DO POOR COUNTRIES CATCH UP TO RICH COUNTRIES? STRUCTURAL CHANGE IN THE WORLD-ECONOMY, 1816-1916

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Political Science

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UTAH STATE UNIVERSITY

Logan, Utah
2023

ABSTRACT

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Do poor countries catch up to rich countries? This research approached that question from a world-systems perspective. There have been multiple operationalizations of the structure of the world-economy using 20th century data but no such studies using 19th century data. This research drew upon existing scholarship and the National Material Capabilities (NMCv5) data set to fill the gap. Primary energy consumption per capita was taken as an indicator of degree of industrialization and used to classify each country as core, peripheral, or semi-peripheral status. For the years 1816-1859, classifications were inferred by triangulating theory, data, quantitative techniques, and extent historical research. For the years 1860-1916, classifications were inferred using weighted frequency distributions and Gaussian smoothing. Histograms depicted a tri-modal structure until 1881 and a quadra-modal structure from 1882-1916. The

appearance of an additional mode in 1882 was understood as a temporary bifurcation of the periphery into two substrata—industrial and non-industrial. The results indicated twenty-three upward transitions and five downward transitions. The probability of a country remaining in the same class from one year to the next was 0.973, while the probability of transition was 0.11. The probability of an upward transition was 0.082 and the probability of a downward transition was 0.028. Asymmetrical upward mobility was explained in the context of geographical expansion, which sufficiently increased the population of the periphery to support larger populations in the semi-periphery and core. Nevertheless, Markov chain analysis revealed a stationary system characterized by high levels of inertia and low probability of country-level social mobility. This supports Wallerstein's conceptualization of a system in statistical equilibrium, where class boundaries are fluid, but the overall structure is fixed. A high degree of intertemporal regional dependence was observed across classes, cresting in the core and reaching a low in the industrial periphery. Although there was upward mobility between 1816 and 1916, there were no instances of a country moving from the periphery to the core. Even so, entropy measures suggested economic convergence was in progress for three of the four periods examined. This challenges the view that economic convergence is a new phenomenon.

(80 pages)

PUBLIC ABSTRACT

Do Poor Countries Catch up to Rich Countries? Structural Change in the World-Economy, 1816-1916

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Do poor countries catch up to rich countries? To answer that question, countries were divided into upper class (core), middle class (semi-periphery), and lower class (periphery) based on degree of industrialization as indicated by primary energy consumption data. Findings indicated twenty-three upward transitions and five downward transitions during the period examined. Asymmetrical upward mobility was understood in the context of geographical expansion of the system. This sufficiently increased the population of the lower class (periphery) to support larger populations in the middle class (semi-periphery) and upper class (core). Nevertheless, probability analysis indicated a stable system characterized by high levels of inertia and low probability of social mobility. Although there were instances of upward mobility between 1816 and 1916, there were no examples of a country moving from the lower class (periphery) to the upper class (core). Even so, entropy measures suggested economic convergence was in progress for three of the four periods examined. This finding challenges the view that economic convergence is a new phenomenon.

ACKNOWLEDGMENTS

I give special thanks to my advisor, Colin Flint, whose patience and counsel have made me a better scholar; to my parents, Jim and Sue, who encouraged me to follow my dreams and not give up; and to Calvin, who was ever in my corner.

Jared Walker

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1 INTRODUCTION

The answer to the question *do poor countries catch up to rich countries?* depends on methodological approach and the temporal scope examined. From an empirical standpoint, poor countries have rarely caught up to rich countries. Between 1816 and 1916 there were countries that achieved upward mobility from the set of the world's poorest countries to those that are commonly referred to as middle-income countries. The world-systems perspective interprets this movement in its historical context and the ongoing geographical expansion of colonialism. However, according to available data, there was only one instance of upward mobility from the middle ranking countries to the set of richest countries, namely, Denmark. By *upward mobility*, I am referring to opportunities for a country to better its position in the core-periphery hierarchy of the capitalist world-economy. Alternatively, social mobility may manifest as a downward trajectory.

The world-system perspective holds that the study of long-term social change must begin at the structural level, not the individual or state level, of analysis.[1] It posits the capitalist world-economy, or current world-system, as the fundamental unit of

[1] Robert A. Denmark, Jonathan Friedman, Barry K. Gills, and George Modelski, "An Introduction to World System History: Toward a Social Science of Long-Term Change" in *World System History: The Social Science of Long-Term Change*, ed. Robert A. Denmark, Jonathan Friedman, Barry K. Gills, and George Modelski (New York: Routledge, 2000), xviii; Robert A. Denmark, "Cumulation and Direction in World System History" in *World System History*, 301.

analysis for studying long-term social change. The capitalist world-economy is "an integrated zone of activity and institutions which obey systemic rules."[2] These rules give priority to the endless accumulation of capital or accumulation of capital for its own sake.[3] In such a system, "there exist structural mechanisms by which those who act with other motivations are . . . eliminated from the social scene, whereas those who act with the appropriate motivations are . . . enriched."[4] Immanuel Wallerstein proposed the world-system concept while searching for the largest coherent unit of analysis.[5]

The world-system concept was also an extension of dependency theory in that it articulated explicitly what was implied by structured inequality—a single economy whose structure and rules turned on class dynamics. Social systems are commonly employed units of analysis that vary along multiple dimensions, including size, complexity, and defining properties. The body of literature developing around the social system as a unit of analysis is referred to as systems theory. World-systems may be politically centralized or decentralized. Han China and Rome are historical examples of centralized systems or *world-empires.* The city-states of Renaissance Italy and the Sumerian interstate system

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[2] Immanuel Wallerstein, *World-Systems Analysis: An Introduction* (Durham: Duke University Press, 2004), 17.
[3] Ibid., 24.
[4] Ibid.
[5] Fernand Braudel, *The Perspective of the World: Civilization and Capitalism 15th-18th Century*, Vol. 3 (1992), 70.

are historical examples of decentralized systems or *world-economies.* The modern world-system, the capitalist world-economy, is unique among historical world-systems in that the capitalist mode of production has become dominant and in that it spans the globe; made up of one economy and multiple political entities, namely states.

Dependency theory itself was a response to modernization theorists' failure to anticipate the persistence of poverty in developing economies. Modernization theory holds countries follow a linear path of economic development.[6] Poor countries are at an earlier stage of development than, say, the United States, and given the correct policies, can be expected to catch up to rich countries over time. Instead, international inequality persisted through the mid-20th century.

In 1950, two separately authored papers advanced ideas that have jointly come to be known as the Prebisch-Singer thesis.[7] According to this explanation, class relations are the primary driver of global economic development. Inequality is a structural feature of core-peripheral relations. Furthermore, the wealth gap can be expected to grow due to

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[6] Walt W. Rostow, *The Stages of Economic Growth: A Non-Communist Manifesto* (Cambridge: Cambridge University Press, 1991). See esp. chap. 2, "The Five Stages-of-Growth—A Summary."

[7] Hans W. Singer, "The Distribution of Gains between Investing and Borrowing Countries," in *Milestones and Turning Points in Development Thinking* (London: Palgrave Macmillan, 1950), 265-277; United Nations, "The Economic Development of Latin America and its Principal Problems," in *Economic Commission for Latin America.* (New York: UN Department of Economic Affairs, 1950); John F.J. Toye and Richard Toye, "The Origins and Interpretation of the Prebisch-Singer Thesis," *History of Political Economy* 35, no. 3 (2003): 437-467.

declining terms of trade for poor countries vis-à-vis rich countries. Together, these ideas constituted the core assumptions and protective belt of dependency theory.

While the model explained the persistence of inequality, it failed to explain the persistence of middle-income countries.[8] This dilemma was resolved in 1977, when Hopkins and Wallerstein introduced the commodity chain construct and used it to model core-periphery relations as transnational rather than international.[9] According to this view, the system being analyzed is made up of transnational production networks called commodity chains.[10] The economic activities that link such chains are of two kinds—core and peripheral. In the context of the interstate system, these elements give rise to a three-tiered structure—core, periphery, and semi-periphery. Since that time, several quantitative approaches to structure have emerged in world-systems scholarship. Despite a lack of methodological convergence, approaches are unified by two questions, namely, *what is the structure of the system and how does it change over time?*

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[8] Rabah Arezki, Kaddour Hadri, Prakash Loungani, and Yao Rao, "Testing the Prebisch-Singer Hypothesis since 1650: Evidence from Panel Techniques that Allow for Multiple Breaks," *Journal of International Money and Finance* 42 (2014): 208-223; David I. Harvey, Neil M. Kellard, Jakob B. Madsen, and Mark E. Wohar, "The Prebisch-Singer Hypothesis: Four Centuries of Evidence," *The Review of Economics and Statistics* 92, no. 2 (2010): 367-377; Giovanni Arrighi and Jessica Drangel, "The Stratification of the World-Economy: An Exploration of the Semiperipheral Zone," *Review (Fernand Braudel Center)* 10, no. 1 (1986): 10.

[9] Terence K. Hopkins and Immanuel Wallerstein, "Patterns of Development of the Modern World-System," *Review (Fernand Braudel Center)* 39, no. 1 (1977): 83-128.

[10] The Prebisch-Singer thesis understands core-periphery relations in terms of international trade. See Singer, "Distribution of Gains," 265-277.

Previous analyses of structure and structural change are focused on the 20th century and have used GDP as the key measure for operationalizing upward and downward mobility. The contribution of this thesis is to examine mobility in the 19th century. In order to accomplish this, given the constraints of data availability, the empirical focus must be on energy consumption as the measure of core activities rather than GDP.

This study does two things: it operationalizes the structure of the world-economy and assesses systemic change. Primary energy consumption data are used to assign each country to the status of core, periphery, or semi-periphery. For the years 1816-1859, assignments are inferred based on historical information. For the years 1860-1916, classification is determined with weighted frequency distributions. Markov and entropy analysis shed light on two levels of change—country transitions through the hierarchy and aggregate structural change. The results depict a reshuffling of the hierarchy in response to the incorporation of new populations. Between 1816 and 1916, there were twenty-three upward transitions and five downward transitions. Nevertheless, Markov analysis reveals a stable or stationary system characterized by high levels of inertia and a low probability of social mobility.

2 LITERATURE REVIEW

Since Immanuel Wallerstein theoretically specified and empirically demonstrated the existence of a semi-periphery, four approaches to the question of structure have emerged: network blockmodeling, income-trough classification, parametric classification, and a stochastic change assessment with entropy measures.[11] Network blockmodeling applies structural or regular equivalence to international trade and other network data to group countries based on similarity of social ties. Income-trough classification identifies class and its boundaries using income frequency distributions weighted by population. Parametric classification is a framework for supervised learning methods such as discriminant analysis, neural networks, and regression trees. The stochastic change framework supplements the above classification methods and extend the analysis of structural change. It introduces ways of thinking about, modeling, and measuring change using probability analysis and entropy-based techniques.

Despite methodological differences, these approaches are unified by two common questions, namely, *what is the structure of the current world-system and how does it*

[11] A fifth approach, not covered here, is Chase-Dunn's complex continuum approach. This approach is grounded in the concept of socio-economic approach and abandons discrete strata in favor of a continuous measure of state positions. See Christopher K. Chase-Dunn, *Global Formation: Structures of the World-Economy* (Lanham: Rowman & Littlefield, 1998); Jeffrey D. Kentor, *Capital and Coercion: The Economic and Military Processes that have Shaped the World Economy, 1800-1990* (New York: Garland Publishing, Inc., 2000); Peter Grimes, *Economic Cycles and International Mobility in the World-System: 1790-1990* (PhD Dissertation, John Hopkins University, 1996).

change over time? It is the answers to these questions that represent points of contention.

In his 1974 book, *The Modern World-System*, Wallerstein demonstrates the existence of stable three-tiered structure dating to 16th century Europe.[12] He stresses economic activities over product types due to the changing nature of production.[13] Core activities have historically been identified with high levels of mechanization, skill, and income versus "the peripheral comparative opposite."[14] Core and peripheral countries are distinguished by the kind of economic activities that predominate within their borders.[15] Countries with a more or less even mix of core and peripheral activities make up the semi-periphery; these countries are both exploiter and exploited, "those regions where the sum of 'surpluses' coming in and going out hovers around the zero point" in the words of Aymard.[16] Each zone is also distinguished by its role in reproducing the capitalist system:[17] core states deploy their state machinery to secure quasi-monopolistic

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[12] Immanuel Wallerstein, *The Modern World-System I: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century* Vol. I (Berkeley: University of California Press, 2011). See also Wallerstein, "Three Paths of National Development in Sixteenth-Century Europe," *Studies in Comparative International Development (SCID)* 7, no. 2 (1972): 95-101.

[13] Terence K. Hopkins and Immanuel Wallerstein, "Patterns of Development of the Modern World-System," *Review* (New York: Fernand Braudel Center, 1977), 126-128.

[14] Ibid., 128.

[15] Ibid., 129.

[16] Maurice Aymard, "Nation-States and Interregional Disparities of Development," in *Semiperipheral Development: The Politics of Southern Europe in the Twentieth Century,* ed. Giovanni Arrighi (Ann Arbor: University of Michigan, 1985), 40.

[17] Hopkins and Wallerstein, "Patterns of Development," 142; Wallerstein, *Modern World-System I,* 162.

positions of domestic firms,[18] the semi-periphery stabilizes the system during moments of downturn,[19] and the periphery serves as a source of cheap labor and inputs.[20] Since hierarchical positions are relational, Wallerstein uses the term "structural position" to denote a country's zone.

A seminal contribution to the world-system conceptual model is Hopkins and Wallerstein's 1977 essay, "Patterns of Development."[21] In it, the authors recast the core-periphery dichotomy as transnational in character. Core-peripheral relations are defined by the activities that link global production networks or *commodity chains.*

> What we mean by such chains is the following: take an ultimate consumable item and trace back the set of inputs that culminated in this item—the prior transformations, the raw materials, the transportation mechanisms, the labor input into each of the material processes, the food inputs into the labor. This linked set of processes we call a commodity chain. If the ultimate consumable were, say, clothing, the chain would include the manufacture of the cloth, the yarn, etc., the cultivation of the cotton, as well as the reproduction of the labor forces involved in these productive activities.[22]

More succinctly, a commodity chain is "a set of products and services linked together in

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[18] Hopkins and Wallerstein, "Patterns of Development," 129; Wallerstein, *Modern World-System I,* 136.

[19] Immanuel Wallerstein, "Dependence in an Interdependent World: The Limited Possibilities of Transformation within the Capitalist World-Economy," in *The Capitalist World-Economy* (New York: Cambridge University Press, 1979), 70.

[20] Hopkins and Wallerstein, "Patterns of Development," 144; Wallerstein, *Modern World-System I,* 219.

[21] Hopkins and Wallerstein, "Patterns of Development," 111-145.

[22] Hopkins and Wallerstein, "Patterns of Development," 128.

a sequence of value-adding economic activities."[23] Such economic activities are of two kinds: core and peripheral. Prior conceptualizations assume an international structure of inequality.

The Prebisch-Singer thesis roots inequality in international trade and the tendency of prices of primary products to decline in relation to finished products. Emmanuel's unequal exchange explains inequality as the joint outcome of capital mobility and labor immobility.[24] Hopkins and Wallerstein depart from these conceptualizations. They describe a single division of labor—core and peripheral—realized in the activities that link transnational production networks. By implication, the semi-periphery is derivative; it is epiphenomenal to the transnational division of labor nested in an interstate system.

World-systems analysis differentiates itself from neoclassical theory by its relational approach to inequality. The Prebisch-Singer thesis was itself a reaction to early formulations of modernization theory. Modernization theory holds poor countries can catch up to rich countries by industrializing and adopting pro-market policies.[25] By contrast, Wallerstein's research describes a system in which the number of countries in

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[23] Gary Gereffi, "The Organization of Buyer-Driven Global Commodity Chains: How U.S. Retailers Shape Overseas Production Networks" in *Commodity Chains and Global Capitalism*, ed. Gary Gereffi and Miguel Korzeniewicz (Westport: Praeger, 1994), 97.
[24] Arghiri Emmanuel, *Unequal Exchange: A Study of the Imperialism of Trade,* trans. Brian Pearce (New York: Monthly Review, 1972).
[25] Rostow, *Stages of Economic Growth.*

each zone is fixed, though boundaries between zones are "fluid."[26] He writes, if "some states rise . . . this must mean that other states decline."[27] This situation is sometimes referred to as a statistical equilibrium.[28] Dezzani models the world-system as a Markov transition dependence system.[29] Among other things, this allows for a statistical test of Wallerstein's claim. Dezzani and Dezzani and Babones apply tests of stationarity to the transition matrices of two classification studies.[30] In both cases, transition matrices are stationary, indicating a stable class structure for the periods under examination.

Babones goes further, arguing not only is the overall structure fixed but also the positions of individual countries with that structure.[31] This contradicts economic convergence, the most recent articulation of modernization theory, which expects the per capita incomes to converge given the right policies. A comparison of per capita

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[26] Wallerstein, *Modern World-System I,* 349.

[27] Note: Punctuation is altered but the meaning is not. See Wallerstein, "Development: Lodestar or Illusion?" in *Capitalism and Development*, ed. Leslie Sklair (New York: Routledge, 1994), 8-10.

[28] Scott E. Page, *The Model Thinker: What You Need to Know to Make Data Work for You* (New York: Hachette, 2018), 245.

[29] Raymond J. Dezzani, "Measuring Transition and Mobility in the Hierarchical World-Economy," *Journal of Regional Science* 42, no. 3 (2002): 595-625; Raymond J. Dezzani, "Measuring Transition and Hierarchy of States Within the World-Systems Paradigm," in *Routledge Handbook of World Systems Analysis Theory and Research*, ed. Salvatore J. Babones and Christopher Chase-Dunn (London: Routledge, 2012), 129-128.

[30] Ibid.; Raymond J. Dezzani and Salvatore Babones, "Mobility in the Modern World-Economy, 1975-2005" (presentation, The Andre Gunder Frank's Legacy of Critical Science Conference, University of Pittsburgh, Pittsburgh, April 11-13, 2008).

[31] Salvatore Babones, "Investigating the Degree of Structure in the World-Economy Using Concepts from Entropy Theory" in *Structures of the World Political Economy and the Future of Global Conflict and Cooperation*, ed. Christian Suter and Christopher Chase-Dunn (Zurich: LIT Verlag, 2014), 22; 13-32.

incomes between 1820 and 2008 yields a correlation of 0.956. This means that not only has there been no convergence but also little to no change of positions within the hierarchy. The convergence outlook attributes inequality to institutional differences, such as protections on contracts and private property. Babones assesses this claim with Monte Carlo and entropy-based modeling. He constructs four Monte Carlo models, each assuming a different level of institutional variation, and runs 10000 simulations on each, using entropy techniques to estimate the probability simulations will return a correlation of 0.956 or higher. In the most promising model, only 6.44% of simulations result in a correlation equal to or greater than observed data.[32] "The conditional convergence framework," he writes, "effectively blames poor countries for their failure to grow."[33] Babones concedes the social mobility of China, O*PEC*, and the Asian tigers, but these are exceptions rather than the rule. The greatest accumulation has occurred in Western Europe and British settler colonies. "Over 188 years they went from being three times to 12 times as rich as Africa."[34]

> Consider a physical system that has high-pressure air on the left side separated by a valve from low-pressure air on the right side. A turbine can be rigged in the middle that would spin (and thus do useful work) when the valve is opened and air rushes from the left side to the right side. On the other hand, a similar physical system that has medium air pressure on both sides has the same amount of total energy in the system, but that energy is not configured in such a way that it could perform any useful work. The unbalanced system is more highly structured than the balanced system. By contrast, the balanced system is more entropic (has higher entropy) because its energy is not available for

[32] Ibid., 18-21.

[33] Ibid.

[34] Ibid., 28.

> performing useful work. Income levels in the world economy or analogous to air pressure levels in the hypothetical physical system. A world-economy divided into high-income and low-income countries has more "potential to perform useful work" (in the entropic sense) than a world economy and which all countries have the same medium income level, despite the fact that both systems may have the same overall level of income.[35]

Dezzani notes that a proper evaluation of structure includes classification of countries, a systemic approach to mobility, and measurement of aggregate change over time.[36] He writes, "the basis of rational classification of states and polities requires a theoretical framework that is potentially quantifiable and logically consistent with the functional frameworks to be employed."[37]

The network tradition pioneered by Snyder and Kick and others is the most quantitatively fruitful of the four approaches to structure, consisting of over a dozen classification studies.[38] It is a flexibility approach that allows operational models to

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[35] Ibid., 15.

[36] Dezzani, "Measuring Transition and Hierarchy," 130.

[37] Ibid.

[38] David Snyder and Edward L. Kick, "Structural Position in the World System and Economic Growth, 1955-1970: A Multiple-Network Analysis of Transnational Interactions," *American Journal of Sociology* 84, no. 5 (1979): 1096-1126; Roger J. Nemeth and David A. Smith, "International Trade and World-System Structure: A Multiple Network Analysis," *Review* 8, no. 4 (1985): 517-560; David A. Smith and Douglas R. White, "Structure and Dynamics of the Global Economy: Network Analysis of International Trade 1965–1980," *Social Forces* 70, no. 4 (1992): 857-893; Ronan Van Rossem, "The World System Paradigm as General Theory of Development: A Cross-National Test," *American sociological review* (1996): 508-527; Stephen P. Borgatti and Martin G. Everett, "Models of Core/Periphery Structures," *Social Networks* 21, no. 4 (2000): 375-395; Edward L. Kick and Byron L. Davis, "World-System Structure and Change: An Analysis of Global Networks and Economic Growth across Two Time Periods," *American Behavioral Scientist* 44, no. 10 (2001): 1561-1578; Matthew C.

explore and test different assumptions. Another advantage is the capacity to elucidate intrazonal structures in granular detail. Network methods employ algorithms to partition networks into blocks based on similarity. Typically, growth rates are regressed on structural position, and models are evaluated by their efficacy as predictors. The flexibility of this approach, which stems from the absence of a single conceptual framework, also results disparate and inconsistent findings. For instance, network-based studies describe a structure composed of anywhere from three to eleven blocks.[39]

Mahutga, "The Persistence of Structural Inequality? A Network Analysis of International Trade, 1965–2000," *Social Forces* 84, no. 4 (2006): 1863-1889; Rob Clark and Jason Beckfield, "A New Trichotomous Measure of World-System Position Using the International Trade Network." *International Journal of Comparative Sociology* 50, no. 1 (2009): 5-38; Rob Clark, "World-System Mobility and Economic Growth, 1980–2000," *Social Forces* 88, no. 3 (2010): 1123-1151; Matthew C. Mahutga and David A. Smith, "Globalization, the Structure of the World Economy and Economic Development," *Social Science Research* 40, no. 1 (2011): 257-272; Rob Clark, "World-System Position and Democracy, 1972–2008," *International Journal of Comparative Sociology* 53, no. 5-6 (2012): 367-399; Nina Bandelj and Matthew Mahutga, "Structures of Globalization: Evidence from the Worldwide Network of Bilateral Investment Treaties (1959-2009)," *International Journal of Comparative Sociology* 54, no. 2 (2012): 95-123; Rob Clark and Matthew C. Mahutga, "Explaining the Trade-Growth Link: Assessing Diffusion-Based and Structure-Based Models of Exchange," *Social Science Research* 42, no. 2 (2013): 401-417.

[39] Snyder and Kick discover a ten-block structure, which is collapsed into three blocks and interpreted as corresponding with core, periphery, and semi-periphery. Nemeth and Smith discover eight-blocks, which are combined into four groups—core, periphery, and two semi-peripheries. Smith and White report a three-block structure, which is divided into five blocks—core, semi-periphery1, semi-peripehry2, periphery1, and periphery2. Van Rossem's analysis produces a four-block partition—core, semi-periphery, periphery1, and peripehry2. Kick and Davis's discover eleven blocks, which is collapsed into five—core, socialist semi-core, capitalist semi-core, semi-periphery, and periphery. Mahutga reports a five-block partition—core, strong semi-periphery, weak semi-periphery, strong periphery, weak semi-periphery. Mahutga and Smith find a six-block

Findings also differ regarding country-level social mobility.[40] With the exception Beckfield and Clark's trichotomous model,[41] network methods are not useful for delineating zonal boundaries.

Where network studies do agree—that upward mobility has occurred in greater abundance than downward mobility—such findings are at odds with received theory. Norkus usefully suggests the distinction between absolute and relative social mobility.[42] As can be the case with anomalies in the nature-theory fit, network methods highlight the need for a more robust conceptual foundation. Norkus takes steps in this direction by showing an additional dimension of class structure that follows logically from Arrighi and Drangel's Neo-Weberian-Schumpeterian conceptualization of core-peripheral

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structure—core, sore contenders, upper-tier semi-periphery, strong periphery, weak periphery, weakest periphery. Kick, et. al. partition the world-economy into ten blocks, which they collapse into six—core, semicore, upper semi-periphery and lower semi-periphery, and periphery. Beckfield and Clark's trichotomous methodology returns a three-block structure.

[40] Smith and White observe 15 cases of upward mobility and two of downward mobility from 1965-1980; Mahutga finds 26 upwardly mobile countries and five downwardly mobility countries between 1965 and 2000; Clark and Beckfield report 34 instances of upward mobility and 5 instance of downward mobility from 1980-2000; Mahutga and Smith report 13 cases of upward mobility and 22 of downward mobility for the period of 1965-2000; and Clark finds that 17 countries are upwardly mobile and two are downwardly mobile from 1972-2008.

[41] Clark and Beckfield, "A New Trichotomous Measure," 5-38; Clark, "World-System Mobility," 1123-1151; Clark, "World-System Position and Democracy," 367-399.

[42] Zenonas Norkus, "On Global Social Mobility, or How Kondratieff Waves Change the Structure of the Capitalist World System" in *Kondratieff Waves: Cycles, Crises, and Forecasts*, ed. Leonid E. Grinin, Tessaleno C. Devezas, and Andrey V. Korotayev (Volgograd: Uchitel Publishing House, 2017), 146.

relations.[43] Whether this can be developed into a cohesive framework capable of providing theoretical direction is another question.

Dezzani's parametric classification is a framework that can be incorporated by a number of supervised learning methods, including discriminant analysis, regression trees, and neural networks.[44] These approaches build classification algorithms on the basis on training inputs. To date, the only study to utilize this framework is Dezzani's classification study of 85 countries, 1960-1990. He applies discriminant analysis to the data at ten-year intervals with training inputs derived from Wallerstein's research.[45] This approach is capable of delineating class-level characteristics that correspond with different zones. The analysis finds that different variables account for varying degrees of explanation at different times. In 1960, core states are distinguished by internal features, such as productivity and population density. By 1990, the three zones are differentiated more by trade composition, such as export diversity and trade partner concentration.[46] Statistical classification methods that use pattern recognition can also detect the appearance of new classes. Dezzani's analysis finds three classes of countries for the year 1960 but four classes for subsequent years. The formation and growth of O*PEC* in the 1960s and 1970s entailed a divergence in the GDP and trade patterns of particular

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[43] Ibid., 121-152.

[44] Raymond J. Dezzani, "Classification Analysis of World Economic Regions," *Geographical Analysis* 33, no. 4 (2001): 339; 330-352; Dezzani, "Measuring Transition and Hierarchy," 129-138.

[45] Dezzani, "Classification Analysis of World Economic Regions," 334.

[46] Ibid., 330, 339-346, 348.

countries. The rise of *OPEC* is described as a bifurcation from the periphery; it falls between the periphery and semi-periphery in terms of status.[47]

Bifurcation is one of two types of systemic change outlined in Dezzani's stochastic change perspective.[48] It involves a sudden change in systemic configuration, or "systemic regime shift" resulting from a specific set of unusual circumstances.[49] Dezzani's use of the term "bifurcation" differs from Wallerstein's, which follows Prigogine usage to describe dissipative structures.[50] Dezzani's concept involves a process similar to Thompson's urban growth ratchet, which describes population growth in cities that reach a critical population threshold.[51] Dezzani writes, "The ratchet effect produces change suddenly when a sufficient concentration of capital has been accumulated. As such, change may occur as discrete jumps or steps corresponding to a bifurcation or threshold change in the state space producing a new variety."[52]

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[47] Ibid., 348.

[48] Dezzani, "Measuring Transition and Mobility," 620.

[49] Ibid.; Dezzani, "Measuring Transition and Hierarchy," 136.

[50] Prigogine shows that thermodynamic systems are stable so long as their microdynamics fluctuate close to equilibrium. If microdynamics fluctuate too far from equilibrium, the system reorganizes itself into a new dissipative structure, qualitatively from the one that came before. The threshold at which this occurs is the bifurcation point. Wallerstein's writings suggest he sees similar patterns in the transition from feudalism to capitalism. Likewise, the end of capitalism will entail the transition to a new type of system that is qualitatively different from the present one. See Debra Straussfogel, "A Systems Perspective on World-Systems Theory," *Journal of Geography* 96, no. 2 (1997): 119-126.

[51] Dezzani, "Measuring Transition and Mobility," 620; Wilbur R. Thompson, *A Preface to Urban Economics* (Baltimore: Johns Hopkins University Press, 1965).

[52] Ibid.

The other more gradual type of systemic change is typical of that seen in country-level transitions between zones. Dezzani's stochastic approach utilizes Markov chains to capture country-level mobility and entropy analysis to measure the rate of aggregate structural change.[53] These methods have been applied in the research of Dezzani and Dezzani and Babones.[54] In both cases, transition probabilities are stationary over the period of examination, indicating high levels of inertia across zones. Stable transition matrices can be used for prediction, but their usefulness decays if bifurcation occurs.[55] In addition, logistic regression can be used to test for relationships between variables and country-level mobility.

In all, four classification studies have implemented Arrighi and Drangel's income-trough analysis.[56] This approach involves weighted histogram analysis to operationalize structure on the basis of income distribution. Arrighi and Drangel use gross national product to estimate the "distribution of the total product" among

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[53] Ibid.; Dezzani, "Measuring Transition and Hierarchy," 129-138.

[54] Dezzani, "Measuring Transition and Mobility," 595-625; Dezzani and Babones, "Mobility in the Modern World-Economy, 1975-2005."

[55] Dezzani, "Measuring Transition and Mobility," 595-625; Dezzani, "Measuring Transition and Hierarchy," 129-138.

[56] Giovanni Arrighi and Jessica Drangel, "The Stratification of the World-Economy: An Exploration of the Semiperipheral Zone," *Review (Fernand Braudel Center)* 10, no. 1 (1986): 9-74; Roberto Patricio Korzeniewicz and William Martin, "The Global Distribution of Commodity Chains," in *Commodity Chains and Global Capitalism*, ed. Gary Gereffi and Miguel Korzeniewicz (Westport: Praeger, 1994), 67-91; Salvatore J. Babones, *The International Structure of Income and Its Implications for Economic Growth, 1960-2000* (Ph.D. Dissertation, Johns Hopkins University, Baltimore, 2002); Salvatore J. Babones, "The Country-Level Income Structure of the World-Economy," *Journal of World-Systems Research* 11, no. 1 (2005): 28-55.

economic activities that link global commodity chains.[57] This is justified through an implicit incorporation of Weberian class theory.[58] Weber defines capitalist exploitation in terms of monopolistic appropriation of market opportunities rather than ownership of the means of production.[59]

> In our view, the use of the term "surplus" is neither necessary nor helpful in defining core-periphery relations. All we need is to assume that economic actors . . . far from accepting competition as a datum, continuously endeavor to shift, and some succeed in shifting, the pressure of competition from themselves onto other actors. As a result, the nodes or economic activities of each and every commodity chain tend to become polarized into positions from which the pressure of competition has been transferred elsewhere (core-like activities) and positions to which such pressure has been transferred (peripheral activities).[60]

If the goal of monopolization is to maximize the share of reward accruing to a particular group, then core and peripheral processes can be distinguished by the quantum of benefits they deliver. An ideal operationalization would entail mapping global commodity chains and measuring benefits accrued at each point in the production process. But, Arrighi and Drangel contend, data constraints make this impracticable.[61] Moreover, accrued reward is capturable in aggregate.

> The greater the weight of peripheral activities in the mix falling within the jurisdiction of a given state, the smaller the share of the total benefits of the world division of labor commanded by the residents of that state. And,

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[57] Arrighi and Drangel, "Stratification of the World-Economy," 16.
[58] Norkus, "On Global Social Mobility," 121-152.
[59] Norkus, 137-138; See also Frank Parkin, *Marxism and Class Theory: A Bourgeois Cri*tique (New York: Columbia University, 1979).
[60] Arrighi and Drangel, "Stratification of the World-Economy," 17.
[61] Ibid., 30.

> conversely, the greater the weight of core activities, the larger the share of those benefits commanded by the residents of a state.[62]

Gross national product is appropriate since it is a measure of both product and income. Per capita GNP is selected to hold population size constant across countries.

Smith and White criticize Arrighi and Drangel for the "extremely dubious assumption that GNP per capita is the key measure."[63] It is possible they take umbrage with one or more of Arrighi and Drangel's assumptions, but they do not say. Arrighi and Drangel's conceptualization is somewhat obscured by their failure to make their assumptions fully explicit. It is more likely, however, that their skepticism stems from an unfamiliarity with the theoretical traditions underpinning Arrighi and Drangel's article. In addition to having deep roots in Weber and Schumpeter, Arrighi and Drangel's approach is the only one rooted global commodity chains; and thus it is the most consistent with Hopkins and Wallerstein's transnational model of core-peripheral relations.

Like Wallerstein, Arrighi and Drangel see technological innovation and diffusion as fundamental to class formation, but they stress the transnational character of competition in this process. "[F]ollowing Schumpeter, we trace the fundamental impulse that generates and sustains competitive pressures in a capitalist economy to profit-oriented innovations defined as 'the setting up of a new production function' or, in our

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[62] Ibid, 31.

[63] Smith and White, "Structure and Dynamics of the Global Economy," 863.

terms, the setting up, widening, deepening, and restructuring of commodity chains."[64] Profit-oriented innovations trigger transnational shifts in competition pressures that occurs through the medium of global commodity chains.

Arrighi and Drangel operationalize their concept by plotting histograms of the sum of national populations corresponding to income bins of a 0.1 width on a logarithmic scale.[65] Logarithmic transformation normalizes the data and indicates relative rather than absolute differences between countries.[66] GNP per capita is measured in U.S. dollars to demonstrate global command of economic resources rather than differences in standards of living.[67] Finally, Arrighi and Drangel employ a three-bin moving average as a smoothing technique.[68] This analysis is applied to data across nine time points—1938 (n=57), 1948 (n=58), 1950, 1960, 1965, 1970, 1975, 1980, and 1983 ($n \approx 100$).[69] A trimodal distribution is reported for five of the nine years examined (1938, 1950, 1975, 1980, and 1983), though the distribution for other years is less clear (1948, 1960, 1965, and 1970).[70] Arrighi and Drangel take trimodally as evidence of the three-tiered structure. Each peak corresponds to a zonal center and each trough, a zonal

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[64] Arrighi and Drangel, "Stratification of the World-Economy," 18.
[65] Salvatore J. Babones, "The Country-Level Income Structure," 39.
[66] Ibid., 31.
[67] Ibid., 31.
[68] Salvatore J. Babones, "The Country-Level Income Structure," 39.
[69] Arrighi and Drangel, "Stratification of the World-Economy," 60-61. Sample sizes for the seven observations points between 1950 and 1983 range from 100 to 105 per year.
[70] Ibid., 32-35.

boundary.[71] The inconsistent location of troughs across time suggests an interval or vestibule approach to zonal boundaries rather than a particular point on the x-axis. Consequently, countries may be grouped into five categories: core, perimeter of the core (PC), semi-periphery, perimeter of the periphery (PP), and periphery. This approach is "a compromise between the need to define the zones in the spirit of our previous [trichotomous] conceptualization and the need to retain for further analysis as many features as possible of the actual distributions."[72]

Wallerstein conceptualizes class formation as a process that begins in the core with the transmogrification of technological innovations into new commercial products. Arrighi and Drangel apply this to interpret their findings, but they extend the conceptualization to explain structural constraints on social mobility. Referring to the troughs of the income distribution, they write,

> Point PC on the x-axis corresponds to the threshold above which states have the capability to upgrade the mix that falls under their jurisdiction, so as to consolidate their core position; and point PP corresponds to the threshold below which states have little or no power, not only to upgrade but even to prevent the downgrading of their mix provoked by the consolidation of core positions. | Between these two thresholds lies the semiperipheral zone, that is the ensemble of all states that, because of the more or less even mix of core-peripheral activities over which they have jurisdiction, wield the power to prevent the downgrading of their mix but have little power to promote its upgrading.[73]

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[71] Ibid., 28-29.

[72] Ibid., 36.

[73] Ibid., 28-29.

Social mobility is constrained by the differential capacities of state actors to "upgrade" their mix of core-peripheral activities.

Arrighi and Drangel report a pendulum-like movement of downward mobility in the years 1938-1960/70 followed by an upward movement during the years 1960/70-1983. They interpret this as a reflection of the falling behind and catching up of countries in response to commercial innovations.

> This pendulum-like movement is easily interpreted in light of . . . the establishment of U.S. hegemony, which ushered in a cluster of technological and organizational innovations of world-economic significance. Core-periphery relations were accordingly revolutionized and a new "standard of coreness" established.[74]

Previous iterations of hegemony also involved institutional transformations that corresponded with waves of decline. In the wake of Dutch hegemony, "Spain and Portugal failed to be, were unable to be, mercantilist," according to Wallerstein, "and thus they became transformed into semiperipheral states, conveyor belts for the interests of the core powers in the peripheral regions."[75] Wallerstein notes that hegemonic and Kondratieff cycles share a common structure.[76] Both involve with the innovation and diffusion of technologies associated with the waxing and waning of quasi-

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[74] Ibid., 48.

[75] Wallerstein, *Modern World-System II*, 158.

[76] Immanuel Wallerstein, "Structural Crisis, or Why Capitalists May No Longer Find Capitalism Rewarding" in *Does Capitalism Have a Future*, ed. Immanuel Wallerstein, Randall Collins, Michael Mann, Georgi Derluguian, and Craig Calhoun (New York: Oxford University, 2013), 19-29.

monopolies—whether commercial or geopolitical.[77] At the outset of U.S. hegemony, these cycles briefly synchronized to produce a single fluctuation of increased amplitude.[78]

Arrighi and Drangel offer additional analyses of structural change by tracking zonal trends in per capita GNP, population size, and industrialization. Contra Frank and Wallerstein, Arrighi and Drangel find no evidence that "polarizing tendencies" are weaker in the B-phase than in the A-phase.[79] Instead, polarizing tendencies take alternate forms throughout the cycle—that of *widening peripheralization* during the A-phase and *deepening peripheralization* during the B-phase. The first refers to an increase in the proportion of world population living in the periphery; the second describes a widening of reward differentials separating the periphery from the core. There is no substantial change in system structure when the period is considered in its entirety.[80] Ninety-five percent of countries and 94 percent of the population are in the same zone in 1983 as in 1938.[81] Twenty-two out of 93 countries transition between zones, but only five such transitions are permanent. [82] Arrighi and Drangel suggest such medium-term

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[77] Ibid.
[78] Wallerstein, "Structural Crisis," 34.
[79] Andre Gunder Frank, *Capitalism and Underdevelopment in Latin America*, (New York: New York University, 1967), 33; Immanuel Wallerstein, "Semiperipheral Countries and the Contemporary World Crisis," in *The Capitalist World-Economy* (New York: Cambridge University Press, 1979), 95-118.
[80] Arrighi and Drangel, "Stratification of the World-Economy," 58, 42.
[81] Ibid., 44.
[82] Ibid., 42-44.

fluctuations of structure are associated with the long-term stability of the system.[83] This is reminiscent of Prigogine's concept of "order through fluctuations."[84]

To evaluate claims of modernization theorists, Arrighi and Drangel compare zonal trends in per capita income and industrialization.[85] They use two indicators of industrialization: manufacturing as a share of GNP and percent of labor force employed in manufacturing. The structural position or "economic command" of each zone is calculated as the weighted average of its members' GNP per capita. From 1938-1960, they find a positive correlation between the two. Changes in GNP per capita are mirrored by changes in levels of industrialization. However, in the period from 1970-1983, these trends exhibit a negative correlation. The semi-periphery and periphery industrialize relative to the core, but the gap in GNP per capita between these zones widens. This undercuts the claims of modernization theory and supports Wallerstein's distinction between industrialization and development. This distinction is grounded in the changing nature of production that unfolds through the constant restructuring of commodity chains. In this process, formerly cutting-edge technologies are demoted to a lower status in the hierarchy as they are displaced by new innovations in the core.[86]

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[83] Ibid., 47.

[84] Straussfogel, "A Systems Perspective," 119-126.

[85] Arrighi and Drangel, "Stratification of the World-Economy," 53-56.

[86] Wallerstein describes this process in *Historical Capitalism*: [G]iven products have had 'product cycles', starting off as core products and eventually becoming peripheral products. Furthermore, given loci have moved up or down, in terms of comparative well-being of their inhabitants. But to call such reshuffles "development", we would first have

Conflating industrialization with "catching up" misunderstands this process. Arrighi and Drangel conclude the "the industrialization of the semiperiphery and periphery has ultimately been a channel, not of subversion, but of reproduction of the hierarchy of the world-economy."[87]

Two subsequent studies replicate Arrighi and Drangel's methodology.[88] Korzeniewicz and Martin's study, 1938-1987, draws data from a larger sample size and operationalizes structure across 34 points in time.[89] They confirm a stable trimodal distribution and extend their analysis to study shifting patterns of production among zones. Babones' research introduces methodological refinements, including Gaussian smoothing and a smaller bin size.[90] He draws data from a consistent sample size (n=103) to operationalize structure annually from 1975-2002.[91] Over the 28-year period, only 17 countries made permeant transitions (lasting five years or longer) across zones.[92]

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to demonstrate a reduction of the global polarization of the system. Empirically, this simply does not seem to have happened; rather polarization has historically increased. See Immanuel Wallerstein, *Historical Capitalism* (Verso: New York, 1996), 35-36.

[86] Arrighi and Drangel, "Stratification of the World-Economy," 56.

[87] Ibid.

[88] Korzeniewicz and Martin, "Global Distribution of Commodity Chains," 67-91; Babones, *International Structure of Income*. Babones, "Country-Level Income Structure," 28-55.

[89] Roberto Patricio Korzeniewicz and William Martin, "The Global Distribution of Commodity Chains," in *Commodity Chains and Global Capitalism*, ed. Gary Gereffi and Miguel Korzeniewicz (Westport: Praeger, 1994), 67-91.

[90] Salvatore J. Babones, "The Country-Level Income Structure," 42-43.

[91] Ibid., 42-43.

[92] Ibid., 50-53.

In sum, Arrighi and Drangel's income trough approach is a reliable heuristic for scientifically describing world-system structure. The use of income frequency weighted by population resembles the way we think about social class, at least its economic dimension. The approach describes a stable three-tiered structure with compelling consistency. It is a flexible approach that can, but does not have to be, used to study political and economic cycles. It also dovetails with Dezzani's stochastic change assessment. This fact, coupled with its parsimony and modest data requirements make it highly replicable. The research presented here leverages the income trough approach to describe classifications from 1816-1916 using primary energy consumption as the key measure of core economic activity within a country's borders.

3 DATA AND METHODS

This study measures structure and structural change in the world-economy between 1816 and 1916. It consists of three tasks: classifying countries into discrete classes, identifying and analyzing permeant transitions between classes, and statistical analysis of structural change. For the years 1860-1916, status was assigned based on Arrighi and Drangel's income trough approach.[93]Analysis was performed with the National Material Capabilities (NMCv5.0) data set. The 1816 classifications were inferred using Arrighi and Drangel's concept of class and available information. Until 1882, the periphery is characterized by zero measurable primary energy consumption. Therefore, from 1816–1859, the appearance of non-zero fossil fuel consumption in the periphery was taken as evidence of transition to the semi-periphery. There is no change in the makeup of the core between 1816 and 1860, thus mitigating the need to define the perimeter of the core (PC) for those years. Dezzani's stochastic-entropy framework was used to evaluate social mobility, path dependence, and aggregate structural change.

The NMCv5.0 dataset was constructed with disciplinary assumptions and is here been repurposed for world-systems research. The creators of the dataset, Singer and Small, conceive the interstate system as a political system above all else. By contrast,

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[93] J. David Singer, Stuart Bremer, and John Stuckey, "Capability Distribution, Uncertainty, and Major Power War, 1820-1965," in *Peace, War, and Numbers*, ed. Bruce Russett (Beverly Hills: Sage, 1972): 19-48; David Singer, "Reconstructing the Correlates of War Dataset on Material Capabilities of States, 1816-1985," *International Interactions*, 14 (1987): 115-32.

world-systems analysis gives priority to economics; politics is secondary. Wallerstein describes populations becoming "incorporated" or "hooked" into the capitalist world-economy, a process signaled by three developments: 1) a new pattern of imports/exports reflective of core-periphery relations, 2) growth in the scale of economic processes and decision-making entities, and 3) a significant increase in forced labor.[94] Typically, incorporation entailed the colonization of indigenous populations by European powers.

Singer and Small give two conditions for system membership between 1816 and 1920. These are 1) a population of 500,000 or greater and 2) diplomatic missions with Britain and France at or above the rank of charge d'affaires.[95] The criteria are intended to identify political entities with populations large enough "to play a moderately active role in world politics"[96] and which are "sufficiently unencumbered . . . to exercise a fair degree of sovereignty and independence."[97] Singer and Small understand membership in the interstate system as a reflection of sovereignty and independence, whereas Wallerstein understands incorporation unfolding through colonization and forced labor. In most cases, Singer and Small's criteria results in a later date for system membership

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[94] Wallerstein, *Modern World-System III*, 137.

[95] Correlates of War Project, 2017 "State System Membership List, v2016," http://correlatesofwar.org.

[96] Melvin Small and J. David Singer (1982). Resort to Arms: International and Civil Wars, 1816-1980. Sage Publications, pp. 38-46, as quoted in Correlates of War Project, 2017 "State System Membership List, v2016," http://correlatesofwar.org.

[97] J. David Singer and Melvin Small (1972). The Wages of War 1816-1965: A Statistical Handbook. John Wiley & Sons, pp. 20, as quoted in Correlates of War Project, 2017 "State System Membership List, v2016," http://correlatesofwar.org.

than Wallerstein's. Consequently, the periphery is underrepresented in this study. Singer and Small date India's system membership to 1947, for example, while Wallerstein dates its incorporation to 1750-1850.[98] Another difficulty is that incorporation is a process which can span up to a century. Wallerstein dates the incorporation of Russia and the Ottoman Empire from 1750-1850, whereas Singer and Small assign these states membership the first year of the dataset, 1816.

Research components are outlined in Table 1.

[98] Immanuel Wallerstein details this process in *The Modern World-System III: The Second Era of Great Expansion of the Capitalist World-Economy, 1730-1840s* Vol. 3 (Berkeley: University of California Press, 2011), 127-189.

Table 1: Research Components

Variables	
• Population	NMCv5
• Primary energy consumption per capita or *PEC per capita*	NMCv5
Units of Analysis	
• Capitalist system or world-economy	Transnational commodity chains Interstate system
• Class or zone	Core C Semi-periphery S Periphery P
○ Substrata	Industrial Periphery P2 Nonindustrial Periphery P1
○ Thresholds	Perimeter of the core PC Perimeter of the periphery PP Perimeter of the industrial periphery PP2 Perimeter of the nonindustrial periphery PP1
Units of Observation	
• State or polity	n = 16–44
• Year	n = 101; 1816-1916
• Kondratieff cycle	A-Phase (1848-1873; 1893-1917) B-phase (1810-1848; 1873-1893)
• Hegemonic cycle	A-Phase (1815-1873) B-phase (1873-1945)
• State-level transition	This variable is constructed of three data points—year, state, and class status—and is conceptualized in two ways: year-over-year transitions and transitions lasting five years or longer. 1. Year-over-year transitions are fitted to Markov chains for probability analysis. Transitions can be upward, downward, or lateral. In the case of annual transitions, a state's class status for two consecutive years constitutes a single transition, e.g., S-S, S-C, C-S, S-P, etc. 2. Transitions lasting five years or longer provide a visual rendering of structural change with reduced noise. See Table 5 of the Results section. Lateral transitions are not counted.

The NMCv5.0 Data Documentation details methods of data acquisition and outlines problems and potential errors.[99] Due to the scarcity of historical data, many values for population and primary energy consumption in the nineteenth century are estimated with quantitative methods. Data hosts Greig and Enterlein observe, "As one moves further back toward 1816, statistical availability and quality deteriorates."[100]

Population: The NMCv5 documentation defines national population as all residents living within a nation's boundaries plus military personnel abroad. Where possible, population data are taken from national tallies, either from census data or official surveys. But, as data hosts Greig and Enterlein note, "modern census-taking was rare before 1850 in Europe . . . and rare before the First World War elsewhere." [101] In the absence of historical sources, estimates are derived through least squares linear regression, interpolation between known data points, and extrapolation. Each value is assigned a quality code depending on the historical sources and methods of estimation.[102] Unlike the Maddison data, the NMCv5.0 data accounts for historical shifts in state boundaries.

Primary energy consumption per capita: As an indicator of industrial activity, primary energy consumption (hereafter *PEC*) correlates with 19th century core activity.

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[99] Correlates of War Project, 2017 "National Material Capabilities (NMC) Data Documentation, v5.0," http://correlatesofwar.org.
[100] Ibid.
[101] Correlates of War Project (2017) NMC v5.0 Supplementary, http://correlatesofwar.org.
[102] Ibid.

The standard of coreness associated with British hegemony is mechanization of industry and transport. Thus *PEC per capita* is taken as an indicator of a country's particular mix of core (industrial) and peripheral (pre-industrial) economic activities standardized by population.

In NMCv5, *PEC* describes the annual national consumption of industrial forms of energy—coal, petroleum, electricity, and natural gas—converted into common units of one-thousand metric coal-ton equivalents.[103] Preindustrial energy sources such as wood, charcoal, fecal matter, and peat are of such small quantities they are not included.[104] The variable is constructed from four component measures—production of energy commodities, import of energy commodities, export of energy commodities, and the change in domestic stocks of energy commodities. Data on coal, petroleum, electricity, and natural gas commodities are converted into common units of one-thousand metric coal-ton equivalents.[105] The formula for calculating *PEC* is straightforward:

$$PEC = Production + Imports - Exports - Domestic\ Stocks$$[106]

Change in domestic stock reflects the fact that states maintain energy commodities in case of disruption to trade.[107] Information for these commodities is taken primarily from

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[103] Correlates of War Project, 2017 "National Material Capabilities (NMC) Data Documentation, v5.0," 58, http://correlatesofwar.org.
[104] Ibid.
[105] Ibid.
[106] Ibid., 57.
[107] Ibid., 58.

Brian R. Mitchell's data.[108] When data for one or more commodity is missing, values are estimated using log-linear interpolation between known data points or log-linear extrapolation. Missing values were also extrapolated using data from states that developed at a similar rate to the state with missing data. Each value is coded according to the quality of original sources and methods used for estimation.[109]

The existence of zero values in the *PEC* data made ninth root transformation ($x^{1/9}$) a natural choice for data normalization. In all, eight transformations were considered, including logarithmic, squared, inverse, inverse squared, inverse square root, third root, ninth root, and Box-Cox.[110] Box-Cox and ninth root transformations had the most normalizing effect. Box-Cox transformed distributions had the least amount of kurtosis, and ninth root transformed distributions had the least amount of skew. Of the transformations examined, ninth root the nineth root transformation had the most normalizing effect. Figure 1 shows the distribution of *PEC per capita* prior to transformation.

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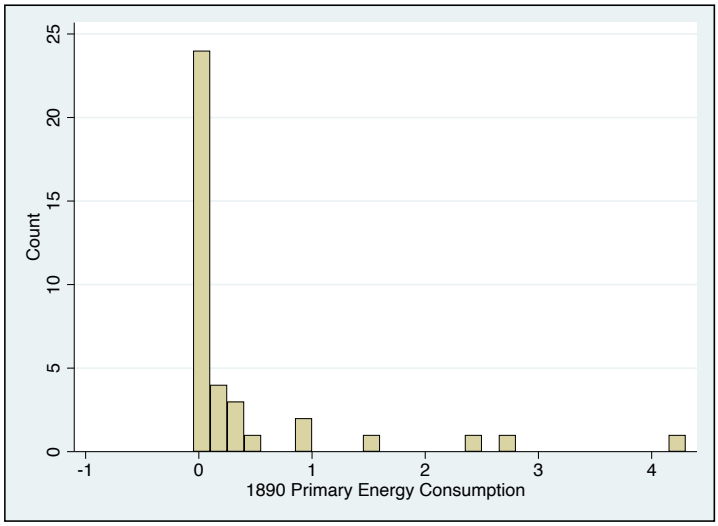
[108] Ibid.; Brian R. Mitchell, *British Historical Statistics* (Cambridge: Cambridge University Press, 1988); Brian R. Mitchell. *International Historical Statistics: Europe, 1750-1993* (New York: Stockton Press, 1998); Brian R. Mitchell, *International Historical Statistics: Africa, Asia & Oceania, 1750-1993* (New York: Stockton Press, 1998); Brian R. Mitchell, *International Historical Statistics: the Americas, 1750-1993* (New York: Stockton Press, 1998).

[109] Correlates of War Project (2017) NMC v5.0 Supplementary, http://correlatesofwar.org.

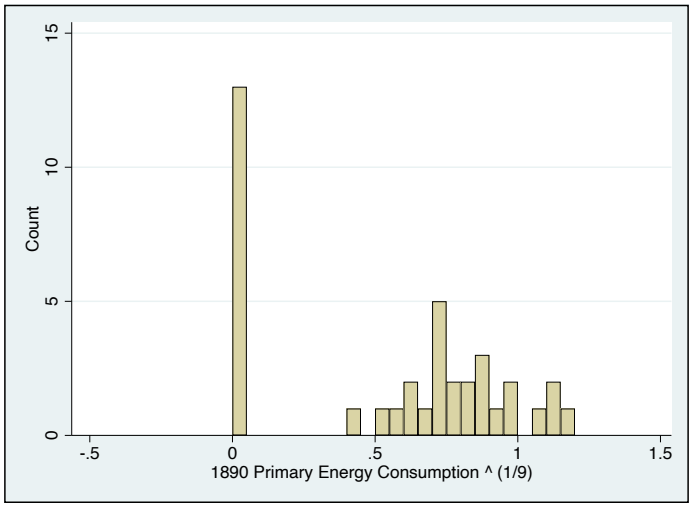
[110] For logarithmic, Box-Cox, and inverse transformations, a constant value of 1 was added to *PEC per capita*.

Figure 1: Distribution of *PEC per capita*



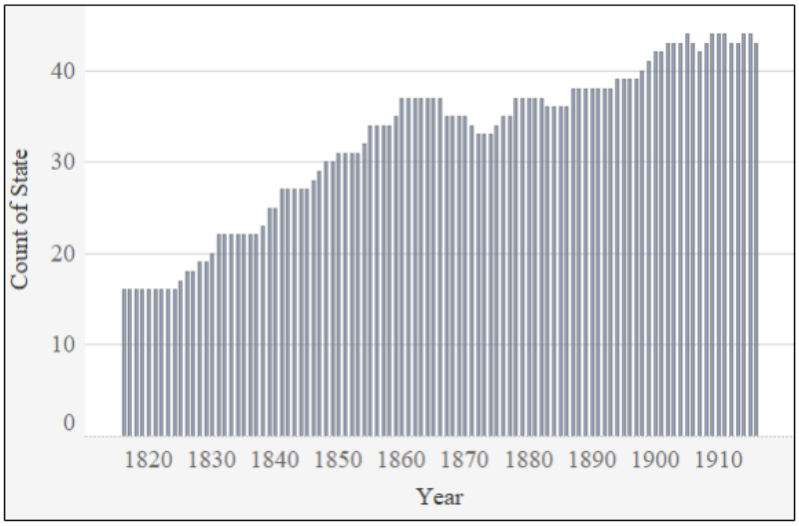
Prior to transformation, the distribution of *PEC per capita* has a kurtosis of 9.44 and skewness of 3.02. Figure 2 shows the distribution of nineth root transformed data—*PEC per capita*$^{1/9.}$ After transformation, the distribution has a kurtosis of –1.62 and skewness of –0.2. Minus the large number of countries falling into the zero bin, the transformed data appears normal.

Figure 2: Distribution of *PEC per capita*$^{1/9}$



State or polity: We have discussed the criteria for statehood for Singer and Small's system—a population of 500,000 or greater and diplomatic missions with Britain and France. The NMCv5.0 data set contains data only for the polities that satisfy these conditions. Figure 3 is a graphical representation of the number of country observations per year.

Figure 3: Number of Observations by Year



System: The world-systems perspective understands the interstate system as the political superstructure of a transnational economy. This world-economy is defined by a single division of labor into economic activities of two kinds—core and peripheral. These economic activities link global commodity chains in a transnational process of production. With respect to operationalizing this structure, Arrighi and Drangel write,

> It must be stated at the outset that there is no operational way empirically distinguishing of between peripheral and core-like activities and therefore of classifying states according to the mix of core-peripheral activities that falls under their jurisdiction. . .. In order to classify activities as core-like or periphery-like, we would minimally need a complete map of all commodity

> chains of the world-economy, as well as an assessment of the relative competitive pressure at each of their nodes.[111]

Any attempt to operationalize the world-economy is necessarily constrained by the data available, which in this case is aggregate data at the level of the state. So, while the world-economy is transnational in character, it is operationalized as international for lack of data.

Zone or class: Zones are geographical regions characterized by one of the following: predominantly core economic activities, predominantly peripheral activities, or a more or less even mix of such activities (in the case of the semi-periphery). These zones can also be thought of as classes or tiers of hierarchy in the interstate system. Since a complete map of commodity chain data is not feasible, Arrighi and Drangel employ aggregate measures of income data to estimate the mix of core-peripheral activities within each state. Histograms of (logged) GNP per capita weighted by population provide graphical representations of the distribution of income in the system. A moving average is applied for smoothing, which Babones has refined with Gaussian smoothing. Babones writes "There is no theoretical guidance as to what is an 'appropriate' level of smoothing."[112] It should be noted that one can derive any number of classes depending on the level of smoothing used.

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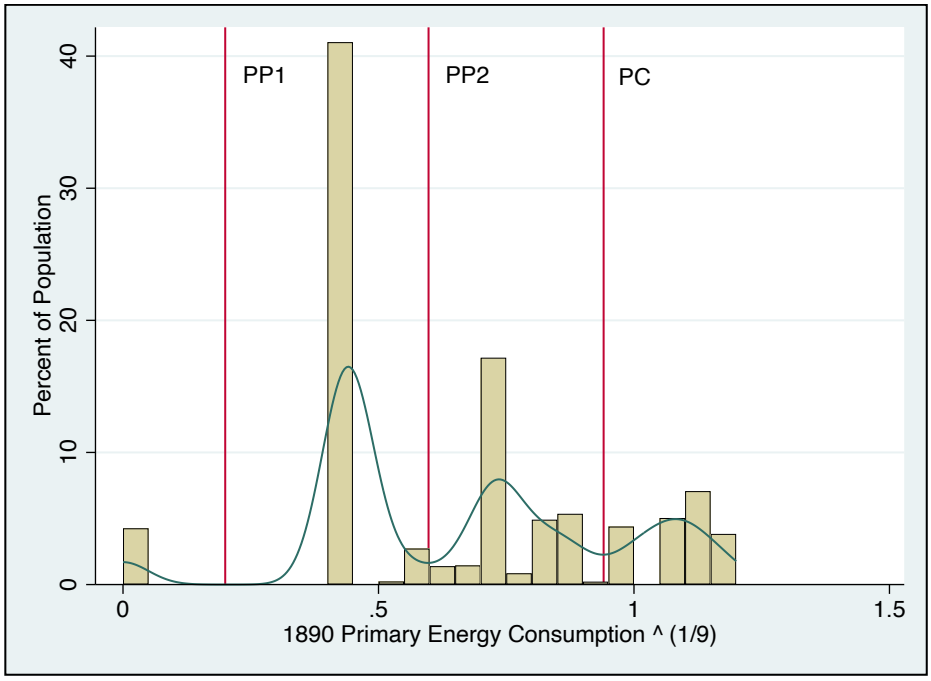
[111] Arrighi and Drangel, "Stratification of the World-Economy," 30.

[112] Babones, "Country-Level Income Structure," 43.

The histogram in Figure 4 displays the same data as the histogram in Figure 2, only weighted by population. In Figure 4, each state's *PEC per capita*[1/9] is plotted along the x-axis and the sum of state populations is plotted along the y-axis. Following Babones, the lowest points in the density plot, or troughs, designate the perimeter of the core and the perimeter of the periphery. Gaussian smoothing allows us to identify zonal boundaries at precise points on the x-axis instead of imprecise margins. Nevertheless, Arrighi and Drangel's conceptualization of the PC and PP remain a significant empirical and theoretical contribution to our understanding of structure and structural change. As notes previously, the PC constitutes the lower boundary of the core, and the PP constitutes the upper boundary of the periphery. In Figure 4, point PC on the x-axis corresponds to the threshold above which states have the capability to upgrade their economic processes and maintain their core position. Point PP corresponds to the threshold below which states have little or no power to upgrade their economic processes. The failure to upgrade does not have a neutral outcome but amounts to a downgrading or falling behind. Since this histogram has a two-tiered periphery, the perimeters are labeled PP1 and PP2.

Figure 4: Distribution of *PEC per capita*$^{1/9}$ Weighted by Population



In Arrighi and Drangel's conceptualization, the PC and PP are those countries that systematically fluctuate between classes due to political and economic cycles. During the A-phase, the PC and PP involve countries trying to retain their status and prevent a downward transition. These countries are those who fail to upgrade their economic activities in the wake of commercial innovation in the core and are thus left behind. During the B-phase, the PC and PP consist primarily of countries attempting to make upward transitions. These countries are poised to exploit shifts in investment toward the semi-periphery associated with the erosion of quasi-monopolies in the core. This conceptual model of class boundaries makes it possible to infer classifications when the data are too sparse for histogram analysis by identifying economic shifts in the context of political and economic cycles. Arrighi and Drangel's conceptualization is

triangulated against Wallerstein's classifications, our 1860 classification, and available *PEC per capita* values in 1816 to infer classifications for that year.

Kondratieff cycle: Wallerstein draws on Schumpeter's Kondratieff hypothesis to elucidate the role of commodity chains in class formation.[113] The Kondratieff hypothesis explains 50-year fluctuations in aggregate time series data based on technological innovation and diffusion. Yet, scientific research of these cycle-like phenomena is wholly descriptive due to the primitive state of conceptual and statistical models.[114] Wallerstein attributes patterns of technological innovation and diffusion described by Schumpeter with the formation and erosion of quasi-monopolies in the core. Wallerstein conceives the Kondratieff cycle as having two phases. During the A-phase, quasi-monopolies or lead industries appear when technological innovations are transmogrified into new 'scarce' products. As these quasi-monopolies erode, falling profits coupled with the growing cost advantage of lower-wage areas causes investment to shift and relocates production to the peripheries in the B-phase.[115] Class formation is a recurrent process that unfolds through the constant restructuring of global commodity chains.

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[113] Immanuel Wallerstein, *Historical Capitalism with Capitalist Civilization* (New York: Verso, 1983).

[114] Gerald Silverberg, "Long Waves: Conceptual, Empirical and Modelling Issues" in *Elgar Companion to Neo-Schumpeterian Economic*s, ed. Horst Hanusch and Andreas Pyka (Northampton: Edward Elgar Publishing, 2007), 800-819.

[115] Immanuel Wallerstein, "Dependence in an Interdependent World: The Limited Possibilities of Transformation within the Capitalist World-Economy," in *The Capitalist World-Economy* (New York: Cambridge University Press, 1979), 70.

4 RESULTS

Classifications and Transitions

Triangulation, 1816-1859

The Napoleonic Wars were resolved in 1815 with the rise of British hegemony. Britain's competitive edge— mechanization of industry—became the new standard of coreness. Countries late in upgrading their mix of economic activities declined initially and afterward recovered. The decline and recovery of these states has an analogue in what Arrighi and Drangel described as a "pendulum-like movement" associated with the establishment of U.S. hegemony.[116] The hegemonic and Kondratieff cycles entail innovation and diffusion of commercial technologies mirrored by the waxing and waning of structural positions. As noted, these temporary systematic fluctuations identify thresholds between classes—the perimeter of the core and perimeter of the periphery. The classes themselves—core, peripheral, and semi-peripheral regions of the world-economy—are identified with non-transitioning economies.

Throughout his work, Wallerstein describes classifications for countries and regions of the mid-17th century world-economy.[117] He assigns the western Dutch

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[116] Arrighi and Drangel, "Stratification of the World-Economy," 47.

[117] Wallerstein classifies the western Dutch Provinces, southeast England, and northeast and western France as part of the core (Wallerstein, *The Modern World-System II,* 75), Brandenburg-Prussia, southern Germany, Sweden, Austria, Spain, Portugal, northern Italy, the New England Colony, and the Mid-Atlantic Colony to the semi-periphery

Provinces, southeast England, and northeast and western France to the core, and Spain, Portugal, and northern Italy to the semi-periphery. He notes that Spain, Portugal, and Italy ultimately decline to peripheral status but does not specify precisely when it occurs.[118] The NMCv5.0 dataset shows zero *PEC per capita* for Spain, Portugal, and Northern Italy in 1816. The total absence of core economic activity or industry indicates peripheral status.[119] Spain, Portugal, and Italy were built on a regime that outsourced labor to far flung colonies. In the wake of the industrial revolution, these economies failed to adapt by upgrading their mix of economic activities and therefore declined to peripheral status. France and the Netherlands also failed to adapt, undergoing semi-peripheralization and declining from the core.[120] The disparity in productive advantage following the Napoleonic Wars can be seen in Figure 5.

(Wallerstein, *Modern World-System II*, 71; Wallerstein, *Modern World-System I*, 196; Wallerstein, *Capitalist World-Economy*, 26; Wallerstein, *Modern World-System II*, 158; Wallerstein, *Modern World-System II*, 179), and Ireland, Scotland, Denmark, Switzerland, Poland, Hungary, the Baltic region, and Iberian America to the periphery (Wallerstein, *Modern World-System II*, 168, 251, 199, 211; Wallerstein, *Modern World-System I*, 103, 196, 307; Wallerstein, *Capitalist World-Economy*, 26).

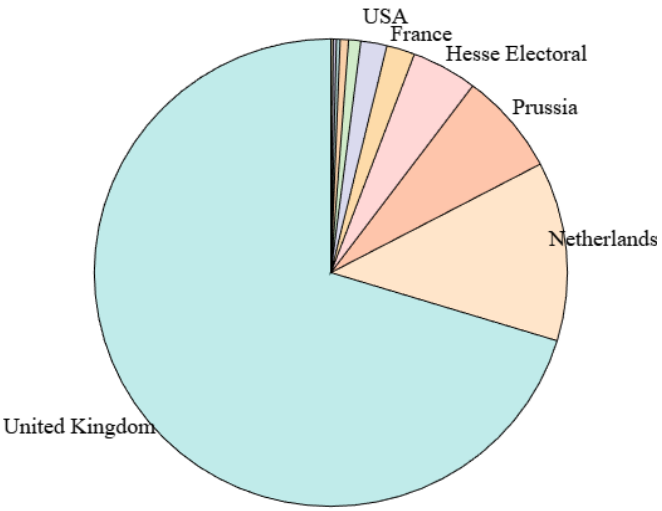
[118] Wallerstein, *Modern World-System I*, 196.

[119] In theory, one would expect a downward transition associated with new commercial innovations to happen in an A-phase, which makes the A-phase of 1880s/90s-1810/17 a plausible time frame.

[120] Jan De Vries and Ad Van der Woude, *The First Modern Economy: Success, Failure, and Perseverance of the Dutch Economy, 1500–1815* (New York: Cambridge University, 1997), 686.

Figure 5: *PEC per capita* in 1816

Rank	Polity	*PEC per capita*
1	United Kingdom	1.15410
2	Netherlands	0.20357
3	Prussia[121]	0.11595
4	Hesse Electorate	0.07387
5	France	0.03178
6	United States	0.02933
7	Denmark	0.01363
8	Bavaria	0.00935
9	Switzerland	0.00421
10	Austria-Hungary	0.00339
11	Sweden	0.00235
12	Russia	0.00033
13	Ottoman Empire[122]	0.00004
14	Spain	0.00000
14	Portugal	0.00000
14	Piedmont/Sardinia[123]	0.00000



If we consult the 1860 classifications in Table 2, we find declining economies have recouped their positions. France and the Netherlands are in the core, and Spain, Portugal, and Italy are in the semi-periphery.[124] We also find Prussia, the United States, and Hesse Electoral firmly in the core by 1860.

[121] Germany in NMCv5.0

[122] Turkey in NMCv5.0

[123] Italy in NMCv5.0

[124] This is in contrast to Wallerstein's research, which places Spain in the periphery until the 20th century. See Wallerstein, *Modern World-System I*, 196.

Table 2: Nominal, Ordinal, and Ratio Scale of Structural Position, 1860

Zone	Rank	Polity	*PEC per capita*	*PEC per capita*$^{1/9}$
Core	1	United Kingdom	2.806	1.121
	2	Belgium	1.320	1.031
	3	Saxony	0.824	0.979
	4	Prussia	0.823	0.979
	5	United States	0.580	0.941
	6	Netherlands	0.545	0.935
	7	France	0.391	0.901
	8	Hesse Electoral	0.386	0.900
Semi-periphery	9	Argentina	0.108	0.781
	10	Hanover	0.083	0.758
	11	Denmark	0.079	0.754
	12	Austria-Hungary	0.069	0.743
	13	Bavaria	0.052	0.720
	14	Spain	0.048	0.714
	15	Sweden	0.048	0.713
	16	Switzerland	0.045	0.709
	17	Greece	0.038	0.695
	18	Chile	0.031	0.680
	19	Portugal	0.027	0.668
	20	Brazil	0.017	0.635
	21	Italy	0.010	0.598
	22	Mexico	0.006	0.569
	23	Russia	0.004	0.542
	24	Ottoman Empire	0.001	0.460
Periphery	25	Bolivia	0	0
	25	China	0	0
	25	Colombia	0	0
	25	Ecuador	0	0
	25	Egypt	0	0
	25	Haiti	0	0
	25	Iran	0	0
	25	Japan	0	0
	25	Morocco	0	0
	25	Paraguay	0	0
	25	Peru	0	0
	25	Tunisia	0	0
	25	Venezuela	0	0

Wallerstein's historical research, the 1860 classifications, and *PEC per capita* data for 1816 make it possible to draw inferences about the system's structure. The similar *PEC per capita* of France and the United States in 1816 suggests they belong to the same class for that year.[125] Therefore, in 1816, the PC comprised the Netherlands, Prussia, Hesse Electorate, France and the United States, and the PP comprised Spain, Portugal, and Italy. Table 3 delineates structural positions of polities in 1816 expressed in terms of class, ordinal rank, and a ratio scale.

[125] It is probable the War of 1812 was the pivot when the United States began to upgrade its mix of economic activities. Coal-powered mechanization of industry became more integral to the U.S. economy when the war cut off U.S. access to British imports, stimulating investment in fixed capital and transforming the economy into a producer of core goods, namely textiles. Wallerstein has Prussia climbing the semi-periphery and taking the lead in 1763, so its upward transition is less surprising. In the years following the Seven Years War, Prussia took steps toward industrialization, and by 1786, it was one of the leading manufacturing economies of continental Europe (William Otto Henderson, *Economic Policies of Fredrick the Great*, 123-124).

Table 3: Nominal, Ordinal, and Ratio Scale of Structural Position, 1816

Zone	Rank	Polity	*PEC per capita*
Core	1	United Kingdom	1.15410
Perimeter of the Core	2	Netherlands	0.20357
	3	Prussia[126]	0.11595
	4	Hesse Electorate	0.07387
	5	France	0.03178
	6	United States	0.02933
Semi-periphery	7	Denmark	0.01363
	8	Bavaria	0.00935
	9	Switzerland	0.00421
	10	Austria-Hungary	0.00339
	11	Sweden	0.00235
	12	Russia*	0.00033
	13	Ottoman Empire*[127]	0.00004
Perimeter of the Periphery	14	Spain	0
	14	Portugal	0
	14	Piedmont/Sardinia[128]	0
Periphery	15	Latin America†	0
	16	India†	0
	17	Africa†	0

* Undergoing incorporation

† Colonies

Zero *PEC* indicates a preindustrial economy and correlates with peripheral status. In addition, frequency distributions identify zero *PEC per capita* as the upper limit of the periphery until 1882. In other words, the shift from zero to non-zero *PEC*

[126] Germany in NMCv5.0

[127] Turkey in NMCv5.0

[128] Italy in NMCv5.0

signals a transition from the periphery to the semi-periphery. This is true excepting the Ottoman Empire, which was still being incorporated into the system in 1816.[129] The Ottoman Empire exhibits a semi-peripheral level of industrialization, but its economic activity was not in service to the world-economy. As a world-empire, it had its own core-peripheral division of labor. As a world-empire, the Ottoman Empire was an economic system unto itself with its own internal logic. Incorporation dismantled such internal distribution mechanisms and repurposed institutions to respond to movements of supply and demand in the world-economy. It also weakened the central government of the state being incorporated. Russia was able to somewhat resist these pressures because of the strength of its state machinery, it is argued, and was incorporated directly into the semi-periphery. Other populations, including the Ottoman Empire, were incorporated into the periphery. Notably, the frequency distributions assign the Ottoman Empire to the semi-periphery until 1883, when it declines to the periphery. This is what one would expect to see of a state being incorporated into the periphery. It is not so much a decline as it is an indicator that incorporation and peripheralization have taken their course.

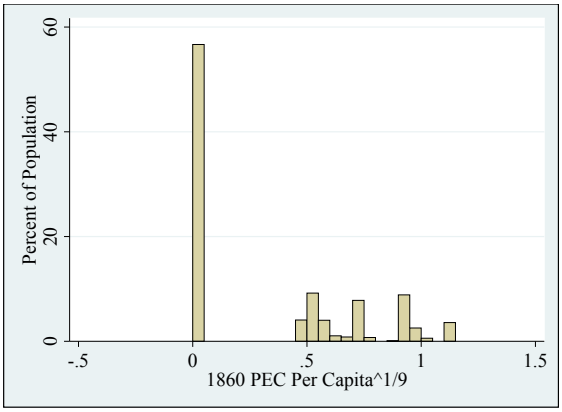
[129] Wallerstein dates the incorporation of Russia and the Ottoman Empire from 1750-1850.

Weighted Frequency Distributions, 1860-1916

Observation years 1860-1869 yield histograms with no PC or PP. Instead, clusters are separated by one or more empty bins, rendering zonal boundaries unambiguous. The histograms in Figure 6 display frequency distributions of *PEC per capita*$^{1/9}$ weighted by national population at 10-year intervals. Peaks represent the modes or central tendencies of each class and troughs indicate boundaries between classes.

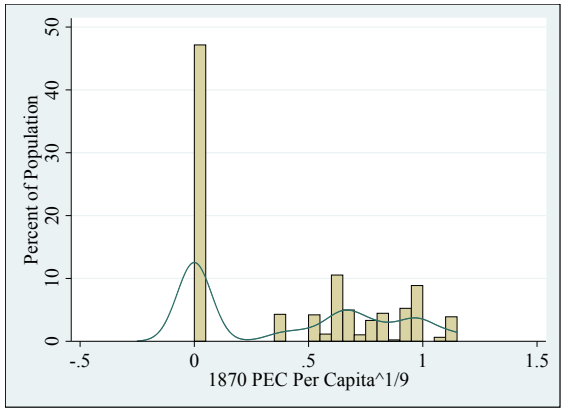
Figure 6: Weighted Frequency Distributions at Ten-Year Intervals

1860



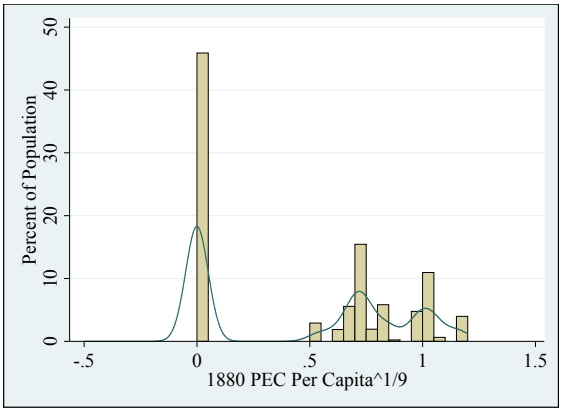
Bin size = 0.05

1870



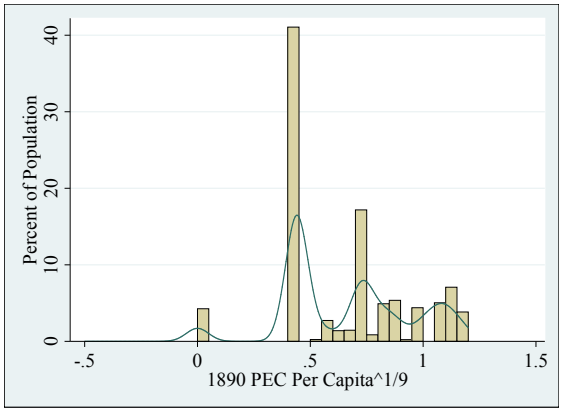
Bin size=0.05; half-width of kernel=0.75

1880



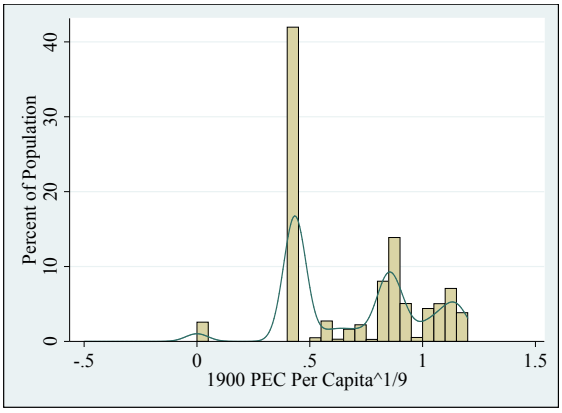
Bin size=0.05; half-width of kernel=0.05

1890



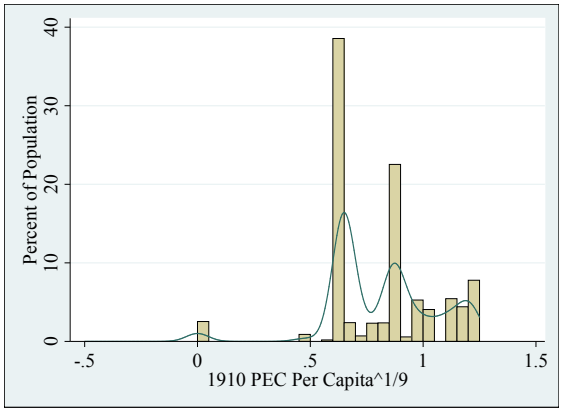
Bin size=0.05; half-width of kernel=0.05

1900



Bin size=0.05; half-width of kernel=0.05

1910



Bin size=0.05; half-width of kernel=0.05

Of the 57 histograms examined, twenty-one depict a three-tiered structure (1860-1880) and thirty-six depict a four-tiered structure (1881-1916). The appearance of an additional tier in 1881 is interpreted as a bifurcation from the periphery. "Bifurcation" is used here in the same sense Dezzani uses the term: to denote sudden structural change within the overarching continuity of core-peripheral relations.[130] Bifurcation of the periphery was triggered by the diffusion of industrial technologies—first to China, followed by Venezuela, Colombia, Iran, Peru, Ecuador, Cuba, Korea, Bulgaria, and Uruguay.

In the decades following bifurcation, the industrializing periphery appears to gain ground relative to the semi-periphery and core. This is represented most clearly in the histogram dated 1910, where the mode of periphery 2 appears closer to the semi-peripheral and core modes. In the early 20th century, mechanization of industry was still a feature of the core, but it was no longer its defining feature. After 1916, *PEC per capita*[1/9] as an indicator of structural position becomes inconsistent and lacking in face validity.

The appearance of an additional tier in 1881 prompts the question of how the new class relates to the system. According to Arrighi and Drangel's concept of class boundaries, economic actors in these countries are entering market domains closed to the non-industrialized periphery. This reflects a recurrent pattern wherein new

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[130] Wallerstein uses the term "bifurcation" in reference to the structural crisis that harbingers the collapse of capitalism and transformation to a new kind of world-system.

technology appears in the core, then diffuses to the peripheries through outsourcing—first to the semi-periphery, then the periphery. If innovation is how economic actors in the core consolidate their position, technological diffusion is the means by which it is eroded. The non-industrial periphery is absorbed into the industrializing periphery over time, resulting in a three-tiered system once again.[131] Therefore, it makes sense to think of the four-tiered structure as composed of a core, semi-periphery, and a two-tiered periphery. The non-industrial periphery is referred to as periphery 1 and the industrializing periphery as periphery 2.

Table 4 provides class boundaries at five-year intervals so classifications can be replicated with the NMCv5.0 dataset. The thresholds for perimeter of the core (PC), the perimeter of the periphery 1 (PP1), and perimeter of the periphery 2 (PP2) are indicated in *PEC per capita*.

[131] Industrial technologies eventually penetrated every country, and today there are no countries with zero primary energy consumption.

Table 4: Classification Benchmarks, 1816-1815[132]

Year	PC	PP2	PP1
1816	0.01149	-	0
1820	0.02235	-	0
1825	0.02597	-	0
1830	0.03807	-	0
1835	0.04586	-	0
1840	0.06699	-	0
1845	0.09024	-	0
1850	0.10783	-	0
1855	0.18477	-	0
1860	0.23162	-	0
1865	0.38742	-	0
1870	0.22796	-	0
1875	0.25733	-	0
1880	0.35607	-	0
1885	0.45400	0.00743	0
1890	0.56212	0.01008	0
1895	0.69253	0.01541	0
1900	0.91352	0.01987	0
1905	1.00000	0.03527	0
1910	1.51189	0.09405	0
1915	1.36290	0.10687	0

Table 5 lists transitions that occur during the period of observation. No distinction is made between organic and nonorganic members of classes. States assigned to the PC in the 1816 classification are grouped with the core, and states assigned to the PP are grouped with the periphery, since the PC and PP "define, respectively, the lower boundary of the core zone and the upper boundary of the periphery".[133] Following

[132]

[133] Arrighi and Drangel, "Stratification of the World-Economy," 29.

Babones, a movement is considered a transition if it lasts five years or longer.[134] According to this criterion, there were twenty-tree upward transitions and five downward transitions from 1816 to 1916.

[134] Babones, "Country-Level Income Structure," 52.

Table 5: Transitions Lasting Five Years or Longer, 1816-1916

H-cycle	K-cycle	Polity	Year	From	To
A-Phase 1815-1873	B-Phase 1810/17-1844/51	↑ Greece	1828	Periphery	Semi-periphery
		↑ Spain	1830	Periphery	Semi-periphery
		↑ Italian states	1835	Periphery	Semi-periphery
		↑ Portugal	1836	Periphery	Semi-periphery
		↑ Mexico	1836	Periphery	Semi-periphery
		↑ Brazil	1836	Periphery	Semi-periphery
		↑ Chile	1839†	Periphery	Semi-periphery
		↑ Argentina	1841†	Periphery	Semi-periphery
	A-Phase 1844/51-1870/75	↑ Japan	1868	Periphery	Semi-periphery
		↑ Denmark	1871	Semi-periphery	Core
B-Phase 1873-1945	B-Phase 1870/75-1890/96	↑ Serbia	1878	Periphery	Semi-periphery
		↑ Romania	1878	Periphery	Semi-periphery
		↑ China	1882	Periphery 1	Periphery 2
		↓ Ottoman Emp.	1883	Semi-periphery	Periphery 2
		↑ Venezuela	1884	Periphery 1	Periphery 2
		↓ Denmark	1887	Core	Semi-periphery
		↑ Colombia	1891	Periphery 1	Periphery 2
	A-phase 1890/96-1914/20	↑ Iran	1898	Periphery 1	Periphery 2
		↑ Peru	1898	Periphery 1	Periphery 2
		↑ Ecuador	1900	Periphery 1	Periphery 2
		↑ Cuba	1902	Periphery 1	Periphery 2
		↑ Korea	1905	Periphery 1	Periphery 2
		↓ Brazil	1906	Semi-periphery	Periphery 2
		↓ Serbia	1906	Semi-periphery	Periphery 2
		↓ Netherlands	1907	Core	Semi-periphery
		↑ Bulgaria	1908	Periphery 1	Periphery 2
		↑ Uruguay	1910	Periphery 1	Periphery 2
		↑ Netherlands[135]	1912	Semi-periphery	Core

† 1839 and 1841 are the earliest years data are available for Chile and Argentina.

[135] The Netherlands transition in 1907 lasts exactly five years. The second transition in 1912 technically does not qualify according to our five-year rubric since the analysis ends on the year 1916, and there are only four years of data, not five. 1917 data would have been included in the analysis, but *PEC per capita* is no longer viable as the key variable beginning in 1917.

Two phases of development or class formation can be seen in the table. From 1828-1878, there is a geographical extension of the semi-peripheral zone through absorption of peripheral regions in Europe and Latin America. 1882 to 1912 is characterized by the bifurcation of the periphery and rise of the industrializing periphery, which expanded by absorbing populations from the non-industrial periphery as well as the semi-periphery.

Since the number of observations increases over time, instances occur where social status is assigned an observation without information as to its status in prior years. These appearances are counted as upward transitions in some cases and in others they are not. Belgium appears in the dataset in 1830 and Saxony in 1850. These states are classified as part of the core, but they are not counted as upward transitions. Belgium declared independence in 1830 from the Netherlands, which was already part of the core. And in 1850, Saxony's *PEC per capita* is higher than that of the U.S., France, and Hesse Electoral, suggesting a former status of core. But other instances of independence have face validity as upward transitions, including Greece, Romania, Serbia, Bulgaria, and Cuba. In 1839 and 1841, Chile and Argentina appear in the data set, respectively, though their independencies date earlier. Since both economies have a non-zero amount of *PEC per capita*, 1839 and 1841 were taken as approximate dates for transition.

The classifications have face validity except for Argentina. Argentina had a more or less even mix of core and peripheral activities in 1841, but it did not have a strong state machinery. Argentina was plagued with weak government and civil war in 1841

and would continue to be for decades. It was not until 1861, when the Unitarians seized control, that a strong central government was established.

Transition Probabilities

Dezzani's outlines an approach to change that models the world-system as a Markov dependence system. The key measure of change—transition probabilities—are estimated by fitting Markov chains to the data. Maximum likelihood estimation is used to calculate single step transition probabilities as shown in equation 1, where n_{ij} consists of the number sequences ($X_t = s_i,\ X_{t+1} = s_j$) in the sample:

$$\hat{P}_{ij} = \frac{n_{ij}}{\sum_{u=1}^{k} n_{iu}} \tag{1}$$

Figure 7 contains transition probabilities and transition counts based on annual classifications from 1816-1916. These data reflect year-over-year transitions, whereas the transitions in Table 5 are those lasting five years or longer. Diagonal elements represent persistence—the probability of a state remaining in the same class from one time point to another. Dezzani interprets persistence as a measure of "inertia" of world-system class. The other the values represent transience and can be aggregated into measures of structural change. Specifically, values left of the diagonal are the probabilities of upward transition and values right of the diagonal are probabilities of downward transition. All transitions are reflected in the data below, including transitions lasting less than five years.

Figure 7: Year-Over-Year Transition Probabilities & Counts, 1816-1916

Probabilities

1816 \ 1916	C	S	P2	P1
C	.985	.015	0	0
S	.009	.979	.013	0
P2	0	.057	.943	0
P1	0	.007	.009	.985

Cumulative upward: 0.082
Cumulative downward: 0.013

Counts

1816 \ 1916	C	S	P2	P1
C	653	10	0	0
S	12	1366	18	0
P2	0	13	215	0
P1	0	6	8	909

Cumulative upward: 39
Cumulative downward: 28

The industrial periphery exhibits the lowest amount of inertia with a persistence of .943 while the core and nonindustrial periphery tie for the highest amount of inertia with a persistence of .985. The transition matrix indicates the industrializing periphery (P2) is absorbing countries from two directions—the semi-periphery and the periphery. The core and semi-periphery have similar rates of persistence but are otherwise unremarkable. Between 1816 and 1916, the probability of remaining in the same class was .973. During the same time, the probability of upward transition was .082, nearly three times that of .028, the probability of downward transition.

Figure 8 reports transition probabilities and counts for transitions according to historical the A- and B-phases of the Kondratieff cycle. The underrepresentation of the periphery discussed in the Data and Methods section can be seen in the count data.

Figure 8: Transition Probabilities & Counts of the Kondratieff Cycle

Probabilities

A-phase, 1816 → 1848

	C	S	P1
C	1	0	0
S	0	1	0
P1	0	.039	.961

A-phase, 1848 → 1873

	C	S	P1
C	.984	.016	0.
S	.010	.990	0
P1	0	.004	.996

B-phase, 1873 → 1894

	C	S	P2	P1
C	.978	.022	0	0
S	.006	.988	.006	0
P2	0	.028	.972	0
P1	0	0	.011	.989

A-phase, 1894 → 1916

	C	S	P2	P1
C	.969	.031	0	0
S	.018	.935	.047	0
P2	0	.063	.937	0
P1	0	0	.019	.981

Counts

A-phase, 1816 → 1848

	C	S	P1
C	210	0	0
S	0	366	0
P1	0	5	122

A-phase, 1848 → 1873

	C	S	P1
C	184	3	0
S	4	390	0
P1	0	1	266

B-phase, 1873 → 1894

	C	S	P2	P1
C	135	3	0	0
S	2	321	2	0
P2	0	1	35	0
P1	0	0	3	261

A-phase, 1894 → 1916

	C	S	P2	P1
C	124	4	0	0
S	6	319	16	0
P2	0	12	180	0
P1	0	0	5	259

Transition matrices indicate a high level of persistence across world-system classes in every period. Since the periphery is underrepresented in the sample, probability values corresponding with this class are the least reliable. Upward mobility is observed every period, which is not surprising given the concurrent geographical

expansion of the system. Figure 9 reports the average and cumulative change of A-phases and B-phases, and Figure 10 displays transition probabilities for the A- and B-phase of the hegemonic cycle.

Figure 9: Average Transition Probabilities of the Kondratieff Cycle

A-phase

	C	S	P2	P1
C	0.977	0.024	0	0
S	0.014	0.963	0.047	0
P2	0	0.063	0.937	0
P1	0	0.002	0.019	0.989

Cumulative upward: 0.098
Cumulative downward: 0.071

B-phase

	C	S	P2	P1
C	0.989	0.011	0	0
S	0.003	0.994	0.006	0
P2	0	0.028	0.972	0
P1	0	0.020	0.011	0.975

Cumulative upward: 0.062
Cumulative downward: 0.017

Figure 10: Transition Probabilities of the Hegemonic Cycle

A-phase

		1873 C	1873 S	1873 P1
1816	C	0.992	0.008	0
	S	0.005	0.995	0
	P1	0	0.022	0.979

Cumulative upward: 0.027
Cumulative downward: 0.008

B-phase

	1916 C	1916 S	1916 P2	1916 P1
1894 C	0.974	0.027	0	0
1894 S	0.012	0.962	0.027	0
1894 P2	0	0.046	0.955	0
1894 P1	0	0	0.015	0.985

Cumulative upward: 0.073
Cumulative downward: 0.054

Goodness of Fit and Stationarity

Kullback's divergence test is used to evaluate the fit between estimated transition probabilities and observed data. This test uses the X^2 Chi squared test to test the null

hypothesis of agreement between theoretical and observed frequencies. If f_{ij} is the raw transition count, it can be shown that

$$2 * \sum_{i=1}^{r} \sum_{j=1}^{r} f_{ij} \ln \frac{f_{ij}}{f_i P(P_i | P_j)} \sim \chi^2 (r * (r - 1)) \quad (2)$$

The test returns a p-value of .988; the model fits, the null is not rejected. However, the data must also exhibit properties of stationarity and Markovianity. Stationarity refers to the stability of a probability distribution over time. The assumption of stationarity is violated if a large number of states move up or down in the hierarchy. Dezzani takes stationarity as a measure of world-system stability. A given sequence of states is stationary when the following condition obtains:

$$p_{ij}(t) = p_{ij} \text{ for all } t \quad (3)$$

The assumption of stationarity or structural continuity can be tested with the X^2 test. This is done by constructing a contingency table of estimated transition probabilities for each possible classification which can then be tested for variance. The results are summarized in Table 6.

Table 6: Stationarity

Interval Tested	X^2 Statistic	Degrees of Freedom	p-value
1816-1848	4.69	14	0.987
1848-1873	5.73	14	>0.972
1873-1894	6.21	14	>0.945
1894-1916	7.24	14	>0.924

The test returns large p-values and small X^2 statistics for each of the four time periods. The hypothesis of stationarity is not rejected. World-system classifications are stable over the period of observation; there are no large deviations from expected values.

Markovianity

A Markov property (of the first order) describes a probability distribution of future states that is conditional solely on the present state and not past states.[136] Mathematically stated:

$$P\{X_{t+1} = m \mid X_t = j,\ X_{t-1} = i\} = P\{X_{t+1} = m \mid X_t = j\} \qquad (4)$$

The verifyMarkovProperty function of the markovchain package for R is used to test classifications for the Markov property. It does so by building a contingency table of counts for all possible transitions and calling the chisq.test function.[137] Tests return a p-value of >0.25, therefore, the null hypothesis of Markovianity is not rejected.

Table 7: Markovianity

Interval Tested	X^2 Statistic	Degrees of Freedom	p-value
1816-1848	1.33	6	.999
1848-1873	5.79	6	.973
1873-1894	10.32	8	.901
1894-1916	9.5	8	.962

[136] Dezzani, "Measuring Transition and Mobility," 605.

[137] Giorgio Alfredo Spedicato, "Discrete Time Markov Chains with R," *The R Journal* 9, no. 2 (2017): 84-104.

Eigenvalues

Eigenvalues are taken as measures of "intertemporal regional dependence" or path dependence. They were derived by applying the eigen function to transition matrices. Dezzani interprets the average eigenvalue as a measure of intertemporal regional dependence in the world-system. A value of zero indicates no intertemporal regional dependence while an eigen value of 1 indicates complete intertemporal regional dependence. Decreasing Eigenvalues reflect decreasing path dependence due to hierarchical destructuring. Table 8 contains the eigenvalues for each period, as well as for the entire observation period.

Table 8: Eigenvalues

Class	1816-1848	1848-1873	1873-1894	1894-1916	1816-1916
Core	1.00	1.00	1.00	1.00	1.00
Semi-periphery	1.00	1.00	0.99	0.98	0.98
Periphery 2			0.98	0.96	0.98
Periphery 1	0.96	0.97	0.96	0.88	0.93
Average	0.99	0.99	0.98	0.96	0.97

The core exhibits the highest intertemporal regional dependence, and the periphery exhibits the lowest, although since the periphery is underrepresented, the eigenvalues are unreliable. The average eigenvalue for the period 1848-1916 is .897, indicating a high degree of intertemporal regional dependence across the period of observation.

Shannon Entropy

Entropy change is employed as a measure of disorder and aggregate structural change. Entropy is formally defined as:

$$E_{sys} = -\Sigma\, p_i \log p_i \tag{5}$$

Disorder corresponds with the loss of structure or hierarchical order in the system and is expected to increase with economic development, systemic complexity, and the number of options available to economic actors.[138] Entropy is also a useful measure of the polarity of wealth distribution in the system. Dezzani takes change in entropy to reflect the rate of economic convergence among states. Table 9 contains estimates of Shannon's entropy and entropy change between 1848 and 1916.

Table 9: Shannon Entropy at Specific Time Points

Year	1816	1848	1873	1894	1916
$E_{sys} =$	1.043	1.014	1.061	1.271	1.338
$\Delta E_{sys} =$		-.029	.047	.210	.067

The empirical.entropy function of the entropy package was used to derive estimates. Overall, disorder increased during the period of examination, and the system became less hierarchically ordered. The greatest change occurs between 1873 and 1894 due to bifurcation, which altered state-space configuration of the system and accelerated economic convergence.

[138] Dezzani, "Measuring Transition and Mobility," 607.

5 DISCUSSION

The results indicate a system characterized by substantial upward social mobility over the period of observation. This is interpreted in the context of ongoing geographical expansion. Between 1816 and 1916, there were twenty-three upward transitions and five downward transitions lasting five years or longer. The probability of a country remaining in the same class from one year to the next was 0.973, while the probability of transition was 0.11. The probability of an upward transition was 0.082 and the probability of a downward transition was 0.028. Even so, the hypothesis of stationarity could not be rejected. Not only was the structure itself stable, but so was the rate of change. This supports Wallerstein's conceptualization of a system in statistical equilibrium, where class boundaries are fluid, but the overall structure is fixed. A high degree of inertia or intertemporal regional dependence was exhibited across classes, cresting in the core and reaching a low in the industrial periphery.

Frequency distributions depict a tri-modal structure until 1881 and a quadra-modal structure from 1882-1916. The appearance of an additional mode in 1882 is interpreted as a bifurcation of the periphery into substrata—industrial and non-industrial. Bifurcation corresponds with a shift in transitions, implying distinct phases of capitalist economic development or class formation. From 1828-1878, the semi-peripheral zone extended geographically through absorption of peripheral populations in Europe and Latin America. That path of development ended in 1882 when industrial

technology penetrated the periphery, opening market domains previously unavailable to economic actors. From 1882-1916, the industrial periphery expanded rapidly, absorbing populations primarily from the non-industrial periphery but also the semi-periphery. These trends coincide with the A- and B- phases of British hegemony, respectively. As technology spread, the industrial periphery absorbed the non-industrial periphery into its path of development. The bifurcation into substrata was a temporary condition.

Shannon entropy measures suggest economic convergence was in progress for three of the four periods examined. Entropy captures aggregate structural change not accounted for by stochastic analysis. It estimates the degree of disorder present in the system and, when measured across time points, the rate of hierarchical restructuring over time. Our analysis shows the system became more hierarchically ordered between 1816 and 1848, and less hierarchically ordered between 1848 and 1916. Between 1873 and 1894, the rate of aggregate change quadrupled but subsequently returned to a crawl. Bifurcation of the periphery altered the state-space configuration of the system and accelerated economic convergence. This is a preliminary finding. More robust measurements over a longer period are required for a clearer picture of systemic change. But the finding challenges the view that economic convergence is a new phenomenon. It also raises questions about concepts in the convergence framework and the techniques used to operationalize them. Economists now understand convergence and divergence as

concurrent and ongoing interrelated trends.[139] World-systems thinkers have much to contribute to this discussion.

This research has three limitations the reader should be aware of. One is rooted in the development of historical indicators and challenges posed by the scarcity of reliable information sources. This is touched upon in the data and methods section and detailed at length in the NMCv5 documentation.[140] The second limitation is one inherent to univariate analysis, namely that it captures a single dimension of the thing being analyzed. Primary energy consumption reflects economic capability but does not consider the political dimension of structural position. This results in random measurement error as illustrated by Argentina and the Ottoman Empire. In both cases, the absence of a strong state machinery has ramifications not captured by the histograms for that state's relationship to the mode of production.

The third limitation involves an absence of indicators for relevant populations in the NMCv5 data. This is discussed in more detail in the data and methods section. NMCv5 data are curated for political science research and have been repurposed here for world-systems analysis. As such, the interstate system is conceived as a political system in which membership depends on state sovereignty and a modicum of political power. This concept of system membership is nearly opposite to that of world-systems

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[139] Derviş Kemal, "Convergence, Interdependence, and Divergence," *Finance and Development* 49, no. 3 (2012).

[140] Correlates of War Project, 2017 "National Material Capabilities (NMC) Data Documentation, v5.0," http://correlatesofwar.org.

analysis, which characterizes incorporation unfolding through colonization and forced labor. In short, membership in the political system is dated much later than incorporation into the world-economy. As a result, the peripheral population is underrepresented in the data, rendering histogram analysis ineffectual for observation years 1816-1859. For these years, classification is inferred qualitatively through triangulation of known data, techniques, and theory. Histogram analysis becomes feasible in 1860 with the appearance of China in the dataset. Incorporation of a population was a gradual process that unfolded over a long period of time. Nevertheless, China's population serves as a useful proxy for the periphery, making histogram analysis feasible. Consequently, although the periphery continues to be underrepresented in the study, systematic measurement error is less of a concern.

6 CONCLUSION

This research set out to answer two questions: *what is the structure of the capitalist world-economy and how does it change over time?* Quantitative and qualitative methods of descriptive inference were brough to bear on these questions, specifically income trough classification and triangulation. Income trough classification was implemented using primary energy consumption per capita as the key variable. While this departs from previous implementations, which relied on income per capita, it is nevertheless in line with received theory. Primary energy consumption has a more direct linkage with core economic activities during the period in question, and from that standpoint, it has more operational validity than income. But its validity is limited to that historic period when industrialization was the defining feature of core economic activities. As Arrighi and Drangel point out, the changing nature of commercial technologies make income a more reliable measure across disparate time periods. For observation years that lacked sufficient data for histogram analysis, classifications were inferred by triangulating Arrighi and Drangel's cyclical concept of class boundaries, Wallerstein's 17th century classifications and subsequent shifts in status, 1816 *PEC per capita* data, and our 1860 classifications derived from histogram analysis.

The concept of bifurcation introduced by Dezzani involves rapid threshold change and is one of two types of systemic change in the world-system. This research describes the second such incidence, suggesting it is a recurrent process. In both

instances, it unfolded as class formation and the opening of a new path of development. Asymmetric upward mobility vis-à-vis downward mobility characterizes the system over the period observed. Other than this, the findings reported here are not unexpected. Stationary transition probabilities indicate the odds of a transitioning in either direction was about 1% in any given year. Except for bifurcation in the 1880s, structural change unfolded gradually. Studies of structure in the 20th century report similar findings. Income trough studies and Dezzani's parametric classification discover a stable system in which social mobility is the exception not the rule.

In short, the fundamental properties of the capitalist system remain unchanged. These approaches to structure are compelling because they capture characteristics that do not change. Another approach to structure, network blockmodeling, distinguishes itself on opposite grounds, namely for bringing a world-systems approach to the study of modernization. These research traditions can produce a more comprehensive description of the system together than they can apart, and yet methodological convergence is elusive. Jeffery Kentor has criticized the categorial approach for presupposing the structure it is attempting to discover. World-system structure, he argues, "should be empirically determined rather than assumed on an a priori basis."[141] And yet the paradigm has not shifted.

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[141] Jeffrey D. Kentor, *Capital and Coercion: The Economic and Military Processes that have Shaped the World Economy, 1800-1990* (New York: Garland Publishing, Inc., 2000), 23.

The fit between theory and data is never perfect, but each is still useful to the other. "There are always difficulties somewhere in the paradigm-nature fit," Kuhn tells us.[142] It is difficulties in the "data-theory fit" that define the puzzles of normal science. The puzzle for world-systems thinkers is the fit between the trichotomous conceptualization of class—core, periphery, and semi-periphery—and the empirical measurement of social structure. Even Arrighi and Drangel allow for additional structures to make a categorical approach to class more operational. They cite incongruency in the paradigm-nature fit as grounds for doing so. It is "a compromise between the need to define the zones in the spirit of our [trichotomous] conceptualization and the need to retain for further analysis as many features as possible of the actual distributions."[143]

The primary culprit for this difficulty has been the semi-periphery concept. Wallerstein's historical research supplied empirical support for the concept. But it was the commodity chain construct that advanced the research program by showing how a single division of labor gives rise to a stable intermediate structure. Nevertheless, a consistent empirical measure eluded researchers until Arrighi and Drangel's income trough methodology. But it was their theoretical specification of class boundaries that

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[142] Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1970), 82.

[143] Arrighi and Drangel, "Stratification of the World-Economy," 36.

gave "precise analytical meaning to the concept of semi-periphery" and made their approach to measurement meaningful.

Arrighi and Drangel posit a Weberian-Schumpeterian concept of class. Weber understands class in terms of monopolistic appropriation of market opportunities. Economic actors maximize rewards through closure or the restricting of market access to a limited circle of eligibles.[144] When paired with Schumpeter's Kondratieff hypothesis, a powerful concept of class formation emerges. From this perspective, closure is secured through innovation of new consumer products, which take form in a new leading economic sector. Monopolistic positions erode as technology spreads to the peripheries, and production is eventually relocated to low wage areas. Before long, this process repeats itself.

The Kondratieff cycle perpetuates capitalist exploitation by reproducing monopoly. At the same time, it is linked with the most salient of change—technological change. Thus, it is a process that underpins both changing and unchanging characteristics of the system. It is perhaps with this in mind that Zenonas Norkus extends Arrighi and Drangel's concept to account for the social structures of modernization. He sees an additional dimension of structure implicit in their Weberian-Schumpeterian concept of class formation. He argues the number of intermediate positions between core and periphery grows with each Kondratieff cycle. "After the

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[144] Norkus, 137-138; See also Frank Parkin, *Marxism and Class Theory: A Bourgeois Cri*tique (New York: Columbia University, 1979).

successful industrialization," Zenonas writes, "newly industrializing countries repeatedly had a bitter discovery that they only host carrier industries from the former Kondratieff wave."[145] Technology is diffused in a stepwise fashion, each wave passing down monopolistic control of specific market domains. But this doesn't imply intermediate structures are static, since each wave brings "change the 'hierarchy ladder' itself."[146] Since the multiplication of middle positions began with the third Kondratieff wave, the formula for determining the number of positions is N-2, where N is the number of the current Kondratieff cycle. Since we are presently in the fifth Kondratieff cycle, the number of intermediate structures between the core and periphery is three. "It is a special research problem, which I am leaving for another occasion, whether the number of middle structural positions in the CWS available at each particular point in time, stands in the relation of the one-to-one correspondence with the number of the former Kondratieff waves."[147]

It matters less whether there is some correspondence with existing research, more the direction provided for future research. Norkus's notion that intermediate structures multiple with each Kondratieff wave is fascinating, but even that is not necessary. It is enough to imagine dimensions of social structure arising from the same process but abiding different rules. The Weberian-Schumpeterian framework offers theoretical

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[145] Norkus, 141.
[146] Norkus, 121.
[147] Ibid., 140.

guidance to operationalizing structure the network approach has been lacking. It is the most obvious candidate for bridging the income trough and network methodologies.

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