JOURNAL OF WORLD-SYSTEMS RESEARCH

ISSN: 1076-156X | Vol. 25 Issue 1 | DOI 10.5195/JWSR.2019.761 | jwsr.pitt.edu

Do China's Environmental Gains at Home Fuel Forest Loss Abroad?

A Cross-National Analysis

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Abstract

The theory and empirical research on ecologically unequal exchange serves as the starting point for this study. We expand the research frontier it in a novel way by applying the theory to China and empirically testing if forestry export flows from low- and middle-income nations to China are related to increased forest loss in the exporting nations. In doing so, we analyze data for 75 low- and middle-income nations using ordinary least squares regression and find support for our main hypothesis.

Keywords: China, Ecologically unequal exchange, Forest loss

In the late 1970s, China instituted reforms that ushered in rapid industrialization, urbanization, and unprecedented economic growth (Chen 2007). Economic growth resulted largely from a strategy that emphasized increased manufacturing capacity for export. During this time, accompanying changes in Chinese consumption patterns developed as growing urban populations were

consuming more food than ever before and deriving larger portions of their diets from meat, diary, and processed foods (Yu et al. 2016). Initially, to support economic growth as well as changing consumption patterns, China utilized its own vast natural resources and land (Mol 2011). However, this decision created extensive environmental problems including increased forest loss, biodiversity loss and endangerment of species, soil erosion, air pollution, and water scarcity (Karl, Roland-Holst, and Zilberman 2013).

In response to such issues, the Chinese government implemented a national reforestation program and a concomitant logging ban starting in the late 1990s (Karl, Roland-Holst, and Zilberman 2013). Viña and colleagues (2016) find that this reforestation program has been quite successful, increasing forest cover in China by 1.6 percent (or 157,315 square kilometers). For scale, this corresponds to an area slightly larger than the state of Georgia in the United States. While evaluating such domestic conservation efforts, these authors speculate that "although China's forest conservation policy may exert positive effects on its forests, China has become one of the world's leading timber importers. Thus, China's conservation policy may be exacerbating forest degradation in other regions" (2016:4).

Despite the apparent connection between domestic conservation efforts and resulting displacement of environmental harms to other countries, we are not aware of any cross-national research that that actually tests this contention, which leaves a rather large gap in the empirical literature. This dearth of research is surprising for three reasons. First, more than 30 years ago, Bunker (1985) theorized how exports from poorer to wealthier nations tend to adversely affect the natural environment in low- and middle-income exporting nations. Second, social scientists using cross-national data have tested and found support for the theory of ecologically unequal exchange in other contexts.[1] Third, scholars have started to refine the theory of ecologically unequal exchange to consider how unequal exchange may also be driven by middle-income nations (and not just high-income nations) as their pursuit of industrialization puts pressures on exporting low- and middle-income nations in (Ciplet and Roberts 2019; Frame 2019). In spite of the theoretical developments and growing body of empirical research that are pertinent to the case of China, there remains a scarcity of research on this particular question.

In this regard, a nascent body of research examines how China's demand for natural resources affects the environments of low- and middle-income nations. However, the empirical results so far have not been consistent. On the one hand, using a multi-region input-output model for a sample of 186 nations, scholars such as Feng and Hubacek (2014) found that China has been able to offset

[1] See a special issue of the *Journal of World Systems Research* edited by Frey, Gellert, and Dahms (2017) (http://jwsr.pitt.edu/ojs/index.php/jwsr/issue/view/67) for a review and examples.

a portion of its carbon dioxide and sulfur dioxide emissions by importing natural resources and agricultural products from low- and middle-income nations (Yu, Feng, and Hubacek 2014). The implication is that such environmental harms are displaced onto exporting nations. On the other hand, Mol (2011) and other scholars contend that China's demand for natural resources from Sub-Saharan African nations will not necessarily have a detrimental impact on the natural environment in those nations. Environmental harms may be avoided because Chinese companies and banks have been participating in voluntary codes of conduct designed to lessen their environmental impacts, and Chinese investments and other economic activities have been under scrutiny by non-governmental organizations and social movements to improve their environmental performance (Mol 2011).

Drawing on the theory of ecologically unequal exchange, we anticipate that China's reliance on exporting nations to reduce its own domestic environmental harms, while also not producing harms in those very same exporting nations, may amount to a sleight of hand. Thus, as the starting point for our study, we draw on the theory of ecologically unequal exchange and the existing but contested empirical research on the topic. Our empirical work responds to calls by scholars to refine the theory by applying it to rapidly industrializing middle-income nations such as China. Specifically, we seek to address a particular gap in the literature, in that no empirical research has assessed whether higher levels of forestry export flows from low- and middle-income nations to China are related to increased forest loss in those low- and middle-income nations.

We now turn to a focused review of the theory of ecologically unequal exchange and the empirical research related to forest loss informed by it. We then discuss why it is important to extend and apply the theory to China, with its potential implications for forests in low- and middle-income nations that export to China. We then describe our research methodology including our sample, variables, modeling strategy, and findings. We conclude with theoretical, methodological, and policy implications of our findings, along with considering some limitations of the study that point to directions for future research.

Ecologically Unequal Exchange Theory and Research: A Brief Review

The theory of unequal ecological exchange is an extension of various political-economic theories that suggest that high-income nations are advantageously situated within the global economy and are more likely to secure favorable terms of trade (Amin 1974). This advantage facilitates disproportionate access of high-income nations to natural resources and ecological sink capacities of low- and middle-income nations (Rice 2007). Put differently, high-income nations are able to shift many of the negative environmental externalities associated with their natural resource demands onto low- and middle-income nations (Jorgenson and Rice 2005).

Why may this be the case? In general, high-income nations benefit from their favorable position in global trade networks (Hornborg 2003) because the prices of exports from low- and middle-income nations, largely based on exploiting natural resources, consistently fall in value relative to the prices of manufactured goods and services exported by high-income nations (Frank 1967). This is the result of several factors that drive down the price of natural resources including competition among the number of nations exporting similar products, subsidies by governments in high-income nations who also produce similar goods, and an abundant supply of cheap labor to produce the goods in low- and middle-income nations (Hornborg 2003).

McMichael (2004) describes how various organizations facilitate the process of ecologically unequal exchange for high-income nations. For example, the World Bank's investment loans often finance infrastructure projects that are meant to facilitate bringing exports to market (Rich 1994). High-income nations also finance similar projects via their export credit agencies (Swamy 2017). At the same time, the International Monetary Fund's structural adjustment lending requires highly indebted low- and middle-income nations to adopt certain macro-economic policy reforms meant to boost natural resource exports, including economic incentives (e.g., tax holidays) and regulatory concessions (e.g., environmental law exemptions) for foreign investors (Shandra, Rademacher, and Coburn 2016). Finally, multinational corporations exacerbate the process by engaging in a "race to the bottom" (Dick 2010) which takes advantage of competition among exporting nations. In such instances, multinational corporations are able to extract economic incentives and regulatory concessions from a host nation by relocating or threatening to relocate their facilities to another low- or middle-income nation (Frey 2012).

Taken together, the result of these policies characterizes unequal exchange—that is to say, requiring nations to export more natural resources in order to buy an equivalent value of manufactured goods and services from high-income nations (Muradian and Martinez-Alier 2001). A low- or middle-income nation may find economic success by exporting more and more natural resources in the short-term, however, these nations will only be able to afford fewer and fewer imports in the long-term (Giljum and Eisenmenger 2004). This situation is thought to be the driving factor behind extensive forest loss in low- and middle-income nations as they expand exports to keep imports of manufactured goods and services from declining (Roberts and Parks 2007).

The earliest research to find support for ecologically unequal exchange involved material flow analysis that developed natural accounting frameworks to measure the flow of biomass and other natural resources from low- and middle-income nations to high-income nations (Fischer-Kowalski and Amann 2001). These accounting methodologies are continuing to be refined to ensure more accurate assigning of impacts to consumers and producers (Lenzen, et al 2007).

However, such work is mostly descriptive by design and does not consider if such flows have impacts on the natural environment of exporting nations.

In response, cross-national researchers have addressed such concerns in a comparative explanatory framework. For instance, Moran et al. (2013) calculated ecological footprints scores for 187 nations, including impacts such as greenhouse gas emissions, water use, water scarcity, air pollution, and biodiversity loss. The authors then compare scores across nations at different income levels to conclude that high-income nations externalize various environmental problems onto low-income nations via imports from these nations. In related research, Jorgenson and Rice (2005) calculated a measure of export flows for a large sample of nations that quantifies the proportion of a nation's total exports sent from a low- or middle-income to a high-income nation. The authors go on to demonstrate that higher levels of exports sent from low- and middle-income nations to high-income nations are related to worse ecological footprint scores across low- and middle-income nations. Rice (2007) also examined the ecological footprint of nations and demonstrates that the impact of exports to high-income nations are especially detrimental in low-income nations. Thus, high-income nations appropriate or take up "environmental space" (the natural resources and sink capabilities of ecosystems) in low-income nations as measured by their ecological footprints. Jorgenson (2009) analyzes panel data on ecological footprints of nations and demonstrates that the harmful impact of exports to high-income nations in low- and middle-income nations has become more pronounced over time in those exporting nations, consistent with the theory of unequal exchange.

The research on ecological footprints has been accompanied by work that examines specific impacts on the natural environment in low- and middle-income nations. For instance, Jorgenson (2006) focuses on forest loss and finds that higher levels of total exports sent from a low- or middle-income nation to a high-income nation corresponds with increased forest loss in the exporting nation. This has been followed by research that examines sector specific export flows. In this regard, Jorgenson, Dick, and Austin (2010) find that a weighted index of agricultural, forestry, and mining exports from low- and middle-income nations to high-income nations are related to increased forest loss in the exporting nations. Shandra, Leckband, and London (2009) find that forestry export flows from low- and middle-income nations to high-income nations produce similar results. Similarly, Shandra et al. (2009) link forestry exports from low- and middle-income nations to high-income nations to increased threatened mammal and bird species in exporting nations.

The literature also contains further refinements that consider the ecologically unequal exchange of specific exports from low- and middle-income nations to high-income nations. For example, in studies that focus on consumption in high-income nations, Austin (2010a), Austin (2010b), and Austin (2012) find that soy, beef, and coffee exports from low- and middle-income

nations correspond with increased forest loss. Noble (2017) demonstrates that higher levels of chocolate export flows from low- and middle-income to high-income nations also correspond with increased forest loss in the exporting nations. The findings from this wide-ranging body of empirical research consistently show that exports to high-income nations are associated with environmental harms.

China, Ecologically Unequal Exchange, and Forests

The preceding discussion describes the how high-income nations benefit from ecologically unequal exchanges. While this body of research yields fairly conclusive results, less is known about the role that rapidly industrializing middle-income nations like China play in the process of ecologically unequal exchange, despite recent calls for social scientists to better understand the issue (Frame 2019). China's economy is still oriented around an export model while also attempting to satisfy its large and growing demand for domestic consumption. It is unclear whether their trade practices displace harms onto poorer nations or if China has been successful in establishing more balanced and less ecological destructive trade relations. As such, we seek apply the theory of ecologically unequal exchange to China and contribute to the nascent and contested research that exists on the topic.

How has China gone about becoming the largest importer of forestry products that predominantly come from other low- and middle-income nations? Most notably, it has provided bilateral financing in the form of loans or grants to its trade partners to support their industrialization (Bräutigam and Xiaoyang 2009). In the forestry sector, China has emphasized developing export capacity of its trade partners, building roads, highways, railways, and ports that facilitate market access to commodities (Sun, Ren, and Van Epp 2014). But over time China has grown worried about the viability of such projects once it ends its financing (Bräutigam and Xiaoyang 2009). Thus, China continues to reform its practices to be more "mutually beneficial" with an emphasis on increasing profits for Chinese companies while still supporting industrialization in its low- or middle-income nation trade partners (Smaller, Wei, and Yalan 2012).

China's new focus was well timed, as it was positioned to take advantage of investments opportunities abroad that opened up as a result of the International Monetary Fund requiring low- and middle-income nations to privatize many government functions as part of structural adjustment lending during the 1990s (Bräutigam and Xiaoyang, 2009). Initially, Chinese companies set up trading companies that purchased timber from domestic producers, entered into a lease to run the project for a specified length of time, or supported a joint venture with a recipient government or domestic firms in a low- or middle-income nation (Bernasconi-Osterwalder et al. 2012). The government supports such ventures by providing Chinese companies with below

market interest rate loans and discounted risk insurance from its export credit agency (Dauvergne and Clapp 2005). As part of the loans, China also provides technical assistance, often in conjunction with inter-governmental organizations like the United Nations Food and Agriculture Organization or with members of the European Union (Mayer 2018)

Further, China has taken step to promote investment by its companies abroad in an effort to facilitate forestry imports. These efforts include waiving import duties on wood, pulp, and paper from low- and middle-income nations and completing bilateral investment treaties with other low- and middle-income nations (Smaller, Wei, and Yalan 2012). The Chinese government also provided financial incentives and regulatory concessions to its companies (Bräutigam and Xiaoyang 2009). The financial incentives include tax holidays, regulatory concessions, and the elimination of administrative requirements that companies receive permission to invest overseas by the central government (Smaller, Wei, and Yalan 2012). China also tends to limit monitoring, enforcement, and prosecution of exports known to have been logged or harvested illegally (Gellert 2005).

These changes have opened the way for more Chinese investments in the forestry sector of low- and middle-income nations. However, such investment has evolved in a number of ways. First, more privately-owned small and medium size enterprises have entered the market (Li and Yan, 2016). The investment of firms with less than $10 million in registered capital is notable because they do not receive any government funding or loans from Chinese commercial banks unlike larger companies (Li and Yan 2016). Because of the limited financial ties to the Chinese government and banks, Kittilaksanawong and Dai (2016) argue that small and medium sized enterprises are less likely to comply with voluntary guidelines related to conservation. Second, large Chinese companies are now directly acquiring forest concessions and setting up pulp and saw mills to process logs for export to China as paper and wood (Li and Yan 2016). These investments allow China to play a larger role in the management of a low- or middle-income nation's forests (Li and Yan 2016).

The factors discussed above are the ways that China has been able to reduce domestic environmental problems by developing and relying more on increased forestry exports from other low- and middle-income nations. This would lead us to expect that exporting nations would absorb the environmental harms displaced onto them. However, the limited research applying ecologically unequal exchange to China has yielded contradictory results.

On the one hand, Mol (2011) carries out detailed case study analyses of China's trade with various Sub-Saharan African nations and offers several reasons why trade with China may not produce adverse impacts in the region. First, normative expectations in the form of pressure and monitoring by international non-governmental organizations, social movements, governments in high-income nations, inter-governmental organizations, and the media are thought to push Chinese

companies to improve their environmental performance when investing in low- and middle-income nations (Mol 2011). Of particular note, non-governmental organizations monitor Chinese investments and publicize in the media any environmental malfeasances like illegal logging that may be occurring. As examples of this tactic's effectiveness, non-governmental organizations have been successful in using such disclosures to press governments into suspending an infrastructure project near a national park in Gabon and closing a manganese mine for failing to implement reforestation measures in Zambia, among others (Mol 2011).

Second, China has attempted to respond to criticism related to the environmental performance of its investments abroad and be more proactive about warding off such criticisms (Mol 2011). In doing so, the government and Chinese companies are preemptively employing voluntary and self-regulatory measures to avoid being criticized for exploiting the weak regulatory environments found in many low- and middle-income nations (Mol 2011). For instance, China's Ministry of Commerce, Ministry of Environment, and its Export-Import Bank, require companies taking a loan or risk insurance to comply with a host country's environmental regulations (Hu 2013). They also require investments to undergo environmental impact assessments and meet various environmental benchmarks (Mol 2011). Other financial institutions supported by the Chinese government like the People's Bank of China and Industrial Bank of China have implemented environmental guidelines that companies who extended credit must follow (Alden and Alves 2009).

Third, China has been more willing to work with the World Bank and United Nations to integrate their regulations on governance and transparency into its investments (Mol 2011). In this regard, China's Export-Import Bank signed an agreement to ensure that its investments in forestry in Sub-Saharan Africa meet the World Bank's and International Finance Corporation's environmental standards (Mol 2011). At the same time, the China-Africa Development Fund has committed to meet the Organization for Economic Cooperation and Development guidelines that include environmental standards (Mol 2011). Further, approximately 150 Chinese companies have signed the United Nation's Global Compact, a voluntary corporate code of conduct related to improving the environment, human rights, labor, and corruption (Mol 2011).

On the other hand, critics note that even while working within a regulatory framework designed to protect the environment and usher in more mutually beneficial trade relations, China's practices may still be driving environmental harms in exporting nations. This is because China, while still classified among other low- and middle-income nations, benefits from its advantageous position in trade networks vis-a-vis other low- and middle-income nations, just as high-income nations do to China. For instance, Feng and Hubacek (2014) find that high-income nations externalize carbon dioxide and sulfur dioxide emissions by importing manufactured goods from China, but China is also able to offset a portion of this pollution when it imports natural resources from other low- and middle-income nations (Yu, Feng, and Hubacek 2014). Prell and colleagues

(2014) find a similar pattern of results, where China is able to offset a portion of its sulfur dioxide emissions from increased economic growth via trade with low- and middle-income nations across six different commodity groups. Despite gains made at the expense of its trading partners, China's economic exchanges with the United States result in higher levels of sulfur dioxide emissions. Thus, consistent with the theory of unequal ecological exchange, the burden of environmental harms is pushed downward.

As the preceding example demonstrates, China is able to export a portion of its carbon dioxide and sulfur dioxide emission onto other low- and middle-income nations while it tries to satisfy demands of industrial production for high-income nations. However, for forestry and agricultural products, China's domestic consumption is the main reason for its trade with other low- and middle-income nations. Consequently, we expect that China has been able to externalize its forest loss elsewhere, and some case study research has suggested this is the case.

For instance, Traenor (2015) compares Chinese customs data on rosewood imports, which is used to make luxury furniture to forest loss statistics in certain exporting nations. The author finds that in the 1990s, rosewood imports in China were correlated with increased forest loss in Vietnam, Myanmar, and Cambodia during the 1990s. As rosewood supplies dwindled among these nations at the turn of the century and prices rose, imports from Sub-Saharan Africa began to increase, as did forest loss in the region (Tranor 2015). A similar study by Yin (2018) found that China's demand for wood from the Solomon Islands increased forest loss. In this instance, China facilitated exports by supporting "industrialization" such as financing the building of roads that are primarily used to gain access to forests in remote regions, which in turn increased forest loss (Yin 2018).

Further, a World Wildlife Fund (2018) report examines the impact of Asia Pulp and Paper's and Asia Pacific Resources International Holdings Limited's pulp and paper mills on forest loss in Indonesia. The majority of pulp and paper produced is destined for export to China. It is not surprising that the companies have received over $2.4 billion in financing from the Chinese Development Bank and other banks supported by the government to build new or upgrade existing pulp and paper mills. Indonesia has provided companies with a 10-year tax holiday. The World Wildlife Fund (2018) gathered information from Indonesian government wood utilization records to identify the companies providing wood to support the mill and the boundaries of the forest concessions for each company. The organization then examined satellite imagery for each concession and found that more than half of the concessions have been cleared in their first three years of a 10-year agreement. Further, natural forests outside concession boundaries were being illegally cleared as well. The World Wildlife Fund (2018) estimates that Asia Pulp and Paper's and Asia Pacific Resources International Holdings Limited's mills do not have access to enough forest concessions to keep running at capacity. Thus, forest loss is anticipated to increase with suppliers clearing natural forests illegally to meet demand. Despite the regulatory framework in

place, we argue that the pressure of consumptive demand fulfilled in the structure of unequal exchange will be the determinative factor for forests.

Having reviewed the ways that China may be facilitating ecologically unequal exchange in low- and middle-income nations, and despite the initial contradictory evidence regarding whether this is occurring, from this discussion we turn to empirically addressing this important lacuna in the cross-national literature: Are higher levels of forestry exports from low- and middle-income nations to China related to increased forest loss in the exporting nations? Before turning to a discussion of our empirical findings, we describe our modeling strategy, sources of our evidence, and the variables used in the analysis.

Method

We analyze the data using ordinary least squares regression (OLS) in Stata 14.[2] Our statistical model for the dependent variable (forest loss) is denoted by the following formula:

$$y_i = a + b_1x_1 + b_2x_2 \ldots + b_kx_k + e_i$$

where:

y_i = dependent variable for each country,

a = the constant,

b_1 *to* b_k = unstandardized coefficients for each independent variable,

x_1 to x_k = independent variables for each country, and

e_i = country-specific error term.

Before the use of OLS, we must ensure that we are not violating any regression assumptions. First, we calculate mean and highest variance inflation factor (VIF) scores for each model, which we report in Table 2. There does not appear to be any potential problems with multicollinearity because the mean and highest VIF scores do not exceed the conservative threshold value of 2.5 (Tabachnick and Fidel 2013).

Second, to help address the linearity assumption, we use Stata 14's ladder and gladder commands to determine if a variable is approximately normally distributed or if it needs to be

[2] We replicated the models using a robust regression technique that uses iteratively-reweighted least squares with Huber and biweight functions tuned for ninety-five percent Gaussian efficiency to ensure there are no problems with outliers (Dietz, Frey, and Kalof 1987). This model assigns a weight to each observation used in the analysis, with higher weights given to observations with smaller residuals and lower weights given to observations with higher residuals (Dietz, Frey, and Kalof 1987). The results of the robust regression are substantively similar to the results obtained by ordinary least squares models, suggesting to us that the reported point estimates are not biased due to outliers.

transformed. Such transformations may also produce more homoscedastic residual variance. The ladder command reports a chi-square test for different possible transformations. The null hypothesis for the chi-square test is that a specific transformation approximates normality (Tukey 1977). Thus, if the chi-square test coefficient is statistically significant, then we reject the null hypothesis and conclude that the specified transformation does a worse job at approximating normality than the variable in its original form. We confirm the statistical tests by visually inspecting graphical distributions for each variable using the gladder command. We transform variables based upon the results of these procedures and note any transformations below (Tabachnick and Fidel 2013).

Third, as a post-estimation check, we calculate standardized residuals to determine if multivariate outliers are a problem. We identify Gambia, Senegal, and Zambia as multivariate outliers because their standardized residuals exceed an absolute value of 2.5 (Tabachnik and Fidel 2013). We removed these nations from the analysis and report results based on their exclusion. We also examined Cook's distance statistics to detect influential cases. The results indicate no potential problems with influential cases among the remaining nations included in the sample.

Fourth, we calculate White's test of heteroscedasticity for each model. The null hypothesis for this chi-square test is that the error variances are homoscedastic or equally distributed (Tabachnick and Fidel 2013). The coefficients for the chi-square statistics do not reach a level of significance in any model, indicating no potential problems with heteroscedasticity (Tabachnick and Fidel 2013). For this reason, we report conventional standard errors of the point estimates.

The sample includes 75 low- and middle-income nations as classified by the World Bank (2015). They are Albania, Angola, Argentina, Armenia, Azerbaijan, Bangladesh, Belarus, Bhutan, Bolivia, Bosnia and, Herzegovina, Brazil, Bulgaria, Burundi, Cambodia, Cameroon, Central African Republic, Colombia, Republic of the Congo, Costa Rica, Cote d'Ivoire, Cuba, Dominican Republic, Ecuador, El Salvador, Ethiopia, Gabon, Georgia, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, India, Indonesia, Jamaica, Kazakhstan, Kenya, Kyrgyz Republic, People's Democratic Republic of Laos, Liberia, Madagascar, Malawi, Malaysia, Mexico, Mongolia, Mozambique, Nepal, Nicaragua, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Romania, Rwanda, Solomon Islands, South Africa, Sri Lanka, Suriname, Tajikistan, Tanzania, Thailand, Togo, Turkmenistan, Uganda, Ukraine, Uzbekistan, Vanuatu, Venezuela, and Vietnam.

Dependent and Independent Variables

Our dependent variable is forest loss. Until recently, cross-national research on forest loss was largely based upon data made available in the United Nation's Food and Agriculture Organization's *Global Forest Resources Assessment* (e.g., Shandra, Rademacher, and Coburn

2016). However, the reliability of the data has been called into question because they are gathered utilizing data collection methods that vary from nation to nation (Grainger 2008). In some nations, forestry statistics are highly reliable because they are based on remote sensing surveys (Food and Agriculture Organization 2015). In other nations, estimates may be of low reliability because they are based on expert opinions or extrapolated from an outdated forest inventory (Grainger 2008). Thus, we use newly available data on forest loss derived from high resolution satellite imagery (30 x 30 meters) to eliminate this potential source of error. The data may be obtained online from the World Resources Institute's (2016) Global Forest Watch web page. See Hansen, Stehman, and Potapov (2010) for an in-depth discussion of the methodology used to arrive at the estimates.

We calculate forest loss in the following way. First, we set the minimum tree cover canopy density level upon which to base the estimates. The tree cover density for a nation is the estimated percentage of a pixel taken from satellite imagery that is covered by tree canopy (World Resources Institute 2016). We follow Rudel (2017) and set the minimum tree cover canopy density equal to 75 percent or greater. Second, we obtain the amount of nation's land area in hectares with the corresponding minimum tree cover canopy density (i.e., 75 percent). These data are measured for 2000. Third, we obtain the number of hectares of forests cleared from 2001 to 2014 in the preceding area. Fourth, we divide the total amount of hectares cleared by the total forest size to compute the rate of forest loss over this time period (Rudel, 2017). We take the natural log of the forest loss rate because it is skewed.

As noted above, we use the theory of ecologically unequal exchange to inform this study. Our main independent variable is a nation's forestry exports to China. From this, we then draw upon Shandra (2007) to guide our choice of other independent variable to include in the models. See Shandra (2007) for a discussion of how each independent variable is related to a given theory of forest loss (World Bank 2016). Descriptive statistics and bivariate correlations for all variables in our analysis are provided in the appendix (Table A1).

Forestry Exports to China. This variable measures a nation's forestry exports sent to China as a percentage of a nation's total forestry exports. The data are from the United Nation's *Commodity Trade Statistics Database* (2017). This database reports export statistics in constant United States dollars for a given nation by commodity and trading partner (United Nations, 2017). We use the first revision of the Standard International Trade Classification to identify forestry exports by using code number 24 (cork, fuelwood, wood charcoal, wood chips, wood waste, wood in the rough / logs, wood simply worked / processed) and code number 25 (pulp and paper). The data on total forestry exports also comes from the United Nation's Commodity Trade Statistics Database (2017). Drawing on ecologically unequal exchange theory, we hypothesize that higher levels of forestry exports sent from low- and middle-income nations to China will be associated with higher rates of forest loss in the exporting nations.

Total Forestry Exports. It is also necessary to control for a country's total forestry exports in order to determine whether it is the flow of exports to a given nation or overall exports that may be contributing to forest loss (Shandra, Leckband, and London 2009). Thus, we include total forestry exports as a percentage of total exports of goods and services. The forestry export data come from the Food and Agriculture Organization (2017). We expect higher levels of forestry exports to correspond with more forest loss.

Forestry Sector Size. This variable measures a nation's forestry sector size, which includes the metric tons of round wood and fuel wood produced per hectare of a country's forest area. The forest area data come from the World Resources Institute (2016) and are measured for the year 2000. We expect that nations with a larger forestry sector should have higher levels of forest loss as extraction of these natural resources are central to their economies.

Forest Proximity to Infrastructure. *This* variable is the percentage of a country's total forests that are located within 10 kilometers of infrastructure including roads, highways, rivers, and ports. The data may be obtained from the Food and Agriculture Organization (2015). We expect that a country with a larger percentage of forests within 10 kilometers of infrastructure should be related to increased forest loss. This is because forest proximity to infrastructure means it can be exploited and brought to market more easily than when they are located in remote regions farther away from transport infrastructure (Rudel and Roper 1997).

Total Population Growth. In our model, we also include the average annual percentage change in total population growth from 1990 to 2000. Rudel (1989) argues that geometric growth in population outstrips arithmetic growth in the means of subsistence, leading a growing population to clear forests to grow crops.

Democracy. We use Vanhanen's (2014) measure of democracy, which is calculated by taking the average of his political competition index with his political participation index. According to Vanhanen (2014), political competition captures the representation of smaller parties in national elections, while political participation measures how many people relative to the population voted in national elections (Vanhanen 2014). Previous research finds that democracy is associated with less forest loss because democratic nations have greater accountability to their citizens' activism as well as civil society pressures for environmental protection (Li and Reuveny 2006). This is a result of democratic nations guaranteeing freedoms of speech, press, and assembly while also being held accountable by voters (Marquart-Pyatt 2004).

Corruption. This variable may be obtained online the from the Varieties of Democracy's site online (Coppedge et al. 2017). We take the average of its executive, legislative, judicial, and public sector corruption scales to arrive at an overall measure of corruption. In the executive, legislative, and public sectors, corruption refers to its members or agents granting favors in exchange for bribes, kickbacks, embezzlement, and misappropriation of public funds for personal or family use

(Dahlberg et al. 2019). In the judicial sector, corruption involves judges and their agents receiving undocumented extra payments or bribes from an individual or company to speed up, delay, or obtain a favorable decision (Sommer 2017). We hypothesize that higher levels of corruption should be related to increased forest loss. This is because corruption across sectors diverts government funds away from investment in conservation (Koyuncu and Yilmaz 2009). It also allows illegal logging and other violations of a country's forestry laws to go unenforced with little fear of punishment (Sommer 2017).

Non-Governmental Organizations. We include the number of international non-governmental organizations working on environmental and animal rights issues in a nation for 2000 per capita. The data were collected by Smith and Wiest (2005). The cross-national research on forest loss finds that higher levels of non-governmental organizations are associated with lower rates of forest loss because they support conservation projects, help organize social movements concerned with environment, and contribute to writing forestry laws (Schofer and Hironaka 2005).

Protected Forest Area. We include a measure of a government's commitment to the environment by including the percentage of protected forest area in the models. When nations demarcate protected forest areas, governments often declare extractive activities off limits within the boundaries of the area, leading to less forest loss (Sommer, Shandra, and Restivo 2017).

Gross Domestic Product. We include a measure of size of the economy, or gross domestic product per capita for 2000, in our models. This variable is logged. Burns, Kick, and Davis (2003) find that higher levels of economic development are associated with less forest loss. They argue that this is the case because wealthier nations tend to externalize their environmentally damaging activities by importing natural resources.

Economic Growth. We include the average annual economic growth rate from 1990 to 2000. The cross-national research that examines how economic growth affects forest loss yields contradictory findings. On the one hand, economic growth has been associated with higher rates of forest loss and other environmental issues (Clausen and York 2008; Jorgenson 2006). This may be the case because nations experiencing rapid economic growth may in invest money in environmentally damaging activities that lead to forest loss (York, Rosa, and Dietz 2003). On the other hand, economic growth may be related to decreased forest loss. The economic growth taking place offers rural populations an incentive to migrate to urban areas for work in manufacturing and other industries (Ehrhardt-Martinez, 1998). As a result, less people work in agriculture and forestry, putting less pressure on forests (Ehrhardt-Martinez, Crenshaw, and Jenkins 2002).

Findings

In Table 1, we present the ordinary least squares regression estimates of forest loss. The first number presented is the unstandardized coefficient, the second number is the standardized

coefficient, and the third number in parentheses is the standard error. We report one-tailed significance tests because of the directional nature of the hypotheses drawn from ecologically unequal exchange theory.

Table 1. Ordinary Least Squares Regression Estimates Wet Forest Loss (2001-2014)

	Model (1.1)	**Model (1.2)**	**Model (1.3)**	**Model (1.4)**
	Wet Forest Loss	Wet Forest Loss	Wet Forest Loss	Wet Forest Loss
Independent Variables				
Forestry Exports to China, 2000	.197*	.228**	.240**	.233**
	.212	.246	.258	.251
	(.099)	(.095)	(.096)	(.097)
Total Forestry Exports, 2000	-49.677	-50.527	-23.056	-29.918
	-.080	-.081	-.037	-.048
	(64.690)	(61.906)	(62.783)	(64.455)
Forestry Sector Size, 2000	.001***	.001***	.001***	.001***
	.410	.378	.390	.378
	(.001)	(.001)	(.001)	(.001)
Forest Proximity to Infrastructure, 2000	.034*	.046**	.056**	.055**
	.198	.725	.330	.323
	(.018)	(.018)	(.019)	(.019)
Total Pop. Growth Rate, 1990-2000		.164**	.207***	.200**
		.282	.357	.343
		(.060)	(.063)	(.065)
Democracy, 2000			.001	.001
			.127	.142
			(.001)	(.001)
Corruption, 2000			-.074	-.080
			-.163	-.176
			(.050)	(.054)
Protected Forest Area, 2000			.001	.001
			.041	.042
			(.001)	.001

Table 1. *(Continued)* OLS Estimates Wet Forest Loss

Non-Governmental Orgs., 2000			-.003*	-.003*
			-.209	-.204
			(.002)	(.002)
Gross Domestic Product, 2000				-.006
				-.076
				(.010)
Economic Growth Rate, 1990-2000				-.001
				-.028
				(.002)
Constant	-.065	-.147*	-.155	-.103
	(.075)	(.077)	(.095)	(.127)
R-Squared	.249	.322	.384	.388
Adjusted R-Squared	.206	.273	.298	.281
Number of Countries	75	75	75	75
Highest Variance Inflation Factor Score	1.06	1.14	1.33	1.45
Mean Variance Inflation Factor Score	1.03	1.06	1.20	1.26
White's Test of Heteroscedasticity	2.384	5.893	7.547	7.201

Notes: a) * indicates $p < .05$, ** indicates $p < .01$, and *** indicates $p < .001$ for a one-tailed test. b) The first number is the unstandardized coefficient, the second number is the standardize coefficient, and the third number in parentheses is the standard error. c) We remove Gambia, Senegal, and Zambia from each model because they are outliers.

We conduct our analysis sequentially to first consider our main independent variables related to forestry exports to China, then incorporate subsequent control variables that may help us elaborate on the initial statistical relationship. In model (1.1), we include variables related to the structure of a country's forestry sector. The main predictor is the percentage of forestry exports sent from low- and middle-income nations to China as a percentage of total forestry exports. The other forestry variables include total forestry exports, domestic forestry size, and proximity of forests to infrastructure. In model (1.2), we add a variable that assesses demographic pressure on forests—population growth. In model (1.3), we add variables related to the political conditions within a nation. These include democracy, corruption, international non-governmental organizations, and protected forest area. In model (1.4), we add economic variables including gross domestic product per capita and the economic growth rate. We use this modeling strategy to demonstrate the reliability of the main findings related to forestry export flows to China across alternative model specifications.

Let us begin by focusing on the forestry sector measures. We find support for ecologically unequal exchange theory that forestry exports from low- and middle-income nations to China are related to increased forest loss in the exporting nations. The coefficients for the Chinese forestry export flow measure are positive and significant regardless of the additional independent variables included in the models. However, we do not find that total forestry exports are related to forest loss.

These coefficients do not reach a level of statistical significance in any model in Table 2. Further, we find that domestic forestry production is related to increased forest loss. The coefficients for this measure are positive and significant across the models. We also find that proximity to infrastructure corresponds with increased forest loss. The coefficients for forests within ten kilometers of roads, railways, rivers, or ports are positive and significant in Table 2. These analytic results, taken together, strongly support the expectations of ecologically unequal exchange.

We find other factors are also related to forest loss. First, we find that demographic pressures are associated with harmful impacts on forests. The coefficients for population growth are positive and significant across Table 2. Second, we find that higher levels of international non-governmental organizations are correlated with increased forest loss in the models that it is included. While this finding is contrary to our expectation, we note that it may result from the cross-sectional nature of our data, which limits our ability to form temporal inferences: it is more plausible that non-governmental organizations are responding to higher rates of deforestation in nations, rather than being the cause of them.[3]

There are also some non-significant factors that merit discussion. First, several political factors fail to explain significant variation in forest loss. The coefficients for democracy, corruption, and protected forest area do not reach a level of statistical significance, suggesting to us that political factors are less consequential for forest loss than underlying economic relations. However, we also find that two economic measures are not related to forest loss. The coefficients for gross domestic product per capita and economic growth do not reach levels of statistical significance.[4] Thus, it is the specific sectors of the economy as well as the ultimate destination of exports that are more determinative for the fate of forests.

[3] We included an interaction term between the export flow measures and non-governmental organizations. It does not reach a level of statistical significance.

[4] We include gross domestic product per capita and its square in the models to test for the existence of an environmental Kuznets curve. The coefficients for the squared term fail to reach a level of statistical significance.

Discussion and Conclusion

We began our study by drawing on the theory of ecologically unequal exchange, its potential relevance to China, and the contested empirical findings regarding the environmental impacts of China's relationship to exporting nations as the starting point for our study. We fill a gap in the cross-national literature by demonstrating that forestry exports sent from low- and middle-income nations to China are related to increased forest loss in those exporting nations. As we discussed, the coefficients for the main substantive variable in this study were positive and significant across Table 2.

This finding supports the central tenets of the theory with the flow of forestry exports being related to increased forest loss in exporting nations. However, our findings also help us refine the theory of ecologically unequal exchange and contribute to the cross-national research on these questions. The theory has been used by researchers to examine how export flows from low- and middle-income nations to high-income nations adversely impact the natural environment of the low- and middle-income exporting nations (Shandra, Leckband, and London 2009). We demonstrate that China, a middle-income nation, is exploiting forests of other low- and middle-income nations in a manner similar to high-income nations as it tries to protect its own forests while meeting its needs for wood, fuel, paper, and pulp from abroad to stimulate its economic growth and satisfy its changing consumption patterns.

Thus, we argue that an important theoretical implication follows. We agree with Frame (2019) and Ciplet and Roberts (2019) that it is essential for social scientists utilizing ecologically unequal exchange theory in their scholarship to consider if and how rapidly industrializing middle-income nations such as China may be adversely impacting the natural environmental of other low- and middle-income nations by importing various natural resources from these countries. It is important to note that our work corresponds with scholars writing in the world systems tradition more broadly. For example, Schwartzman (2015) shows how China's economic expansion in the export sector exacerbates issues of inequality and poverty in Mexico. In both instances, the basic premises of world-systems theory and analysis is being documents shows—how 'development' in one region (China) comes at the expense of those at the peripheries (Mexico in Schwartman's study and 75 other low- and middle income nations in the present study)—see also Dunaway and Clelland (2017). Toward this end, such research has the potential to refine our thinking around ecologically unequal exchange and world-systems analysis by helping to debunk prevailing myths about capitalist development as a means for furthering the interests of low-income countries and people.

There are methodological implications related to the theoretical implications. It is now easy to obtain data from the United Nations (2016) on exports flows by sector (Stretesky and Lynch 2009), commodity (Henderson and Shorette 2017), and trading partners (Huang 2018). The

availability of such specific data means social scientists can test theoretical propositions with more specificity than ever before. Such data permit more nuanced tests of the consequences of trade position and relations among nations. We demonstrate the utility of this approach here. It is our hope that other social scientists will follow our lead and use such measures in cross-national research in an effort to refine the theory and to offer policies that can be tailored to specific contexts based on the refinements.

Similarly, we also use newly available data on forest loss from the World Resources Institute (2016), which improves upon previous forest loss estimates because it is derived from high resolution satellite imagery rather than collection methods that vary across nations. These data improve the validity and reliability of our findings because they remove a potential source of error that has complicated cross-national comparisons in previous research (Grainger 2008).

From our theoretical insights and empirical findings, we offer the following policy suggestions. First, we note that the drivers of forest loss are consumption. Thus, non-governmental organizations and social movements should focus their efforts on projects that seek to decrease consumption both in China while supporting conservation efforts in low- and middle-income nations exporting to China. The Climate Alliance of European Cities serves as an example of what such a program may look like. This non-governmental organization has worked with 200 municipalities across Europe to ban the use (in public projects) of tropical timber harvested from illegal logging in low- and middle-income nations, and instead purchase wood that has been certified by the Forestry Stewardship Council (Rich 1994). It also works with municipalities in Europe to reduce their carbon dioxide emissions by purchasing electricity from alternative fuel sources (Rich, 1994). In Brazil, this non-governmental organization has funded domestic non-governmental organizations efforts to replant previously logged forests and to engage local communities in agroforestry and eco-tourism as alternatives to extractive activities (Rich 1994). There should also be special attention directed at replanting forests in areas close to infrastructure that are often cleared first before moving inward to forests in more remote regions. A similar program may work if Chinese municipalities are looking for ways to lessen their environmental impacts at home and abroad.

This strategy may prove difficult if access to cheap natural resources abroad remains central to China's efforts at their own as well as partner nations' industrialization and development. The strategy we offer above may be considered "reformist" because it does not seek to bring about fundamental change to address the causes of forest loss (Bryant and Bailey 1997). Rather, it relies on voluntary programs, such as the Forestry Stewardship Council, that use self-reporting and have few enforcement mechanisms like fines to ensure compliance (Bryant and Bailey 1997). While such problems are not unique to Chinese investments, it may be more pronounced because of

China's official policy of "non-interference" in the affairs of other nations and its own weak environmental record at home (Economy 2010).

Thus, a more "radical" or confrontational strategy may be necessary that aims to address the root of the problem: one in which non-governmental organizations, social movements, and concerned citizens work with local communities to monitor and publicize violations of a country's forestry regulations by Chinese companies. These efforts should be combined with governments enforcing existing conservation laws and passing new legislation (Lewis 2003). This approach has been successful in closing Chinese mining operations in Gabon and a hydroelectric dam in Zambia that were being scrutinized for human rights abuses, forest loss, and water pollution (Mol 2011). There is no reason to expect that such tactics cannot be applied forestry companies. Ultimately, a combination of tactics can be employed to reduce forest loss due to China's demand for natural resources, especially forestry products (Keck and Sikkink 1998). Efforts should be taken to both reduce demand as well as improve sustainability and conservation efforts.

There are some caveats that should be noted and directions for future research that follow.[6] First, we measure forestry exports sent to China from other low- and middle-income nations at the turn of the century. This is due to the availability of the forest loss data for a single time point (World Resources Institute 2016). However, forestry exports to China have increased over time (United Nations 2016). We most likely underestimate the impacts of these flows on forests. Future research needs to be carried out once longitudinal forest loss data become available. Second, Chinese society has not only a voracious appetite for forestry products but is also a leading importer of various crops and minerals, which may also have detrimental effects on the natural environment in low- and middle-income countries exporting to China (Downey, Bonds, and Clark 2010). Third, Brazil, Russia, and India, as well as other rapidly developing countries, are also importing large amounts of natural resources from other low- and middle- income nations (Siddiqui 2017). It is essential to understand the extent to which these middle-income nations may be externalizing their forest loss and other environmental problems onto their trading partners in pursuit of their own industrialization (Frame 2019).

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Disclosure Statement: Any conflicts of interest are reported in the acknowledgments section of the article's text. Otherwise, authors have indicated that they have no conflict of interests upon submission of the article to the journal.

Appendix

Table A1: Descriptive Statistics and Bivariate Correlation Matrix for Forest Loss Analysis (2001-2014)

	Mean	Standard Deviation	1	2	3	4	5	6	7	8	9	10	11
(1)Wet Forest Loss	.081	0.085	1										
(2)Forestry Exports to China	.034	0.091	0.152	1									
(3)Total Forestry Exports	.001	0.001	-0.102	-0.014	1								
(4)Forestry Sector Size	831.146	6052.027	0.42	-0.043	-0.046	1							
(5)Forest Proximity to Infrastructure	4.064	0.502	0.184	-0.22	-0.004	0.078	1						
(6)Total Population Growth Rate	.180	0.146	0.239	-0.065	0.002	0.099	-0.236	1					
(7)Democracy	12.681	12.681	8.67	-0.015	0.104	-0.022	-0.057	-0.175	-0.238	1			
(8)Corruption	.669	0.669	0.187	0.005	0.027	0.013	0.078	0.13	0.203	-0.335	1		
(9)Protected Forest Area	12.213	14.022	0.023	-0.069	-0.187	0.003	-0.261	0.151	-0.123	-0.08	1		
(10)Non-Governmental Organizations	3.059	5.473	-0.156	0.001	0.147	0.009	-0.091	0.027	0.257	-0.295	-0.126	1	
(11)Gross Domestic Product	6.718	1.038	-0.157	0.002	-0.104	-0.152	-0.176	-0.213	0.414	-0.425	0.025	0.188	1
(12) Economic Growth Rate	3.924	4.648	-0.112	-0.127	-0.085	-0.121	0.205	-0.106	-0.204	0.243	-0.004	0.098	-0.166

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