



*Research article*

## **World geography and power, national capitals, and inequality as cross-national causes of food security and environmental outcomes**

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**Abstract:** Treatments of sustainability outcomes such as food security, economic development and environmental degradation typically have adopted monocausal approaches. Many have argued for substantial increases in world meat production as the panacea to global food insecurity. We use global and national synthetic explanations and path analytic approaches to examine sustainability outcomes for 200 nations. Both strong direct or indirect links are found among global geography, global power and national capitals, as well as warfare and military expenditures, and economic development. These factors are differentially predictive of the other key measures of sustainability.

**Keywords:** food distribution; biomes and natural resources; structural equation modeling

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### **1. Introduction**

According to the World Bank [1] the world must produce “at least 50% more food to feed the 9 billion people” we expect to inhabit the planet by the year 2050. World Bank analysts contend that climate change could further attenuate crop yields by more than 25%. Indeed, the world’s natural capital in the form, among other things, of land, biodiversity, oceans, and forests are being depleted at unprecedented rates. Food insecurity is predicted to be substantially greater, especially for the poorer segments of the world’s population.

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The World Bank further warns that without appropriate action regarding global warming, there will be dangerous effects on agriculture, water resources, and on ecosystems, all effecting human health [2]. Every world region will be impacted, especially those least capable of adapting.

Global and related national capital attributes also are key to food security and the related economic and environmental characteristics of nations. Major international organizations such as the FAO [3] have adopted approaches to global food security that are only partially in harmony with, relevant scientific literatures and recognizing differences in findings within that literature. Causality is a major question and is addressed in the following analysis and discussion of food security. The generic role of global Green Revolution and political economic forces in affecting national capitals are considered. Building on path analyses, our broad conclusion is that achieving food security involves global and national changes to a number of complex and interdependent linkages within the production, distribution and financial systems.

### *1.1. Foundational issues*

We begin with hunger and think it is important to address the historical context within which hunger and hunger policies have been debated. This includes, especially, the Green Revolution. For instance, the leading plant biologist most often identified with developing hybridized seeds, Nobel Peace Prize winner, Norman Borlaug, asserts that global hunger is a result of declining or inadequate food production [4]. An important component of the Green Revolution included domestic modernization through agricultural industrialization in developing countries [4,5]. The Green Revolution also entailed other objectives more directly aimed at developing countries. These objectives included aims to raise farmer incomes, employ rural laborers, and feed the world's growing population [6-9]. Associated development strategies encompassed the implementation of centers for agricultural development, such as the Consultative Group on International Agricultural Research, which promoted an anti-poverty and anti-hunger agenda [10].

Equally compelling theorizations assert that global hunger is the result of inadequate access to resources, due to multiple causes ranging from comparative national geography, global power and dependency, inadequate national capitals (human, financial, political, infrastructural and military), inequality, and the nature of domestic agricultural systems. This reasoning strongly suggests that the problem of world hunger cannot be solved simply by augmented food production.

Sen makes a strong case that the Bengali famine and subsequent hunger emanate from personal and household economic and political vulnerability [11,12]. Further, under the global food regime, countries that have recently begun growing for the export market are competing directly in the more competitive global food markets. Friedland [13] outlines the emergence of a new globalization in agriculture as the production of fresh produce for the permanently in-season market in the global North. Thus, an important factor contributing to the transformation of global agrarian structures is export production and concentration in high value commodities, such as fruits and vegetables. The global food regime marks the transition from a nationally-based Green Revolution that focuses on grains and basic food stuffs, to internationally-based global restructuring of agriculture that focuses on trade, thereby altering local production practices and outcomes [14], and reducing local food security otherwise associated with affordable domestic food consumption.

Food security issues similarly are under the control of sustainability dynamics such as national financial and environmental conditions. Many have argued that the dependency on chemicals and

expensive advanced breeding techniques have created ecological problems, ranging from water pollution to soil salinization, that may offset production gains [6,15,16]. Even if global grain production increased threefold in the latter part of the 20th century, fertilizer and pesticide use increased more than tenfold during the same period as a result of the spread of high-yield seed varieties and their associated production technologies [16]. These developments provide conclusive evidence that while the Green Revolution marks the most significant increase in agricultural yields and production in the history of humankind [17], it has not eliminated the reliance on capital-intensive and ecologically destructive inputs [18], and it has not eliminated global hunger. National development proponents and modernization theorists suggest that global agricultural production and trade improves human sustainability generally [19]. On the other hand critics of the global capitalist system posit that global agricultural production and trade are predicated on a system that exploits developing areas for the benefit of developed ones (e.g. [5,20,21]). This casts the food security issue, as well as issues of finance and environment, in an entirely different light.

We consider these points of departure theoretically and empirically in more depth below. But we begin with a review of other related causal forces primarily postulated in the academic literature. These are centered on world geography and the condition of the many national capitals that flow from them, since it is these conditions that in many ways causally pre-date all others of primary interest here.

### *1.2. Geography, national capitals and food security*

Long ago Malthus [22] tied population growth to national calamities, with physical disasters and war culminating in widespread death from hunger. More recently, Sachs and Warner [23] and others have initiated significant discussion of the role of geography and related natural resources in aiding food security. For instance, it has been suggested that the geographic latitude of societies, reflected in locales such as tropical and desert spaces, are associated with a range of other domestic natural and human resources that adversely impact food security [23,24] and societal development. Few would question that Africa's geographical position hinders development [25], insofar as it is characterized by the absence of fertile soils, and abundance of pests and parasites, hindrances to photosynthesis, and frighteningly broad-based infectious diseases [25,26].

Diamond [24] contends that the lead established in the Global North (e.g., Western and Eastern Europe, Eurasia) that grew grain species with a resistance to pathogens created an advantage over regions in the Global South (e.g., Latin America, Africa). The latter had comparatively little chance to compete. He continues his logic to include the presence and production of animal species that undergird superior relative production. These species also impact human disease and, by selective attrition, human capital leading to success in weaponry production and conquest by growing empires. Taken together these dynamics helped to ensure improvements in national well-being, including food security, for the Global North of Eurasia but the obverse for the Global South.

Easterly and Levine [27] address endowment theory, which maintains that geographic dynamics shaped initial national capitals and that these forms of capital have had enduring repercussions on one another. However, Easterly and Levine add that despite their sharing of the same latitudes, there have been enormous capital changes as well as capital differences over time even in commonly situated tropical countries. They continue to suggest natural endowments impact economic development outcomes. Their endowments approach indicates that, among others, latitude differentials and access to the sea are significantly associated with national development. They empirically determine that net

of controls, natural resources, pathogens, and crops are more significant than tropical latitude (see Diamond [24]) or coastal access in explaining an index of multiple “capitals,” as elaborated by Flora and Flora [28], and as used here. These capitals include items such as human capital (education), infrastructural capital (buildings, roadways), political capital (democracy; political stability), economic capital (the gross domestic product), cultural capital (homogeneity in worldview and absence of warfare over it), and social capital (such as the absence of class divisions and commonality in goal attainment). Easterly and Levine’s [27] seminal treatment suggests that natural endowments impact several capitals including economic development, consistent with the “geography hypothesis” which emphasizes endowments directly influence what has been termed “work effort” [29] and agricultural productivity, which relates to the gross domestic product per capita [24,26,30]. Their findings are consistent with the “institutions hypothesis” which argues endowments affect in an enduring way economic development and the resulting possibility of adequate food production.

Easterly and Levine [27] offer a crucial test that provides an “empirical sense” that the impact of institutional or capital development on economic development may be substantial, but such endowments do not explain economic development “beyond the ability of endowments to explain institutional development”. Unfortunately, Easterly and Levine [27] leave us with the nettlesome question of how these forms of national capital relate to one another. It is important to know that national capital outperforms geographic dynamics as an explanation of economic development, but if the capitals are equally influential in this role, is there an ordering among them that can be determined, in which certain capitals clearly bootstrap the others? This, too, is a key focus of our undertaking.

Romer [31] and Lucas [32] clearly acknowledge that national capitals spur national development and investment in infrastructural capital and human capital (education) could generally play a much greater role than is typically acknowledged. Putnam [33] has argued social institutions stimulate innovations, mutual learning, and productivity. Comparable arguments are forwarded by sociologists Coleman [34] and much earlier by Tonnies [35] and Weber [36]. As North [37] explains national institutions are “the underlying determinant of the long-run performance of economies.”

For Rodrick [38], economic capital spurs multiple interrelated capital investments under nuanced circumstances and it enhances the probability of equitable gains from national productivity. For instance, the “design” of economic capitals depends upon the allocation of political power among elites, however, consolidated democracy is linked to favorable investment, thus the political drives the economic.

It can be argued as well that political capital develops in structures and economies where voice and accountability are established, as are practical stability, the absence of violence, effective governments, the non-interference of government, and the rule of law. When taken together, these characteristics help ensure widespread access to societal well-being. It is the political apparatus that determines the allocation of society’s resources, enhancing or limiting all of the other capitals. Insofar as political capital shapes the allocation process, it determines whether only a minority eat well or whether the population as a whole is served.

### *1.3. Societal and global approaches*

Modernization theory in the social sciences views development as the progression of a society’s human values, culture, and technology. The Westernization of developing societies encompasses processes linked to advancement in the national capitals, offers a great deal of the logic foundational to

the Green Revolution, and consequently is pertinent to economic development, food security, and the environment. Developed economies have the modern values, work ethics, superior technologies [39,40] and evolved capital institutions that are essential for development. Early modernization theorists in particular considered Western nations as the blue-prints for how nations should industrialize and develop into modern societies [41-45].

In more modern writings, Parsons [46] follows the evolutionary thinking of his forbears and proposes societies are comprised of significant capitals, conceptualized somewhat differently, that determine their progress: goal attainment, served by the capitals that set societal goals and objectives; political systems (political capital) and agencies of social control (e.g., police and military); and latency, the conservation of basic societal integration, fostered by the perpetuation of cultural values and human capital. In economics, Rostow [40] proposed stages of societal growth through evolutionary stages—traditional, preconditions for take-off, take-off, and achievement of the ultimate stage of high mass consumption—all to be achieved through economic and infrastructural capital advance. For others, human capital attainments foster the advance that aids societal well-being, including environmental safety and related food security [47]. Indeed many focus on the importance of economic development to food security [48,49], and environmental risk [50], while others focus instead on the determining role of modernizing political capital [51,52].

Modernization of agriculture is a corresponding theme adopted by multilateral agencies during the Green Revolution era and more recently by the World Bank's *World Development Report 2007* [53]. Agricultural development theories have mirrored the transition from the development to globalization project [5] within the modernization theoretical camp. This includes the transition from a primary focus on agricultural technology development, to agricultural free-trade production strategies and, more recently, Bio-Revolution genetic technologies [18,54]. The basic premise of these approaches is that by adopting Western modernization capital technologies, and by industrializing their production in agriculture, national economies could develop with concomitant food production and food and environmental security. This has been extended to include export-oriented production strategies for development [55].

#### *1.4. Dependency and world-systems theories of social and economic development*

Political economy proponents counter many of the claims and findings of modernization scholars. Dependency writers [56-58] and world-systems theorists [59] focus on the inequitable power relationships among nations across the globe that result from exploitative production, trading, investment, and the overall structural positions of power and dependency of nations in the world division of labor. These processes are crucial to the political, economic, environmental, and food security concerns in all world sectors. According to Wallerstein [59] there is a three-tiered world system of core, semi-peripheral, and peripheral countries in which the core extracts surplus value from cheap labor and raw materials endemic to the periphery, and to a lesser degree the semi-periphery. This fosters nearly across-the-board advance for core countries. While it is less true for the semi-periphery or “transitional” societies (e.g. India, China), the periphery in particular experiences under-development in its many forms [58,60]. The capitals that the core may take for granted, political, economic, infrastructural, military and human capitals, for example, are vestigial and disarticulated from one another in the developing world. In turn, limited domestic capital formation and a malalignment among them limit the amount of investment that can go into social welfare and development promotion, resulting in severe social problems including

hunger [61-63] and the transfer of waste and other environmental maladies to the periphery, and to a lesser degree the semi-periphery [64].

While many world-systems scholars emphasize the exploitative economic arrangements in the world order that benefit the core, other theorists within this tradition emphasize political arrangements, such as imperialism [65], that afford the core uneven global power and influence over peripheral nations. Political, economic and cultural and military processes together under-develop the non-core [66]. The very nature of global agricultural production in the periphery undermines the developmental outcomes in these countries, jeopardizing universal food security, while simultaneously enabling luxury and excessive food consumption in the core [67]. Some indicate that this has resulted in a “hunger/obesity paradox” [68]. Devereux [69] reports that modern famines are a consequence of increased vulnerability due to globalization processes of integration and marginalization. As a result of dependency on food-imports, dependent economies are increasingly vulnerable to commodity price fluctuations. This vulnerability is heightened in severely marginalized regions, in particular sub-Saharan Africa, experiencing exceedingly high levels of poverty and political instability, which contribute to endemic hunger and famines [69]. Each of these new vulnerabilities due to globalization is further aggravated by transnational structures that cause peripheral nations to suffer the most extreme cases of hunger and “inherit” the environmental maladies of the core [70]. Due to Westernization of the modernization process, sociological research views these circumstances as necessary to understand, in order to account for food security, economic stagnation and environmental maladies, both theoretically and empirically.

It is no surprise that political economists suggest that hunger, wealth and environmental degradation are best addressed through reducing both global and domestic inequality perpetuated by uneven structures of power and dependency across the world-system. All three are a matter of global and local structures that create distributional dynamics which cause the well-being of the Global North at the expense of the Global South.

## **2. Method of analysis**

### *2.1. Sample*

To adjudicate the many complementary as well as contradictory themes reproduced above, we drew a sample of 200 nations from the over 218 countries that comprise the world. Excluded from our sample were small countries with populations of just a few thousand. Excluded also were countries that are not politically independent from another nation, and those that do not report conventional indicators to international organizations (e.g. North Korea). Our sample is larger than is typically the case in this study area, in part because our effort took relevant data from known sources that typically lead the world in breadth of data coverage (e.g. World Bank, FAO, UNESCO, SIPRI). We list the countries analyzed in Appendix A. We do not detect any easily discernible sample bias (except for the above), and believe our sample broadly represents all geographical areas in the world.

### *2.2. Analytic technique*

We use path analysis [71,72], the special case of structural equation modeling, to estimate models of the causal processes discussed above. The models estimated represent a web of variables with paths

of origin, or independent variables, drawn to dependent variables; causation is shown in a variable's position as recipient of a path with an arrow head pointing to it. Where possible we employed the more straightforward technique of using one measure for each variable of interest as suggested in relevant literature. In some cases, we employed indexes comprised of variables represented by several latent measures of the construct of concern. In the latter case we gleaned from the literature the major variables that represented the construct of interest. Tests were performed to ensure our constructs met the conditions prescribed by the ordinary least squares technique as described in Blalock [73] and in statistical programs such as SAS, SPSS, R and others. Our software of choice is SPSS.

Variables were causally connected by the theoretical expectations or hypotheses described above. No single researcher hypothesized the models tested but each contributed hypotheses that we linked in order to create a “big picture” of the food security process. In so doing we were able to address related questions that formed a portion of the overall model. For example, we were able to treat a key question in the economics literature about whether economic development is a product of geography, one or more of the capitals, or a combination of geography and all the capitals in concert. Further we could address the question of increasing meat and cereal production as the best solution to the serious problem of food security now and especially by the year 2050. We also address probable sustainability consequences for the world as a whole of current solution sets.

Cognizant of omitted-variable bias, we modeled numerous variables through direct effects and examined the relevant statistics. We excluded those variables and/or direct connections that did not produce statistically significant coefficients. We also determined that all variables were normally distributed as assumed for regression analysis. Multiple collinearity was considered and the bivariate correlation matrix was examined; this was concluded to be inconsequential as no value greater than 0.80 was found. All coefficients were standardized to allow direct comparison to each other. The relative power of all variables could be compared directly because we used standardized coefficients.

The equation that describes the generalized form of the model is given below [74].

$$Y_i = p_1X_1 + p_2X_2 + \dots + p_iX_i + \dots + p_nX_n + R_i$$

Where:  $Y_i$  = *ith independent variable*;  $p_i$  = *coefficient of  $X_i$  on  $Y_i$* ;  $R_i$  = *ith residual*.

### 2.3. Dependent variables

We report results for the central food security dependent variable coded by the World Bank as the average daily intake of protein. The equal treatment of all meats in the variable is warranted since an ounce of cooked meat of virtually any species produces near equal protein value [75].

As a complementary dependent variable we use the Ecological Footprint as defined by Wankernagel and Rees [76]. This dependent variable is the most commonly used indicator of the state of the international environment and measures both the biocapacity and ecological demands of nations. The ecological footprint captures key consumption-based activities that strain the environment across five primary economic sectors—energy, settlement, timber, food and fiber, and seafood. While we examined many alternatives for the environmental dependent variable, including nitrous oxide and grey water, the footprint offers robust validity in reporting and breadth in the availability of data. Other alternative measures were rejected because they often were confined to a marginal number of cases and subject to issues of recording and reporting difficulties. Moreover, they did not capture the central feature of our

food security conceptualization, that consumption, rather than production, is the key to understanding food security in the world today. Thus by including an ecological indicator driven by consumption processes, we are able to capture the impact of agricultural production and consumption in our model.

Consistent with the initial portion of our paper, we place emphasis on a third leg of sustainability to complement our social and environmental measures—financial capital [49,77]. This variable, the national GDP/c (gross national product per capita) is the subject of vigorous debate as our earlier coverage of the literature suggests. We tried a number of other proxy measures too such as openness to trade, but found they were not “loading” satisfactorily in our exploratory factor analysis, or even if they marginally fit the financial capital construct, in combination with the GDP/c, the variable addition did not cause the measurement to respond in consistent ways or ways expected by the theoretical or empirical literature.

## 2.4. *Independent variables*

### 2.4.1. Capital and its forms

To examine earlier reported arguments, we used measures of internal capital variables. Some researchers had principle interest in economic capital while others reported interest in causal relationships involving a wide variety of capitals. Capital as used in this paper refers to resources or assets. Often they are invested in their many forms to create new resources, frequently of a variety of new types, creating new capitals. We follow Flora and Flora [28] in identifying seven capitals, and emphasizing six of them in our analyses. Most important initially to our treatment is “natural capital” that includes air, water, soil, biodiversity, weather, plant life, and other related items including those of high value such as oil. The literature identifies some forms of capital as assets and others as “curses.” Our hypothesis is in line with the former—natural capital in the form of eco-systems that are conducive to plant life and the animals supported will aid all forms of sustainability.

Political capital permits social units of any size to translate its mores and norms into rules and regulations that enforce what has been referred to as the “social contract,” while distributing the pool of collective resources (gleaned e.g., from taxation) into many components that serve the collective good (highways, individual health, education and welfare) [78]. It determines the collective will on the distribution of resources and enacts that will. With this role political capital enhances democracy and stands as a central variable in subsequent advantage, determining the others, including economic capital. We are consequently following the lead of many who posit that political capital leads to economic capital and through a variety of other capitals effects food security and the environment (for discussion, see [27,28,36]). Our political capital variable is taken from the Worldwide Governance (WGI) projects which report country-level data for 1996 to circa the present on six dimensions of government: Voice and Accountability; Political Stability and Absence of Violence; Government Effectiveness; Regulatory Quality; the Rule of Law and, Control of Corruption [79].

Financial capital, in the words of Flora and Flora [28] includes “savings, income generation, fees, loans and credit, gifts and philanthropy, taxes and tax exemptions. Financial capital is much more mobile than the other capitals and tends to be privileged because it is easy to measure.” We commonly think of our incomes (or others’) and collection of “riches” (wealth), but of course at the most collective levels these translate into national production income (the GDP/capita). The wealth per capita variable used is taken from the World Bank and log transformed to reduce skewness.

Infrastructural capital is built by humans for the purpose of collective living and goal attainment.



Roadways, bridges, trains, planes and other conveyances are longstanding forms of infrastructure. In contemporary times it has increasingly become means of communication (such as cell phones) and other electronic forms for the achievement of the individual and collective wills. The infrastructure variable included an index of the number of fixed broadband internet subscribers per 1000 people and passenger cars per 1000 people [80,81]. The data were compiled by the World Bank and accessed through their data portal; data used were circa 2000.

We add military capital to the Floras' list. Military capital has been the critical mechanism used by states to achieve their national will using the real or the prospects for real coercive force across most of human history. These may in the most crisis-filled times be employed to enforce the will of the state on segments of the nations' population. Typically, military capital has become institutionalized as a means to achieve national goals that either oppose the goals of other nations, or work in tandem with them. President Eisenhower identified a "military-industrial complex" in the U.S. that had come to define and pursue their views of the goals of the nation, and impose them on the wills of citizens and opposing nations. A number of authors link military expenditures to well-being, facilitating employment and wages [82]. We employ a measure of national expenditure per soldier taken from the World Bank (Military expenditures/Armed forces personnel) for circa 2000, as our military capital measure [83,84].

The GINI index measures wealth differentiations throughout the national system. Inequality scores range from a hypothetical "0" score (no inequality whatsoever) to a hypothetical "1" (the presence of total inequality in wealth distribution). The inequality data are taken from the World Bank [85] for the circa 2000 period.

#### 2.4.2. Geographical variables

We also used a geographical variable to represent earlier contentions in what might be called the "natural resources: blessing or curse" contention after the article by Sacks and Warner [23]. We added coastal area, which measures in total kilometers the length of shoreline bordering a nation, and is taken from the World Resources Institute [86]. For the U.S. this primarily includes the combined lengths of the Atlantic and Pacific Oceans, and the Gulf of Mexico.

Eco-system capital is a continuous score assigned on the basis of the map of biomes or eco-systems as defined by the Museum of the University of California, Berkeley. Descriptions provided by that source and other comparable sources such as the University of Michigan, University of Missouri, and the National Geographic Society classification of biomes were used to rank order on an ordinal scale those eco-systems most conducive to the production of plant and animal life. Our scores range from "1" assigned to the least productive (e.g., desert), "2" for the next to least productive (e.g. tropical rainforest and savannah) and "3" for the most productive biomes (e.g., temperate forest, grasslands, and taiga).

Finally, we include a measure of the latitude for each country to capture the essence of Diamond's argument about the importance of a society's latitude for its ultimate well-being [24]. Recall Diamond emphasizes the geographical advantages of the East-West axes characteristic of the North-Eastern latitudes.

#### 2.4.3. Other independent variables

We also included a conflict variable based on earlier arguments and the intuitive understanding that protracted internal wars may disorganize critical forms of capital and rob them of necessary monetary support. For example, warfare may take human capital that would be more optimally employed in other

national sectors. It likely will disrupt internal production including crucial food production, destroy otherwise productive land and, until resolved successfully, even stand in the way of an evolving national identity based on cultural legacies [28]. Our source relies on SIPRI (Stockholm Peace Research Institute) and war data reported by Sivard [87]. Ultimately global news reporting agencies (the BBC, the NY Times) provide onsite conflict accounts that frequently corroborate second-level sources. While wars in modern times typically occur on the soils of developing countries, forty-six instances during the period examined involved the military interventions of the powers of the Global North.

We use a variable measuring the centrality of a nation in the international arena, or its world system position. The data involve matrices of nation-to-nation multiple networks—economic trade, military exports, the existence of embassies from foreign countries on host soils, and political treaties (a symmetric matrix) for the years 1995–1999—which identify the degree of centrality of each nation vis-a-vis all others in the global political economy. Their centrality and power/dependency is demonstrated through the application of a “multiple-network analysis” (“blockmodel”) program that simultaneously analyzes the structural positionality across the four networks for each nation. The results show which nations cluster into similar structural positions insofar as they are similarly related to all other nations across all four dimensions of connectivity. The software to produce the final results is from UCINET from the University of California. An early discussion describing the technique is found in Snyder and Kick [66] and the exact country classifications are provided in [88]. For illustrative purposes we mention the United States stands as the head of the “core” of the world system in the results, joined by Japan and the bulk of Western Europe, Australia and Canada. The periphery is comprised of the bulk of the developing world of South East Asia, Africa and Latin America. Between these extremes are the semi-peripheral nations of Eastern Europe, the rapidly rising nations of India and China, and several larger oil-producing countries. These tripartite distinctions correspond with Wallerstein’s [59] world-systems approach as discussed above.

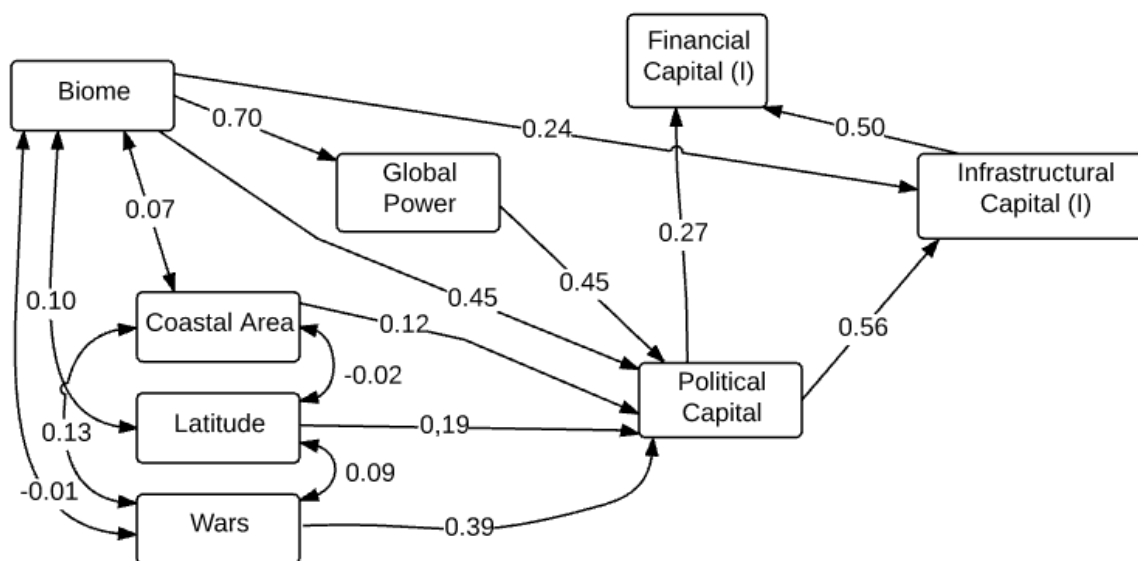
Our treatment of societal food production is the production of crops and meat available in principle for consumption by the national population. Total crop production is defined as the total food crops produced in a year that are edible and contain nutrients; thus, coffee and tea are excluded due to its lack of nutrient value [89]. Livestock production is defined as the total livestock produced in a year (in tons) that includes meat and milk from all sources, dairy products and eggs, honey, raw silk, wool, and hides and skins [90]. The data were compiled by the World Bank and accessed through their data portal; data used were circa 2005. Our assumption, however, is that despite these changes to overall available domestic food, it is the absence of wages to purchase food produced internally or imported externally that is a limit placed on food security for poor countries. This limit is reflected in the GINI which measures the distribution of wealth. Certainly as described food sources are fostered by the domestic production of meat, crops and the available wealth (GDP/c) to purchase them, as well as by other dynamics discussed earlier that facilitate domestic production on smaller farms. Also, while food is imported for the population, some unknown portion is often “pirated” by officials in government positions or common robbers in the distribution system, who may garner, hoard, and sell a variety of foodstuffs.

### 3. Results and Discussion

#### 3.1. Findings of analysis

Figure 1 presents the path model for the estimated links between geographic and global system

precursors to the various national capitals, and the capitals' effects on economic development. Only paths of statistical significance are presented, although a sizeable number were estimated.



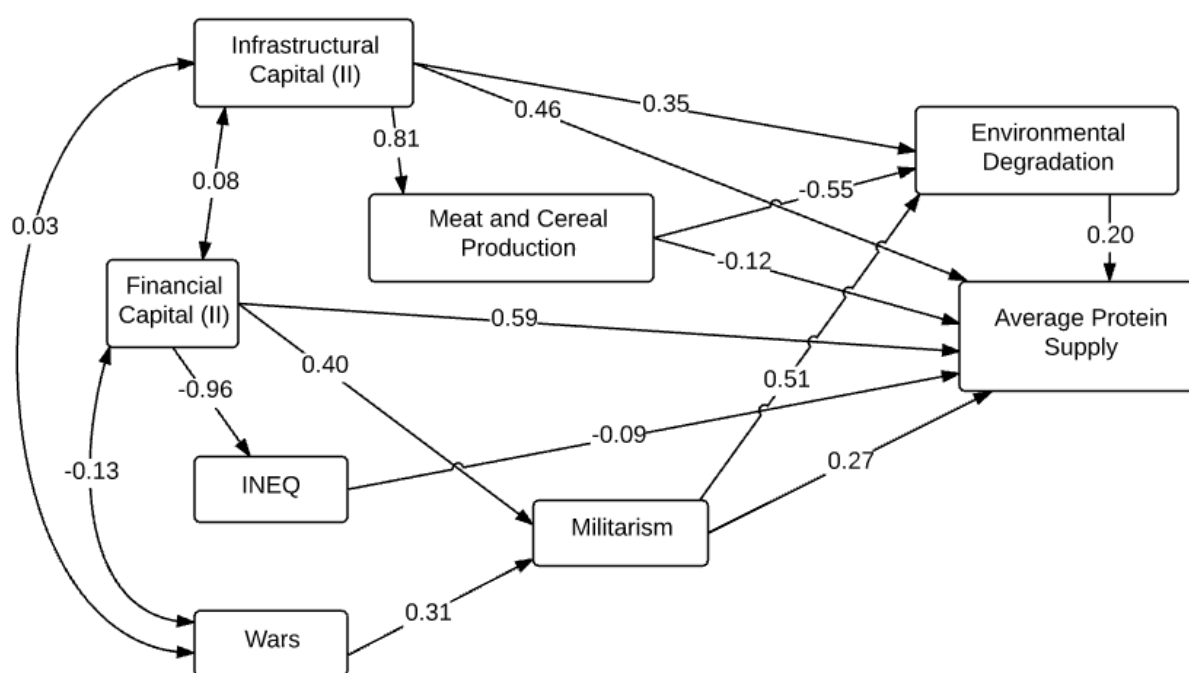
**Figure 1.** Geography, capitals, and economic development. The numbers on each path are statistically significant standardized coefficients representing the impact of the causal variables on the caused variables.

The readers' attention is drawn to the strong pathway between national eco-systems (Biome) and their global power and global powers' moderately strong impact on political capital, and the favorable economic returns (financial capital) to political capital. To be sure, latitude and size of coastal boundaries also impact the political capital index, consistent with the East-West axes themes developed by Diamond [24], and with others who emphasize the criticality of the seas to national trade, conquest, and power as well, especially the world systems theorists [59]. When considered historically, this helps interpret the experiences of Western Europe in particular. The Western European countries enjoyed the advantages of natural resources that are part of their well-endowed eco-systems. These included the availability of food and housing potentials, and advantages in the construction of the machinery and weaponry of conquest. The national biome influences domestic infrastructure directly while the latitude works indirectly through political capital to influence infrastructure; payoffs to infrastructure will be considered when Figure 2 is examined. Aside from geography, wars could in principle weaken the political capital and overall well-being of a nation this is particularly true in the Global South where political capital is already weak. However it is arguable in the Global South, wars also may settle longstanding disputes, serving positive functions for future national stability. Nevertheless, the pathways of Figure 1 also reflect the involvement in wars of the Global North (with its stronger political capital) in its interventions into the Global South.

Notable results from Figure 1 are the powerful effects documented for geographic inputs, which commonly are ignored in studies of national development. We also note the widespread biome effects relative to other geographical measures, which we assume is due to it being the most localized measure of the climate of a nation, whereas latitude is a general descriptor. Notable as well is the explanatory consequences of geography for domestic capitals (political and financial) and for international capital

in the form of global centrality and power of nations. There is little question this feeds back into the domestic system as global prominence enhances domestic well-being.

Figure 2 relationships link these factors to food security as well as to ecological consequences. Economic development, as modeled by Financial Capital, is directly tied to the national infrastructure. The huge effect of the gross national product per capita, part of Financial Capital, on the Gini index of inequality is especially worthy of attention. This finding is far from unusual, although the strength of the relationship for the contemporary period is surprising. One plausible explanation is that typically the strong relationship between national wealth and greater inequality is most manifest as transitional societies grow in population. The modern period has been characterized by this dynamic, and it apparently has included the emergence of significant surpluses that are especially mal-distributed. In relative terms there plausibly is much greater equalization among wealthier nations, even if that equalization is among classes below the wealthiest ones.



**Figure 2.** Economic development, infrastructure, militarism, food production and security. The numbers on each path are statistically significant standardized coefficients representing the impact of the causal variables on the caused variables.

National wealth, as modeled by Financial Capital, would seem likely to improve the national power to produce high protein foods, however it does not improve protein-related food security through the route of meat and cereal production. Meat and cereal production require a certain degree of infrastructural development, and this is confirmed in the coefficient between infrastructural capital and total meat and cereal production. All of these trends are shown in Figure 2.

Infrastructural usage or improvements of virtually any sort should increase the ecological footprint, insofar as the infrastructure facilitates production and transportation of products and often does so with a high profile usage of fossil fuels. Infrastructure also facilitates the consumption of those products which also increase the ecological footprint as does the energy consumed and the waste

produced. By the same logic the impact of expenditures on the national military apparatus, a logical consequence of warfare, appear likely to augment energy production, waste generation, and the concomitant CO<sub>2</sub>-dominated footprint. In a related vein, as might be anticipated, wars exacerbate state expenditures on the military by a considerable margin, and the development of the military complex results in infrastructural benefits, likely in the form of equipment for soldiers and related developments such as the growth in military installations, armament industries, and related offshoot technological industries are either expanded or created anew.

Relative to industrial production, it appears that agricultural production and waste is less pernicious in its footprint consequences. This is not to say that agricultural production is void of impact on the environment. Production and use of pesticides, fertilizers, and machinery ensure that agriculture leaves its imprint on the Earth. Yet its footprint remains trivial in the CO<sub>2</sub>-dominated measurement of the ecological footprint, relative to industrialization in all other sectors of the economy combined.

The footprint marginally is related to the protein supply. It seems most possible that wealth and infrastructure that increase the footprint also contribute to commercial sources of the food.

### *3.2. Discussion of findings*

As stated by the World Bank, nations must produce substantially more food to feed the 9 billion people expected by the year 2050 while changes in rainfall patterns, soil quality, available arable land, crop yield, plant diseases, dietary choices and in other important resources are likely to exacerbate the problem. While some optimistically posit that technological fixes will improve food production and environmental protection, others more pessimistically question if the nature of the global structure, both geographically and socio-economically, can contribute to universal food security. Based on our analyses, we offer a series of perspectives on global food security.

Our path analysis of 200 countries shows biomes' direct impact on national wealth is trivial, but its influence is substantial when considered indirectly, through the international strength of states, which is seen in power and political capital. Superior geographical positions permit accumulation of substantial surplus that is manifested by political capital. Latitudes contribute to the biomic characteristics of countries but the relationship is weak. For example, the non-homogeneous countries of Eurasia share approximately the same latitude, though not biomes, and these countries differ substantially in their economic strength, state viability, and environmental circumstances. Diamond's [24] early treatment of such issues appears to emphasize the near sole importance of east-west versus north-south axes, and consequently latitudes. Yet, his argument is a great deal more nuanced and includes biomic considerations. Perhaps due to his own emphases, the many other geographical precursors to economic well-being in Diamond's work commonly are secondary in treatment of his work. Our results document the need for future research to pay a great deal more attention than has been the case in the past to the ecosystems of nations and to recognizing the heterogeneity of ecosystems within nations in order to understand economic development. The United States, for example has some of their most productive lands (such as Indiana, Illinois, Iowa, and Kansas) at approximately the same latitude as the least productive (such as Nevada, Utah, and parts of Wyoming). It also has some of the driest areas (southern parts of Arizona and New Mexico) at the same latitude as some of the wettest areas (Louisiana, Mississippi, and Georgia). Similarly, the most productive agricultural areas of Europe are at the same latitude as those areas of eastern Canada with much more limited agricultural options.

It is common for studies in Sociology to report strong, direct linkages between the structural

positions of the power of nations and consequent national economic development and growth, as well as inequality. For the contemporary period tapped by our data however, we found world power vis-à-vis other nations predicted to national state strength or political capital, which in turn determined economic development. This finding is different from emphases adopted in a number of prior treatments in that we had never before seen an estimation that employed state strength as a mediating variable translating the effect of global power on a range of domestic outcomes, including economic capital. We could only recollect estimations of direct effects between world-system position and economic development. It is plausible that Wallerstein's [59] popular and pioneering approach to the world system was a Marxian-inspired approach which established a legacy that seemingly ignored the possibility of a nation state translating its international power to significant economic advantage through domestic capital advantage. Possible mechanisms include the state's collection of taxes and determination of domestic usage of those revenues, to the setting of land ownership rules and regulations, to the state's coalitional powers with giant multinationals, and in the modern era, its power to dole out support to portions of the corporate world and the public to keep them afloat during the most challenging of times. By so doing, the wealthiest of states at least have avoided or postponed cataclysmic national economic consequences.

Do geographic effects operate through domestic capitals to impact economic development? Our results suggest geographic effects operate through domestic capitals. Domestic capitals are important in their own right, but they often translate geographic factors into a range of outcomes, including those that are economic in nature. The interaction of the two domains and their consequences is an absolute necessity for future empirical examination.

Results shown in Figures 1 and 2 support the modernization themes that technological advances seen in infrastructural capital improves meat and cereal production. Infrastructural improvements are commonly accompanied by wealth enhancements, although the correlation seen here is small (+0.08). Increases in wealth (financial capital) reduces warfare, which would appear fortunate because warfare increases national expenditures on the military apparatus. Empirical linkages demonstrated in earlier studies showing the military helps poor farmers in settings across the world (Nigeria, China) are shown here as increases in average protein supply. These indirect ties indicate that the military helps ensure the population is fed in both the Global North and South, at least over the time covered in our analysis.

The large negative effect of economic development on the Gini was not entirely expected. Modernist theory suggests development will help ensure the equalization of wealth distribution but recent popular movements around the world have challenged governments to increase equity in the sharing of wealth. The economic downturn has brought an equalization in the wealth of the middle and lower classes, but a sharp concentration of wealth in the hands of those at the very top of the hierarchy only (Amnesty International). This is an important empirical question that requires an in-depth answer that is beyond the scope of our effort.

Our central concern has been with the impact of technological processes and modernization on the production and distribution of food in the year 2050. The Global North can be expected to be the locus of well-fed populations, but the same cannot be said of the Global South (correlation is +0.59). This points to a divergence, in the future hunger profile of the world due to a widening of the income gap between rich and poor of the world. While some are expecting an increase in global wealth and well-being and evaporation sharp drop of the income gap between rich and poor except for the deeply distressed continent of Africa, World Bank data show the opposite. World Bank data show that the GDP/c for most of Africa at this time is around \$1000 per year or less, and clusters between \$1000 and

\$2500 per year for developing nations. The GDP/c for Western Europe has is around \$50,000 per year and around \$55,000 per year for the United States [91]. Rates of annual growth in the Global South may be somewhat higher than in the Global North but it is doubtful convergence will stem from slightly higher growth rates and phenomenally different bases. Three decades ago the wealth gaps between nations were within \$20,000 of one another. By 2050 there may be a convergence among those at the bottom of the global distribution, among some transitional societies, and among the wealthiest, but divergence will be the character of the gap among the highest and lowest sectors of the distribution.

As we confirm the growing concentration of wealth within countries, we raise the possibility that this will be true between Northern and Southern nations as well. It is not clear that the associated discrepancy in food security can be offset by technological innovations and increased production of cereal and meat, as suggested by the World Bank. The negative effect of the GINI coefficient of inequality on average per capita protein supply suggests that increases in food production will continue to be mal-distributed in the developing world. Without increased wages and roader wealth distribution true food security may be out of reach for some significant segment of the world's population. On the basis of our analyses, the food security gap cannot be reduced by 2050, not because of insufficient technology and global food production but because of inadequate wealth distribution within countries and the concomitant inability of a portion of countries' population to purchase sufficient food locally.

We find a relatively small but negative relationship between meat and cereal production and the average daily intake of protein. The production of food does not bear a one-to-one relationship with the consumption of food. Food waste and mal-distribution by the state will impair the average protein intake of the masses. Domestic production may increasingly be destined for export by agribusiness. World-system and dependency authors argued as early as 1948 that the Global South's production of food was "distorted" bringing profits to local elites in alliance with foreign powers, much to the detriment of farm workers or peasants [56-58]. Modernization programs for the infrastructural development of poorly developed countries may foster the production or import of food but are based on the planting, fertilizing, pest management and water management techniques and preferences of the Global North without considering the practices and cultural legacy of developing nations.

Agriculture, represented here by meat and cereal production, converts solar energy and atmospheric CO<sub>2</sub> into human food but can also contribute harmful emissions of methane and nitrous oxide [92-94], both of which are strong greenhouse gases. The ecological footprint that was used to represent the ecological degradation variable only includes CO<sub>2</sub> emissions; it specifically does not include methane and nitrous oxide [94,95]. The moderately strong but negative effect of meat and cereal production on environmental degradation (-0.55, Figure 2) reflects the conversion of atmospheric CO<sub>2</sub> by crop production while ignoring the very real environmental consequences of other emissions. If either or both of these gases were incorporated into the footprint calculation as Walsh demonstrated with methane [94], the footprint estimates around the world would in all probability be very different, leading to very different conclusions.

Thus we are not sanguine about an improved global environment by 2050 either. Virtually all theorizations on the environment assume that the accrument of population, wealth, and technology impacts will continue to drive the world environment in a negative direction for the immediate future [5,20,27,70]. The natural resources that bootstrap political, financial, and infrastructural capitals and economic development will advance societal and global expansion and, according to our results, will indirectly drive the system toward greater environmental degradation with its attendant hazards. Although the environment has not been a central concern of this manuscript,

we note its importance to and potential impact on food security in a pernicious manner, even if it does not appear to do so through the footprint variable in our model.

#### 4. Conclusions

Our empirical findings offer linkages that relate to our foundational issues, in tying national geographic conditions to global power, a series of national capitals (political, financial, infrastructure), to national inequality, warfare and militarism, and ultimately our most dependent variables of interest, food security and the environment. Our discovery of many rich linkages among these variables leads us to conclude that our three most dependent variables are the direct or indirect product of far-reaching and diverse causes that often are singularly emphasized in individual disciplines. In other words, interdisciplinary work may very well advance scientific answers to important questions raised by our most prominent international institutions, such as the World Bank, the FAO, and the United Nations.

Yet, we acknowledge that we have not expressly treated other important dynamics in our analysis. For example, while meat products (e.g., milk) are valued in the Global South, its consumption of meat is far lower than that of the Global North. Africans or portions of Africa appear to more highly value yams, plantains, green bananas, barley, black-eyed beans, curry, eggplant and lentils. It could be that if the Global South were only richer they would purchase the meat and cereals enjoyed by the Global North with their newfound wealth. It could also be true that the provision of meat and cereals that are not routinely part of the diets of third world citizens will go uneaten. The actual preferences and culinary culture of people around the world should be examined before vast resources are devoted to the infrastructure necessary to recreate Western diets for the entire world. The health implications and the associated financial and human costs of those diets should also be investigated.

#### Conflict of Interest

The authors have no conflicts of interest.

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