bunker and Ciccantell, 2005, for an extended presentation of this theoretical model).

The tension of this contradiction between the economies of scale and the cost of space foments technological innovation in transport, in chemical and

mechanical means of reducing component inputs per unit of output, and improvements in control of heat, pressure and the mix of chemicals that make the unit material inputs stronger and thus enable smaller, lighter amounts to perform the same work. All of these technological fixes drive each other, and all of them tend to generate increases of scale, thus exacerbating over the long term the very contradiction between scale and space that they are designed to solve (Bunker and Ciccantell, 2005).

The national economies that most successfully initiated technological and organizational solutions to this contradiction simultaneously generated their own rise to economic dominance, restructured the mechanisms and dynamics of systemic and hierarchic accumulation, and expanded and intensified the commercial arena of raw materials trade and transport. Solving the raw materials problem – the tension between increasing economies of scale in raw materials extraction and transport and the accompanying diseconomies of the increasing cost of space – is daunting. It requires the coordination of multiple physical and social processes across geopolitical and physical space with domestic relations between firms, sectors, the state, labor, and new technologies. Rising economies resolve these problems at the same time as, or even before, they increase industrial competitiveness. These solutions stimulate complex processes of learning and of institutional change that fundamentally mold the organization of the national economy at the same time that they change international markets and the rules binding participants in them (Bunker and Ciccantell, 2005).

The challenges and the opportunities presented by the basic raw materials industries, and by the transport systems on which they depend, foster generative sectors. These sectors, beyond creating the backward and forward linkages that underlie the concept of a leading sector, also 1) stimulate a broad range of technical skills and learning along with formal institutions designed and funded to promote them, 2) contribute to vast and diversified instrumental knowledge held by interdependent specialists about the rest of the world, 3) produce financial institutions adapted to the requirements of large sunk costs in a variety of social and political contexts, 4) lead to specific formal and informal relations between firms, sectors, and states, and 5) shape the form of legal distinctions between public and private and between different levels of public jurisdiction (Bunker and Ciccantell, 2005).

Generative sectors are more numerous, more easily observed, and more efficacious in those national economies that are growing so rapidly that they must achieve massive increases in throughput and transformation of raw materials. The concept is relational, however, within a world-systems perspective, and thus implies that generative sectors in a rising economy will have significant consequences for other economies that export raw materials or trade in other kinds of goods. In other words, these changes will redound throughout the world-economy and impact far-flung webs of commodity chains the world over.

Generative sectors are not necessarily those in which profits are highest, even though high profit sectors (whether gold and silver in the 17th century or computer technology in the 20th century) are those that typically attract the most analytical attention (see e.g. Arrighi, 1994; O'Hearn, 2001). Moreover, as has been shown elsewhere (Bunker and Ciccantell, 2003a, 2003b), highest profit sectors are not necessarily generative sectors. Instead, generative sectors provide the material building blocks, cost reductions across many sectors to increase competitiveness, and patterns of state-sector-firm relations and other institutions that combine to drive economic growth and ascent. They become the 'drivers' of economic development, with spin-off effects on other parts of the economy. And the changes they create – not only in production and products but also in technology, infrastructure, transportation, and logistics – have wide-ranging effects throughout the rest of the world.

How can rapidly growing economies acquire the raw materials essential to sustain their generative sectors, particularly in the face of domestic raw materials depletion and the resulting diseconomies of space as these raw materials must be brought from more distant areas outside the political control of the ascendant state? One critical strategy to accomplish this task has been to 'steal' raw materials peripheries from earlier ascendant economies that have already undertaken the difficult and expensive tasks of building the necessary infrastructure, creating political, organizational, and legal forms that promote international trade and investment relations between a particular raw materials-producing state and the world economy, and incorporating these peripheries economically and politically into the world economy. Earlier processes of economic ascent progressively globalized the world economy and brought new raw materials peripheries into the global trading system to supply the earlier ascendants' industries, so new ascendant economies and states have the opportunity initially to purchase raw materials from this established supply system (Ciccantell, 2009).

The newer ascendants' rapid growth, however, means that their demand is increasing dramatically; this necessitates a similar increase in supply if these growth rates are to be sustained. The combination of the existing social and material infrastructures in the raw materials peripheries established by earlier ascendants, rapid demand growth in the ascendant economy, and the willingness of the newer ascendant economy to pay higher prices for raw materials in order to sustain their domestic growth creates an opportunity that states and firms in the raw materials periphery find very attractive. Higher prices for rapidly increasing volumes of exports (in contrast to slower demand growth in the mature economies of earlier ascendants) motivate firms and domestic elites in the periphery – and even from existing core powers with fewer opportunities for profitable investments – to invest in production for export to the new ascendant. States in raw materials exporting regions typically support this investment with subsidies for transport and extraction, both in an effort to promote economic development and in hopes of gaining better returns and more political freedom

from the power of the existing hegemon. This is particularly apparent in post-colonial situations in which newly independent states seek to break free from neocolonial ties and in situations of resource nationalism in which states seek greater control over and benefits from raw materials exports. Firms, elites, and states in raw materials peripheries come to see the new ascendant as a potential ally in their attempts to promote political independence and economic development (Ciccantell, 2009).

From the perspective of the new ascendant, building these relationships with existing raw materials peripheries is much less expensive and difficult than creating their own new peripheries. One of the most important benefits is that most of the cost and the risk of expanding extraction and transport is borne by firms and states in the extractive periphery and often by firms from the earlier ascendant. At the same time, these investments in mines and transport systems also often create opportunities for exports of industrial products from the ascendant economy to the periphery to support the development of these extractive industries and for consumption by the owners of, and workers in, these industries. 'Stealing' these peripheries from earlier ascendants thus further enhances the rapid growth of the new ascendant by reducing costs and risks while simultaneously creating significant new opportunities for profit from trade and investment, as raw materials supplies are redirected away from existing core markets, despite the efforts of the core state and firms to maintain this relationship that had been so costly to create. This competition between existing core powers and new ascendants is a key element of long-term change in the capitalist world-economy, since ascendant economies that successfully steal raw materials peripheries from existing powers dramatically increase their global competitiveness (Ciccantell, 2009).

Clearly, there is a huge geographically manifested power differential in this overall dynamic. As production and consumption in the wealthiest core urban areas proceeds, procurement of key natural resources is extended farther and farther, and the contradiction between the economies of scale and the diseconomies of space become increasingly obvious. Extractive peripheries develop which are designed by the ascendant economy as appendages of their metropolitan accumulation, with little regard for either local 'development' or sustainability. Indeed, various pressures push, rather relentlessly, toward local ecological degradation in these areas at the 'beginning' of ever lengthening global commodity chains. This, we argue, is a crucial mechanism of 'ecologically unequal exchange'.

Articulation, Disarticulation, and Contestation over Creating and Maintaining GCCs

The focus in the mainstream GCC literature on firm strategies and state development policies and the emphasis in the new historical materialist approach on long-term change rooted in raw materials access and resulting competitive advantages both tend to obscure important dimensions of how GCCs are

created and maintained. GCCs must be built and linked together materially and socially, but this may require expropriating farmland to build export processing zones, displacing fishing villages to build ports, relocating indigenous groups from traditional lands to build mines, and a host of other actions by states and firms that negatively impact a variety of groups and may be ecologically costly. State development policies and firm strategies often run directly counter to the interests of indigenous groups. These impacted people often contest the loss of land and redefinition of the natural resources on which they depend, albeit typically unsuccessfully. This contestation takes a variety of forms in the Amazon rainforest, the Nigerian river deltas, and many other locations (see e.g. Bunker, 1985; Bunker and Ciccantell, 2005; Gedicks, 2001; Kaup, 2008; Watts, 2008), but it often challenges the process of articulating these GCCs and even threatens to disarticulate and disrupt GCCs that were built at enormous costs, sometimes running into billions of dollars. Our proposed methodology allows us to examine and compare these processes of contestation over articulation and disarticulation of GCCs in a wide variety of industries, locations, and time periods.

Earlier research highlighted how the creation of GCCs in key raw materials industries shaped the institutional patterns in the most dramatic cases of system-changing ascent (Bunker and Ciccantell, 2005, 2007). The institutional patterns that are created by generative sectors in raw materials and transport in the economies that rise to challenge for hegemony (e.g. the formation of global shipping networks, the creation of a stock market supported by the state in its efforts to expand British business globally, building the first global communications network via undersea cables, and other innovations in Great Britain, creating a stock market to support the building of continental railroads in the US, etc.; Bunker and Ciccantell, 2005) reshape the world economy and ecosystems around the world in ways that support these rapidly growing nations' economic ascent. The other side of this process, however, is the progressive impoverishment and ecological degradation of many areas around the world that are incorporated as raw materials and labor-supplying peripheries. The same institutional patterns that underlie rapid economic development in ascendant core economies create the patterns of underdevelopment and ecological damage in these peripheries. These processes, in turn, form the foundation for the long-term evolution of the world-system across hegemonic cycles and through the progressive globalization of the capitalist world-economy (Arrighi, 1994; Bunker and Ciccantell, 2005).

4. HOW TRANSPORTATION AND COMMUNICATIONS TECHNOLOGIES SHAPE GCCS AND THE EVOLUTION OF THE WORLD-SYSTEM

The construction of the increasingly global commodity chains in raw materials that transformed the capitalist world-economy depended on the development and employment of progressively larger transportation equipment that could

move growing volumes at lower cost per ton. States in rapidly ascending economies provided financial, technical, and other types of support to domestic shipbuilding firms to help them develop and put into production larger and larger ships (see Bunker and Ciccantell, 2005 for an analysis of this process in Holland, Great Britain, the US and Japan and Bunker and Ciccantell, 2007 for an extended analysis of the Japanese case). These economies of scale, created by the combined efforts of these states and firms, gave these rapidly ascending economies huge competitive advantages relative to the existing hegemon and to other competitors in transport costs for their raw materials imports and manufactured exports (Bunker and Ciccantell, 2005). The most important element of these economies of scale in transport was the increasing size of ships since the 1400s. A state-of-the-art sailing ship in 1400, for example, could carry around 400 tons of cargo; in 2008, the world's largest bulk carriers can carry 400,000+ tons of cargo.

Dutch shipbuilders led this process of technological innovation from the 1500s through the early 1700s, when shipbuilders in what were then the British North American colonies and later the independent United States took the lead in bulk shipping construction. British shipbuilders, however, were global leaders in naval shipbuilding technology in the 1600s and then pioneered the development of steamships in the 1800s for both military and bulk shipping purposes. After the Second World War, Japanese shipbuilders took the technological lead, building large bulk carriers that allowed Japanese steel firms to dramatically reduce the cost of ocean shipping of iron ore, coal, and other raw materials (Bunker and Ciccantell, 2005, 2007).

In addition to these dramatic increases in ship size, other technological and organizational innovations in shipping helped shape the evolution of GCCs in a wide variety of industries. The shift in motive power from sail to coal-powered steamships and then to oil-powered diesel engines had tremendous implications for geopolitical strategies during the 19th and 20th centuries. During the period of British hegemony, the British state built a global network of coaling stations to fuel their civilian and naval ships. This system supported the growth of a British-dominated global liner shipping industry (regularly scheduled cargo ship visits to a predetermined series of ports that was the main means of moving manufactured goods around the world). As shipping and land transport shifted to petroleum for fuel, British imperial and later neo-imperial strategies in the Middle East sought to guarantee access to oil to maintain British military power through the decades after the First World War – a role taken over by the United States after the Second World War that continues today. In the post-Second World War era, a technological innovation first developed in the United States, container shipping, was implemented on a large scale by Japanese shipbuilding and shipping firms to move manufactured goods from Japan to US and European markets. Japanese shipbuilding firms developed progressively larger container ships that provided a critical transport mechanism for the globalization of the

apparel, electronics, and other manufacturing industries by lowering the cost and increasing the speed of movement of manufactured goods around the world (Cafruny, 1987; Stopford, 1988; UNCTAD, various years).

Parallel developments in communications technologies that increased the volume and especially the speed of communications in the progressively globalizing world economy helped shape the evolution of the capitalist world-economy, as well. Until the early 1400s, horse-based land travel and ships with limited ability to sail against prevailing winds limited the speed of movement of information around the world to two years or more. Innovations in sailing ship technology in the 1400s and 1500s reduced this time somewhat, but the advent of steamships, the telegraph, and particularly the British construction of undersea telegraph cables in the second half of the 19th century cut global goods transport times to a matter of weeks and global information flows to a matter of hours. The same basic technology of undersea cables, combined with satellite communications, telephones and the internet, now serves to carry massive amounts of information around the world virtually instantaneously. This increasing scale, and especially speed, of global communications enables today's tightly integrated and rapid flows of information and finance and the attendant benefits and costs that are very apparent now. Of course, the move to larger and more energy intensive transport had major environmental consequences across the globe, from the areas where coal and oil were extracted to the ports and oceans where the fossil fuels were burned.

These communications technologies are a critical link to examine in our analysis of GCCs in raw materials and manufacturing industries. These technologies evolved from the use of trading agents sending letters on sailing ships to steamships, undersea telegraph cables, telephones, satellite communications, and the Internet organizing the movement of millions of tons of goods and many billions of dollars around the world every day. Further, much of this information flow and technological innovation was about moving raw materials and other products more quickly to places with high profit potential. Access to and control over key pieces of information gave tremendous competitive advantages to Dutch traders, British shippers and manufacturers, imperial armies, and a variety of other groups over the course of the evolution of the capitalist world-economy. Further, in today's 'postmodern world' of 'postindustrial information technology' where raw materials seem to be quaint 'old economy' issues, the most important uses of communications technology are often still about organizing the stages of extraction, processing and consumption on a global scale. 'Dematerialization' is convenient myth underlying the inconvenient truth of the massive cost (in dollars and energy) of moving enormous cargoes of raw materials.

Another critical aspect of transport and communications technologies in the evolution of the capitalist world-economy relates to military uses of these technologies in geopolitical competition. Long before satellite-guided bombs and missiles were developed, British control over undersea cables gave them

valuable information advantages over competing European powers and British shipbuilders built the world's most powerful naval steamships. Rising economies recognized the importance of transport and communications technologies and sought to use them to their advantage, as Japan did based on its massive investments in naval shipbuilding to defeat Russia in 1905. As a result, Japan gained a seat at the table of world naval powers, although its failure to develop adequate communications protection technologies before the Second World War helped lead to its defeat in that conflict. We will build on world-systems analysis of geopolitics (Arrighi, 1994; Chase-Dunn, 1989) to use our model of GCCs as a lens to examine geopolitics in an empirically grounded, material way, emphasizing how geopolitics rests on this material foundation of global competitiveness in generative sectors and other GCCs.

5. POSSIBLE CASE STUDIES OF LENGTHENED GCCS

In the final substantive section of this article, we would like to suggest (very tentatively) some possible case studies that will illustrate the analytical utility of our 'lengthened' GCCs and illustrate their potential role in emerging patterns of ecologically unequal exchange. We are beginning to analyze some disparate cases: garment production in 19th-century Great Britain versus clothing production today in Vietnam, the case of iron and coal in 18th/19th-century Britain, 19th-century Pittsburgh and 21st-century Australia, etc. (Ciccantell and Smith, 2009). But because of space limitations, we will focus here on a single case of oil extraction, comparing contemporary Canada and Iraq.

21st-Century Petroleum in Iraq versus Alberta

The material, economic, and geopolitical centrality of petroleum for the capitalist world-economy has been widely recognized for a century. Two contrasting cases of the impacts of incorporation into the petroleum GCC in the early 21st century, Iraq and Alberta, provide informative comparative case studies. The areas share a few important similarities. Both have some of the world's largest remaining resources of petroleum. Both have been major locations of oil extraction for export for almost a century. Both were under British imperial control (direct imperial control and then indirectly as part of the British commonwealth in Alberta and indirectly in Iraq as a British protectorate after the defeat of the Ottoman Empire in the First World War). Despite these similarities, other dimensions of these two petroleum-rich regions are very different.

From the perspective of natural characteristics, Iraq is a much more favorable location for petroleum extraction. Its high-quality light petroleum is cheap and easy to extract and process, with relatively limited negative environmental impacts from extraction. Its location on ocean shipping lanes in the Middle East allows low-cost transport of oil to consumers around the world. In contrast, Alberta's production of high-quality oil is declining, and the future of its oil industry rests

on production of low-quality, tar-like, heavy oil that is difficult and expensive to extract and process, requiring large amounts of energy and creating massive amounts of air and water pollution. An existing large-scale pipeline network connecting the area to the US market can transport some of the expected increase in exports, but new, very expensive pipelines must be built to meet the expected increase in production and refineries require very expensive retrofitting to process the low-quality oil. Based on a comparison of these natural characteristics, it would seem that billions of dollars of foreign investment would be flowing to Iraq to increase oil production to meet rapidly growing world demand in the context of unprecedented high prices for crude oil that existed until late 2008 and the onset of the global financial crisis.

However, the socioeconomic and geopolitical conditions of these two regions present a radically different picture. The postcolonial states that emerged in Iraq and Canada were very different, with an authoritarian monarchy and then a coup-initiated authoritarian state in Iraq, while Canada became a democratic state with a weak federal system. More importantly, Canada enjoyed a long tradition of peaceful political conditions internally and in the broader North American context. The democratic Canadian political system, however, opens the door for another form of contestation over the growing role of the oil sands in the petroleum GCC. Local, national, and international environmental groups are increasingly opposing the growth of this industry because of its impacts on air and water pollution and its contribution to global warming, as are some indigenous groups in the area. This type of contestation has become increasingly important in many areas in recent decades, and Canada's political system is particularly open to this sort of participation and challenge to firm and state development strategies based on this industry.

In contrast, Iraq's postcolonial state emerged in the decades of conflict following the First World War as the result of British efforts to manipulate economic and political conditions to guarantee British access to the region's oil. The region has been characterized for almost a century by repeated wars and the region's populations have often faced repressive authoritarian states with little legitimacy. The US invasion of 2003 in the context of the US war on terror and the broader context of social and political conflicts in the region destroyed the Ba'ath authoritarian state, but this state was replaced by a military occupation, a weak central government, and an ongoing civil war. Oil extraction, pipeline, and shipping facilities were favorite targets of various groups during the civil war, creating not only massive economic losses but also severe environmental damage. Iraqi oil production remains far below pre-war levels, and despite repeated efforts to stimulate foreign investment, few firms have undertaken the large and extremely risky investments needed to increase Iraqi oil production. This longtime major link in the global oil commodity chain was badly damaged by this ongoing conflict, and it is not likely to be fully rearticulated in the near future.

These sharply contrasting political realities mean that, in the context of historically high oil prices that obtained until late 2008, tens of billions of dollars of foreign investment were being poured into heavy oil extraction and processing in Alberta, while Iraq's higher quality oil remains in the ground. The collapse of oil prices in late 2008 and early 2009 is bringing oil exploration and development investments everywhere to a halt, including in Alberta's oil sands region. Geopolitical stability, however, thoroughly trumps natural characteristics today and for the foreseeable future. Wildly fluctuating oil prices and their economic impacts on the core, as well as the geopolitical involvement of the US, European Union, Russia and China in the Middle East, belie efforts to label the current era as postmaterialist. The future evolution of the capitalist world-economy will continue to be shaped by efforts to secure access to the raw materials fundamental to economic activity.

Yet in what are otherwise 'contrasting' cases, there is a common dilemma for those concerned with ecological sustainability. It turns out that *neither* Iraq nor Alberta can offer oil extraction that is environmentally optimal. In the Iraqi case the petroleum is remote from end markets, the region is racked by war and instability and transport (whether through pipelines across the borders of often hostile nations or via tankers through the Strait of Hormuz) and the potential for environmental disaster is almost as high as the likelihood that this supply will be unreliable due to war and political instability. In Canada the geological limitations on the raw material make extraction costly, difficult and extremely ecologically damaging. While Alberta is in a highly developed core country, it still plays a role parallel to that of other raw material peripheries and it becomes part of a logic of ecologically unequal exchange.

6. CONCLUSION: LENGTHENED COMMODITY CHAINS, ECOLOGICALLY UNEQUAL EXCHANGE

This article focused on developing a synthetic model of 'lengthening' the standard image of global commodity chains to fully incorporate extractive regimes (which also collaterally should heighten focus on transportation systems). Our goal was to convince the reader of the theoretical value of this exercise as a way to move the GCC framework beyond a heuristic for industrial case studies to one that incorporates more meaningful comparative analysis and has more purchase on longer-term large-scale social and economic transformations. We also wanted to make a general argument against those who see 21st-century globalization as 'dematerialized' – 'matter matters'. Sociologists, especially those interested in world-historical social change, need to explicitly build an understanding of the relationship between society and nature, of space and transport systems, and of the institutional structure (and often disarticulation) of extractive economies, particularly those on the periphery of today's world-economy.

In terms of informing state development policies, a longstanding concern of GCC research, our analysis highlights the essentiality of raw materials in a

decade that has included both an unprecedented rate of increase in prices and demand for most raw materials due to China's rapid economic rise and then, in late 2008 and early 2009, a similarly spectacular bust in prices and demand in the face of a global economic crisis. State actors seeking to use raw materials wealth as a basis for economic development must take a long-term view of the value of these resources. As global mining firms cut production and workforces and delay new investments, state development planners need to recognize that these deferrals will eventually increase the future value of these resources. When global economic growth resumes and demand increases, planners will then have the opportunity to strike better bargains for royalties, taxes, and job-generating domestic upgrading of resources. Taking advantage of these times of opportunity, however, must also include bargaining over the technologies to be employed and the environmental costs of using these resources. The social and economic costs to local populations that use these locations in other ways should also be factored into decisions. When demand and prices are high, global firms will be better able and willing to make attempts to ameliorate the often highly polluting and locally destructive impacts of their operations.

More generally, our reworking of GCC analysis allows us to utilize comparative methods to examine the relationship between society and nature in specific times and places and across time and space. Our ideas for case sketches suggest several important principles about the relationship between society and nature that warrant further investigation. First, in contrast to critiques that claim that paying careful attention to natural and material processes is a form of environmental determinism, we think that case study work will show that natural and material processes structure but do not determine social outcomes. Favorable natural conditions do not necessarily lead to either positive or negative developmental outcomes. Under some historical and socioeconomic conditions, favorable natural conditions support the creation of sustained economic development based on raw materials (e.g. the US in coal and iron, Great Britain in woolen textiles), while similar favorable natural conditions under other circumstances fail to do so (Australia in coal and iron ore, the southern US in cotton, Iraq in petroleum). Unfavorable natural conditions can in rare circumstances be socially manipulated to produce positive economic development outcomes (e.g. Japan in steel after the Second World War, the oil sands in western Canada, Great Britain in cotton textiles) – but, even in these cases, it is not clear that the entire chain is ecologically sustainable. Indeed, even in GCCs that are largely 'successful' and 'generative', we expect to find some key nodes that are sites for 'underdevelopment' and ecological degradation.

Second, seemingly constant natural characteristics (e.g. distances between two points on the globe) can be socially manipulated via new forms of technology and social organization (e.g. increasing scale of bulk raw materials ships and container ships) in ways that fundamentally alter both relative economic competitiveness in the world economy and human uses of and impacts on the natural

environment in different areas. Examples include removing the ‘natural tariffs of distance’ that helped to protect local iron and steel industries and local textile industries in earlier eras, both of which had played critical roles in economic development in many areas over the past three centuries, while making it possible for countries like Vietnam with large pools of low-wage labor but distant from core markets to compete in the textile industry.

Third, unfavorable natural conditions in key industries shape state political and military strategies to compete in the world economy. British imperial and then neo-colonial strategies evolved to a significant degree to gain access to cotton in the 1800s and to petroleum in the first third of the 1900s, and Japan’s imperial and then globalization strategies evolved to gain access to iron ore and coal for domestic industrialization.

This focus on longer GCCs also helps us to understand what might be referred to as ‘ecologically unequal exchange’. At the base of *all* commodity chains and production processes are both raw materials and energy. Both involve the often gritty, dirty work of extracting value from the environment. Furthermore, since raw materials and fuel are often bulky, both require the development of large, often very ecologically destructive infrastructural and transport systems to evacuate them from areas where natural resources are found (which, particularly in today’s world, tend to be in remote and often relatively environmentally pristine and sensitive parts of the globe). Of course, all this moving of heavy materials itself uses vast amounts of additional energy. Moreover, these processes are *not* uniformly distributed across the face of the earth. When we lengthen the GCC to start at the ‘beginning’, we find that much environmentally destructive and economically unsustainable extraction goes on in peripheral regions of the world-economy.

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NOTES

- 1 In a recent essay, Immanuel Wallerstein (2008: 89), hails the importance of studying commodity chains and warns that ‘The only thing we have to fear is looking too narrowly.’
- 2 Recently there has been a great deal of discussion of the relationship between global commodity chains (GCCs) and two related concepts: ‘global production networks’ (GPNs) and ‘global value chains’. Both of these formulations are more closely associated with scholars associated with business and management schools, tend to be somewhat less ‘critical’ of capital/labor relations (distancing from the world-system roots), and focus more explicitly on the idea of various economic ‘governance

structures'. For a full discussion of the genealogy and the familial rivalries, see Bair (2008).

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