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The Impact of Transport and Communication Technology on the Division of Labor and Stratification of Small-Scale Societies

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by

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ABSTRACT OF THE THESIS

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This article presents a societal level cross-cultural analysis that explores the relationship between division of labor and stratification, as well as the effect that transport and communication technology have on this relationship. It is reasoned that social stratification and political hierarchy, as the byproduct of integrative forces are, in part, a function of the division of labor, transport and communication technology. The analysis finds a positive relationship between occupational specialization and political and economic inequalities in 186 small-scale societies, as well as an increased concentration of political and economic power as the cost of exchanging information and resources decrease resulting from innovation in transport and communication technology. In other words, concordant with the pessimist view of technological progress, transport and communication technology innovations seem to have historically benefited mostly the individuals at the top of

these political and economic stratification systems as they have an amplifying effect on the division of labor and stratification relationship. The results are discussed in terms of understanding the role that information systems, and transportation play in the de-centralizing or centralizing of resource as well as decision-making. The article closes with a discussion of possible implications for contemporary societies.

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INTRODUCTION

The reasons for the emergence and perpetuation of economic stratification and political hierarchy in pre-industrial society have been the object of long standing debate. Although there is agreement that institutions are required to maintain cooperation among large human groups (Dunbar 1992, 1993; Turchin & Gavrilets 2009), researchers attribute their existence to many different phenomena. The creation and sustenance of such institutions is explained in terms of inter-group competition or "costly cooperation" (Mathew & Boyd 2011, Turchin 2009; Turchin, Currie, Turner & Gavrilets 2013), the development of capital-intensive subsistence techniques (Nolan & Lenski 1996, Gilman 1981), greater cultural isolation among subpopulations within a society (Henrich & Boyd 2008), surplus and labor structure – "slavery" or "wage labor" (Ruyle 1973) or the presence or absence of "landesque" capital – intensive agriculture that involves permanent changes to the landscape (Atkinson et al. 2018).

Although all of the above may play a role, Spencer focuses on the differentiation of the *operative functions* – activities of extraction and transformation material resources that sustain a social system – as the principle cause of the emergence of hierarchies. The consequence is the increase in complexity and resource intensity of the *distributive* – activities that allocate

resources among subgroups of extraction and transformation – and *regulatory functions* – activities that enforce rules and regulations as well as mediate conflicts.

To this is added the effect to technology, whose effect can either be equalizing or polarizing as "technical change occurs in […] an arena in which power and influence are unequally distributed among a relatively large number of agents" (Hard 1993: 423). Technologies are seen as unequally benefitting segments of society which creates the potential for resistance or cooptation.

This paper has three main objectives. The first is to detail Spencer's Theory of Societal Evolution as it relates to the emergence of economic and political stratification. The second is to introduce the role of transport and communication technology (henceforth TCT) as a moderating factor in Spencer's theory. The third is to formulate and test hypotheses consistent with Spencer's theory of economic and political stratification, and with the role of TCTs in moderating key mechanisms of Spencer's theory.

1. The Stratifying Effect of Division of Labor According to Spencer

In this section, I elaborate Spencer's theory of the relationship between division of labor and both economic stratification and political hierarchy. Spencer's theory begins with the notion that the maintenance of human society requires that they successfully pursue basic biological needs within the constraints of a more or less fixed environment. Through this negotiated process, patterns of extraction,

transformation, distribution and consumption emerge[1]. In a Robinson Crusoe-like hunter-gatherer tribe, this social manipulation of the environment leads to a stable structure of production and exchange between members. Each of the constitutive activities can be done by all members of the social unit or by specialized individuals[2].

In the hunter-gatherer society, the labor is relatively homogeneously distributed among members (although sex and age are important determinants). All members perform the two tasks – hunting and gathering – required for the material reproduction of the unit. As societies become more complex, however, divisions of labor begin to emerge. In an agrarian surplus society, for example, a subset of individuals specializes and become responsible for the protection of the farmers and surplus.

The division of labor creates divergent interests and increasing interdependence among the respective subunits. In an agrarian surplus society composed of soldiers and farmers, the farmers have an incentive to keep all of the production for themselves and the military has an incentive to expropriate all the production from agriculture. At the same time, the two subgroups also become more interdependent. Farmers need soldiers to protect the crops and soldiers need farmers to eat. As the number of tasks requiring specialization increases so does the number and intensity of interdependencies as well as competing interests.

[1] Operative functions
[2] Undifferentiated or differentiated, respectively.

For society to persist in the context of this increasing tension, it must establish institutions for coordination and control[3]. As the division of labor increases, so does the complexity of the production relations. *Coordination* is necessary to allocate resources and information among subgroups [4]. Part of the farmer's output is distributed to the soldier, who in turn provides protection for the farmer. As the society gradually becomes more complex, engineers responsible for irrigation and sewage, and metalworkers that provide weapons and tools, gradually emerge. Each of the subgroup's production must be allocated efficiently enough to all other subgroups and all of the transformed products must subsequently be reallocated.

Similarly, diverging economic, political interests and increasing social distance, increase the likelihood of conflict occurring. These conflicts must be mediated by institutions for *control*, which make decisions and enforce them[5]. In our agrarian society some institutions are established to constrain the opportunities for violence, such as courts of law or a publicly funded army. By making some courses of action viable and others not, these emergent institutions shape the flow of resources and information. Indeed, these institutions themselves become a new subgroup in the division of labor. The ability of these institutions to shape the structure of interaction is dependent on their ability to acquire greater decision-

[3] Integration
[4] Distributive functions
[5] Regulatory functions

making power and resources than the subgroups they mediate and coordinate. Both political hierarchy and economic stratification are manifestations of this differential.

The creation of institutions for coordination and control creates the possibility for further division of labor. The processes of differentiation and integration must be tightly coupled for the social system not to "disintegrate". In sum, the differential in resources and decision-making power required by institutions for coordination and control translates to an inequality in economic and political power. Hence Hypotheses 1, derived from the Spencerian Theory:

- Hypothesis 1a: The greater the labor specialization, the greater the economic stratification

- Hypothesis 1b: The greater the labor specialization, the greater the political hierarchy

2. Transportation and Communication Technologies, and the Stratifying Effect of Division of Labor

In the section above I described the causal process that links the division of labor to political hierarchy and economic stratification. In this section I theorize the impact that TCTs have on the relationship between the division of labor and political/economic stratification. Technology is seen here as inextricably embedded

in power relations and therefore as an essential force shaping social relations: "Technological change […] can best be understood as the result of conflicts between […] professional 'status groups' fighting for influence and control." (Hård 1993: 426).

When new technologies are introduced in a social system, they tend to restructure interaction due to their effect on the cost of performing a function – in our case, that of exchanging information or resources. This reduction in cost can lead to two opposite outcomes. On the one hand, it may enhance the ability of the above-described institutions to expropriate additional economic resources and political power. In this potentiality, transportation and communication technology increases the effect of the division of labor on economic and political stratification. On the other, these technologies may reduce the dependency of society's various parts on the coordinating and control functions of the emergent institutions. Here, other subgroups can interact directly to negotiate their conflicting interests, which limits the ability of institutions of coordination and control to expropriate economic resources. In this scenario, transportation and communication technologies reduce the impact of the division of labor on political and economic stratification.

Any focal social sub-unit requires that information, like resources, be allocated efficiently between subgroups. For example, information about the stock of raw resources required for production must be allocated to the metal smith. Similarly, the farmer needs to be aware of the number of citizens he must produce for. The same applies to material resources. The unit has a finite amount of ore and

must decide where to allocate it based on the information about its different subgroup's needs. The transmission of information has a cost, and technology reduces these costs.

Subgroups resulting from the division of labor may require more institutions to mediate transactions because of the entry cost & complexity increase. The higher entry cost (giving access to technologies) increases the need to concentrate resources, decreasing diffusion capacity, and higher complexity associated with the use of certain technologies increase the need to concentrate decision-making, decreasing diffusion capacity. In the first case, no single group can bear the cost of building the technology, requiring groups to concentrate resources in a third party that is then able to, requiring a delegation of resources. In the second case, the time required to master a certain technology might prevent all members from accessing it, requiring them to delegate some of their decision-making.

Consider our agrarian society, being subject to a division of labor, is organized hierarchically. Heads of occupational groups allocate resources within subgroups. They also consult the chieftain, who decides were to allocate resources and information, mediates conflicts and enforces rules. On the one hand, the introduction of writing could allow him to codify rules, to transmit orders faster, further or more reliably. Similarly, the introduction of a wheeled wagon pulled by horses could allow him to transport soldiers and resources where needed faster, further and more reliably. The overall cost of coordination and control decreases,

increasing the ability of the chieftain to expand his power, ultimately increasing stratification.

- Hypothesis 2a: Transport and communication technologies increase the effect of the division of labor on economic stratification.
- Hypothesis 2b: Transport and communication technologies increase the effect of the division of labor on political hierarchy.

On the other hand, the introduction of writing in the agrarian society ruled by the heads and the chieftain could reduce the dependency of other groups on these figures. With the ability to write more widely diffused, each individual can communicate complex information directly, which requires less delegation. Similarly, with transport innovations, the dependence of the individuals or the subgroups is reduced. Instead of requiring a central institution whose role it is to collect and subsequently coordinate the redistribution of production, the subgroups can directly communicate information and exchange resources amongst themselves, alleviating the need to delegate decision-making power and resource to the chieftain. The overall cost of coordination and control decreases, increasing the ability of specialized subgroups to bypass these traditional institutions.

Subgroups resulting from the division of labor require fewer institutions to mediate relationships because the entry cost & complexity decease. The lower entry costs decrease the need to concentrate resources, increasing diffusion potential of

technologies whereas the lower complexity decreases the need to concentrate decision-making. In the first case, every subgroup is able to afford the costs of adopting the new technologies, increasing its ability to use them to coordinate with other subgroups having similar technologies. In the second case, every subgroup is able to access and use technologies without technocratic intermediaries.

- Hypothesis 3a: Transport and communication technologies reduce the effect of the division of labor on economic stratification.
- Hypothesis 3b: Transport and communication technologies reduce the effect of the division of labor on political hierarchy.

In sum, if economic stratification and political hierarchies emerge as a result of the greater command over material resources of institutions of coordination and control, we should expect innovations in TCTs to impact the ability of these institutions to expropriate societal resources. If transportation and communication technologies enhance the capacities of institutions for coordination and control to usurp power from subgroups, we should expect that they also increase the stratifying effect of the division of labor. Conversely, if technologies allow subgroups to coordinate without the necessity of institutions of coordination and control, they should reduce the stratifying effect of the division of labor

DATA

George P. Murdock and Douglas R. White's Standard Cross-Cultural was used to test these hypotheses. The Standard Cross-Cultural is a dataset containing 186 ethnographically "best-described" small-scale societies. These were cases were selected for maximal independence of cases in terms of cultural and historical origin (Galton) as well as geographical representativeness (Eff 2004, Eff & Dow 2009). Small-scale societies were selected for methodological reasons. They can be argued to be independent of one another, allowing us to argue the independence and representativeness of these societies. This allows us to generalize. On the other hand, large scale, industrialized societies have influenced each other (diffusion of ideologies, resources, etc.) making a comparative approach aiming to extract communalities between cases, almost meaningless.

Dependent Variables

Economic Stratification is coded as: (5) the society exhibits a complex stratification into three or more distinct classes or castes regardless of the presence or absence of slavery, (4) the society is stratified into two social classes of freemen, plus hereditary slavery and/or recognized caste divisions, (3) the society is stratified into two social classes of freemen but lacks both caste distinctions and hereditary slavery, (2) formal class distinctions are lacking among freemen, but hereditary

slavery prevails and/or there are important status differences based on the possession or distribution of wealth, (1) the society is essentially egalitarian, lacking social classes, castes, hereditary slavery, and important wealth distinction. Category four describes three or more class distinctions in society, with or without slavery, categories three and two describes two class distinctions, with and without slavery, respectively, and categories two and one reflect societies with no class distinction with and without slavery, respectively.

(5) 3 + class division + slavery

+ no slavery

(4) 2 class division + slavery

(3) 2 class division + no slavery

(2) 0 class division + slavery

(1) 0 class division + no slavery

Political hierarchy is coded as: (4) three or more administrative levels are recognized above that of community, as in the case of a large state organized into provinces are subdivided into districts, (3) two administrative levels are recognized above that of the local community, as in the case of a small state divided into administrative districts, (2) one administrative level is recognized above that of the local community, as in the case of a petty state with a paramount chief ruling over a

number of local communities, (1) the society is stateless but is composed of politically organized autonomous local communities.

(4) 3+ administrative levels above community level

(3) 2 administrative levels above community level

(2) 1 administrative level above community level

(1) 0 administrative levels above community level

Independent Variable

Division of Labor is categorized as: (5) The society is reported to have a variety of craft specialists including at least smiths, weavers, and potters, (4) The society is reported to have specialized metalworkers or smiths but to lack loom weaving and/or pottery, (3) Loom weaving is practiced but metalworking is absent or unreported, (2) Pottery is made but metalworking and loom weaving are absent or unreported, (1) Metalworking, loom weaving, and pottery making are all absent or unreported. This scale is designed to "measure the degree of complexity and specialization in technological crafts" (Murdock and Provost, 1973)

Moderating Variables

Transport and the Communication Technologies variables were standardized ($x^* = (x-\mu)/\sigma$) and added to give the TCT index. This index was created because both technology types have the same theoretical expected effects (positive) and can therefore me aggregated into a single measure of TCT development.

Communication technology is coded as: (5) The society has an indigenous system of true writing and possesses written records of at least modest significance, (4) The society has an indigenous system of writing but lacks any significant accumulation of written records, or alternatively has long used the script of alien people, (3) The society lacks true writing but possesses significant non-written records in the form of picture writing, quipus, pictorial inscriptions, or the like, (2) Writing and significant records are lacking but the people employ mnemonic devices, e.g., simple tallies, (1) Writing, records, and mnemonic devices in any form are lacking or unreported.

This scale was devised to take account of the "widely recognized distinction between literate and non-literate (or preliterate) societies […] it assigns higher scores to writing and lower ones to non-written records and mnemonic devices" (Murdock and Provost 1973).

(5) Writing + Records

(4) Writing + No records

(3) No writing + Records

(2) No writing + No records

(1) No writing + No records + No mnemonic devices

Land Transport is categorized as: (5) automotive vehicles, e.g., railroads and trucks, are employed extensively in land transport. Since these have commonly been introduced by foreigners in formerly colonial areas they are indicated only where they were thoroughly integrated into the indigenous economy at the pin-pointed date, (4) animal-drawn wheeled vehicles are employed in land transport but motorized vehicles are seldom or never used, (3) land transport is conducted to a considerable extent by means of draft animals dragging a sled, travois, or other vehicle without wheels, (2) land transport is effected mainly by pack rather than draft animals, (1) Land transport is effected exclusively by human carriers.

This measure is designed to "measure the degree of complexity in the means of land transportation and thus presumably indirectly the extent of intergroup trade" (Murdock and Provost 1973).

(5) Automotive

(4) Draft animal + Wheels

(3) Draft animal + No wheels

(2) Pack animal

(1) Human carriers

Control Variable

Spencer theorized that demographic factors have an effect on political and economic structures. His contention was that societies could not grow by mere linear increase in numbers. The social structure has to be compounded, where multiple small integrated groups aggregate into multiple intermediate integrated groups which in turn aggregate into a large integrated group: "holding a compound structure implies a head of the whole as well as heads of the parts" (Spencer 1898). These groups are integrated at multiple levels, which creates a hierarchical form of organization that can be summarized by the idea of "chiefs and the chief of chiefs". This definition of compounding corresponds to our operationalization of political hierarchy; if we were to omit this control, we risk measuring the effect of population compounding due to size increases instead of the effect of division of labor. We will therefore control for this demographic factor. In addition to the concentration of decision making-power, we extend his definition to the concentration of resources.

Population Size is our demographic control variable and is simply the number of individuals that compose the social system. It is categorized as: (1) '< 50', (2) '50-99', (2) '100-199', (3) '200-399', (4) '400-999', (5) '1,000-4,999', (6) '5,000-49,999', (7) '> 50,000'. The population size of the "focal or typical community is ranked by a numerical symbol in one of the categories" (Murdock and Wilson 1972).

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Economic Stratification	175	2.451429	1.449013	1	5
Political Stratification	172	2.034884	1.112898	1	4
Division of Labor	175	3.097143	1.421001	1	5
Information Systems	175	2.36	1.466719	1	5
Transport	174	1.770115	1.160039	1	5
TCT	173	-.0025073	1.764571	-1.592768	4.569625
Population Size	174	3.45977	1.705514	1	8

METHODS

The data analysis was performed in two stages. In the first phase, models are estimated using multivariate Ordinary Least Square regression treating the data as continuous (4 models). In the second phase, after dichotomizing our two dependent variables to more closely approximate the actual relationships given the nature of our variables (categorical & ordinal), we estimate the second models using Logistic Regression (4 models). In both phases, the Transport and the Communication Technologies variables were standardized ($x^* = (x-\mu)/\sigma$) and added to give the TCT variable. This index was created because both technology types have the same theoretical expected effects (positive). The analysis was performed in two phases for robustness. The objective is to cross validate the results found in the first phase with the one's found in the second phase.

As moderating variables, TCTs are expected influence the strength of the effect of division of labor on economic stratification and political hierarchy. The interaction term quantifies the change in the effect of an independent variable on a

dependent variable by a moderating variable. Thus, the coefficient given to us by the interaction terms reflect the strength of the effect of division of labor on both economic stratification and political hierarchy by values of TCTs. For example, division of labor may have a weak effect on economic stratification when Communication Technologies are 'low' but a very strong effect when Communication Technologies are 'high': it moderates the effects.

Predicting the different outcomes, if division of labor must be accompanied by a certain amount of inequality, as Spencer contended, we expect to find positive and significant relationship between division of labor and both political hierarchy and economic stratification. If innovations in TCTs moderate this relationship, we should find significant relationships between the interaction terms and our dependent variables. In addition, if the reduction in the cost of exchanging information and resources benefits disproportionately the elite – techno-pessimist perspective – we expect positive coefficients for the interaction terms; conversely, if this reduction of the costs of exchanging information and resources benefits disproportionately the specialized sub-clusters – techno-optimist perspective – we expect negative coefficients for the interaction terms.

FINDINGS

In this section, we will go over each of the two phases of our analysis sequentially, beginning with least squares followed logistic regressions. We fit a model to our

data using OLS regression, treating the variables as continuous, and refit using logistic regression for robustness. The objective being to show that with both set of assumptions we arrive at similar results. The first results were estimated by ordinary least squared regression with and without interaction (Table 1). The second phase describes the results for four logistic regression models with and without interaction (Table 2).

First Phase: Ordinary Least Square Models

Table 2 shows the results for two multivariate least square regressions models with interaction. Model 1 describes the relationship between Political Hierarchy and Division of Labor, the additive term Transport and Communication Technology (TCT), controlling for Population Size. Model 3 describes the same relationship with Economic Stratification as outcome. These models refer to hypothesis 1a and 1b.

To adjudicate between contending claims (techno-optimist and techno-pessimist), we include the TCT moderation to the relationships previously analyzed. Models 2 show interaction effect of TCTs and Division of Labor on Political Hierarchy, while model 4 shows the same interaction for Economic Stratification. These interaction terms quantify the change in the effect of Division of Labor on Political Hierarchy and Economic Stratification by TCTs. These models refer to hypothesis 2a and 2b as well as 3a and 3b.

Table 2. Least Square Regression of Economic Stratification and Political Hierarchy on Division of Labor,TCT and Population Size, with and without the Interaction of Division of Labor and Information Systems/Transport

	(1)	(2)	(3)	(4)
	Political Hierarchy	Political Hierarchy	Economic Stratification	Economic Stratification
Division of Labor	0.260***	0.291***	0.254***	0.334***
	(0.058)	(0.058)	(0.073)	(0.070)
TCT	0.202***	-0.040	0.333***	-0.305
	(0.045)	(0.136)	(0.049)	(0.165)
Division of Labor * TCT		0.058		0.152***
		(0.030)		(0.036)
Population Size	0.126**	0.118**	0.181***	0.156***
	(0.043)	(0.042)	(0.048)	(0.046)
Intercept	0.809***	0.666***	1.039***	0.667**
	(0.171)	(0.197)	(0.216)	(0.234)
N	170	170	173	173
R-sq	0.460	0.468	0.493	0.526
F	(3, 166)= 70.17***	(4, 165)= 53.82***	(3, 169)= 74.42***	(4, 168)= 53.82***

Note: p< .05; p< .01; p<.001

Model 1 describes the relationship between Political Hierarchy and Division of Labor, TCT, controlling for Population Size. Our overall model is statistically significant and is a decent fit as it explains 46.0% of the variance in our dependent variable (R^2= .460). Division of Labor (ß= .260; p= 0.000) is positive and statistically significant, as predicted by Hypothesis 1a. The statistical significance and positive sign of the first coefficient indicate that, for a one unit increase in Division of Labor, Political Hierarchy increases by .260, when TCT and population size = 0.

Model 2 describes the relationship between Political Hierarchy and the interaction of Division of Labor and TCT, controlling for Population Size. Our overall model is statistically significant and is a decent fit as our model explains 46.8% of the variance in our dependent (R^2= .468). Our interaction term, TCT * Division of Labor, is positive and barely non-significant (ß= .058; p= .052). For a one-unit

increase in TCT, the effect of Division of Labor on Political Hierarchy increases by .058. These results do not allow us to adjudicate between Hypotheses 2a and 3a.

Model 3 describes the relationship between Economic Stratification and Division of Labor and TCT, controlling for Population Size. Our overall model is statistically significant and is a decent fit as our model explains 49.3% of the variance in our dependent (R^2= .493). The statistical significance of Division of Labor (ß= .254; p= 0.000), indicates that, for a one unit increase in Division of Labor, Economic Stratification increases by .333 when TCT and Population Size = 0. This is evidence in favor of Hypothesis 1b.

Model 4 describes the relationship between Economic Stratification and the interaction of Division of Labor and TCT, controlling for Population Size. Our overall model is statistically significant and is a decent fit as our model explains 52.6% of the variance in our dependent (R^2= .526). The interaction of Division of Labor and TCT (ß= .152; p= 0.000) is statistically significant and positive. For a one-unit increase in TCT, the effect of Division of Labor on Economic Stratification increases by .058. These results are consistent with Hypothesis 2b and 3b.

In addition to Division of Labor being positive and significant in all four models, the coefficient for the interaction of Division of Labor and TCT in model 3 suggests that as TCT capabilities increase, so does the effect of Division of Labor on Economic Stratification. It is less clear weather or not this is the case for Political Hierarchy. These findings suggest that, not only does division in labor increase the need for coordination and control – as predicted by hypotheses 1a and 1b –, but the

reduction in the cost of coordinating and controlling has historically disproportionately benefited those with already available resources – the techno-pessimist hypotheses 2a and b.

Second Phase: Robustness Check

We test the same hypotheses with alternative specifications. Table 3 shows two logistic regression model results. Logistic regression coefficients give the change in the log odds of the outcome for a one-unit increase in the predictor variable.

Table 3. Logistic Regression of Economic Stratification and Political Hierarchy on Division of Labor,TCT and Population Size, with and without the Interaction of Division of Labor and Information Systems/Transport

	(5)	(6)	(7)	(8)
	Political Hierarchy	Political Hierarchy	Economic Stratification	Economic Stratification
Division of Labor	0.699**	0.788**	0.678*	0.805**
	(0.257)	(0.260)	(0.265)	(0.258)
TCT	0.405**	-0.551	0.486***	-0.929
	(0.142)	(0.681)	(0.134)	(0.616)
Division of Labor * TCT		0.231		0.341*
		(0.157)		(0.146)
Population Size	0.322*	0.303*	0.252	0.222
	(0.144)	(0.138)	(0.132)	(0.134)
Intercept	-4.508***	-4.925***	-4.487***	-5.083***
	(0.883)	(1.000)	(0.972)	(0.976)
N	170	170	173	173
R-Square	0.348	0.358	0.367	0.387
Wald Chi-Square	(3)= 48.03***	(4)= 44.89***	(3)= 44.42***	(4)= 40.77***

Note: p< .05; p< .01; p<.001

Model 5 describes the relationship between Political Hierarchy and Division of Labor controlling for Population Size and TCT, corresponding to Hypothesis 1a.

Our overall model is statistically significant and is a decent fit as our model explains 34.8% of the variance in our dependent (R^2= .348). Division of Labor (ß= .699; p= 0.007), is positive and statistically significant, as expected, indicating that for a one unit increase in Division of Labor, Political Hierarchy increases by .699 when TCT and Population Size = 0. As expected, as Division of Labor increases, so does Political Hierarchy.

Model 6 shows the moderation of TCTs on the relationship between Division of Labor and Political Hierarchy controlling for Population Size, corresponding to Hypothesis 2a and 3a. Our overall model is statistically significant and is a good fit as our model explains 35.8% of the variance in our dependent (R^2= .358). The interaction term (ß= .231; p= .142) is not statistically significant. The Division of Labor coefficient describes the effect of Division of Labor on Political Hierarchy when TCTs and Population Size = 0. For every one-unit change in Division of Labor, the log odds of high Political Hierarchy (versus low Political Hierarchy) increases by 0.788. The Division of Labor * TCT coefficient describes a .231 change in the effect of Division of Labor on Political Hierarchy for every unit increase in the TCT variable. The lack of significance of our interaction term in Model 6 does not allow us to make any conclusion about the effect of TCTs on the relationship between Division of Labor and Political Hierarchy.

Model 7 shows the moderation of TCTs on the relationship between Division of Labor and Economic Stratification, controlling for Population Size. Our overall model is statistically significant and is a good fit as our model explains 36.7% of the

variance in our dependent (R^2= .367). The coefficients for Division of Labor (ß= .678; p= 0.011) is positive and statistically significant, as predicted by Hypothesis 1b, indicating that for a one unit increase in Division of Labor, Economic Stratification increases by .678. As expected, as Division of Labor increases, so does Economic Stratification.

Next to it, Model 8 is statistically significant and is a decent fit as our model explains 38.7% of the variance in our dependent variable (R^2= .387). The interaction term (ß= .341; p= .02) is positive and statistically significant as predicted by Hypothesis 2b and 3b. The Division of Labor * TCT coefficient describes a .341 change in the effect of Division of Labor on Economic Stratification for every unit increase in the TCT variable. The positive and significant coefficient of the interaction in Model 8 suggests that as TCTs have developed, the effect of Division of Labor on Economic Stratification increases in size, positively moderating the relationship. The results suggest that the impact of Division of Labor on Political Hierarchy and Economic Stratification varies significantly with the level of TCTs in a society.

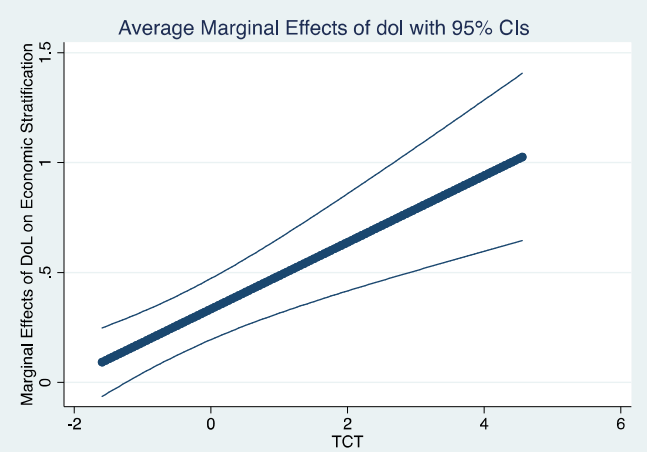
Substantive Significance

To examine the substantive importance of the variation (*how much*), we examine the marginal effects of Division of Labor on both Economic Stratification and Political Hierarchy as they vary by TCTs, for both the least-square and logistic models. That is, the variation of the overall effect of our independent variable on our

dependent variable as it varies across the observed range of our moderating covariate. The x-axis denotes the observed range of the moderating variable, the y-axis displays the marginal effects of Division of Labor on, separately, Economic Stratification and Political Hierarchy, and the upper and lower lines indicate the 95 percent confidence intervals.

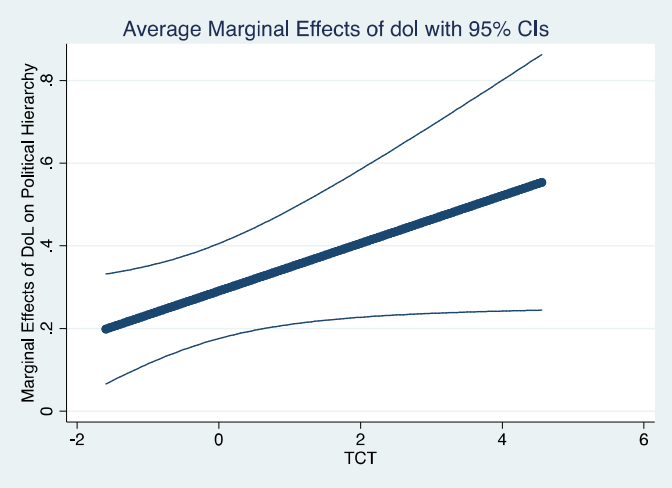
Each Figure shows the marginal effects across the analyses in Tables 2 and 3. Figure 1 illustrates the analysis of Model 2 in Table 2. Figure 2 illustrates the analysis of Model 4 in Table 2. Figure 3 illustrates the analysis of Model 6 in Table 3. Figure 4 illustrates the analysis of Model 8 in Table 3. These marginal effects are obtained from the coefficients reported in models 2 and 4 of table 2, and 6 and 8 of table 3. All figures suggest that variation in the effect of TCTs is large. We estimate unique coefficients for Division of Labor at each level (.05 intervals) of TCT, within a range (from -1.592768 to 4.569). In all Figures the effect of TCT is positive. In addition, in all Figures, except 3, the effect at the lower levels of the moderating variable is non-significant.

Figure 1. Marginal Effects of Division of Labor on ***Economic Stratification*** *across Observed Range of Information Systems and Transportation (Table 2 Model 2)*



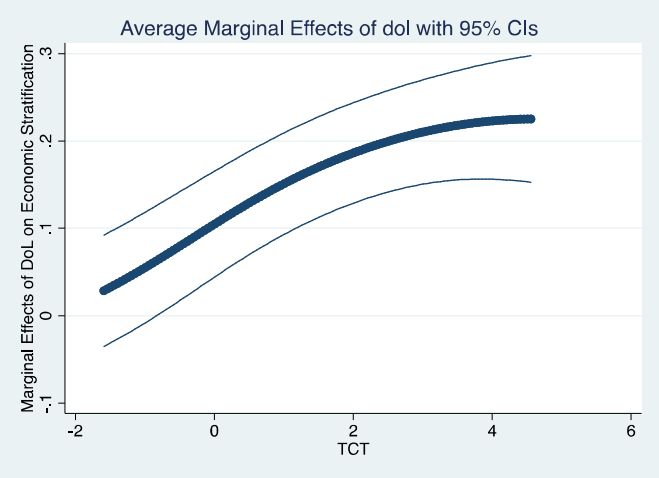
The first figure illustrates the marginal effects of Division of Labor on Economic Stratification across the observed values of TCT in our Least-Square model. I fail to reject the null hypothesis that Division of Labor significantly increases Economic Stratification across the full range of TCT. Though not significant (p= 0.241), at the minimum value of TCT (-1.592768) the coefficient is .0927074. Significance is gained when TCT has a value of -1.242768. At the maximum value of TCT (4.569), on the other hand, the coefficient is 1.027094 and is statistically significant (p= .000). This represent an overall change of 1007.888% in the effect of Division of Labor on Economic Stratification across the range of TCT. The effect of Division of Labor on Economic Stratification is 1000% bigger for societies with more cost efficient TCT.

Figure 2. Marginal Effects of Division of Labor on ***Political Hierarchy*** *across Observed Range of Information Systems and Transportation (Table 2 Model 4)*



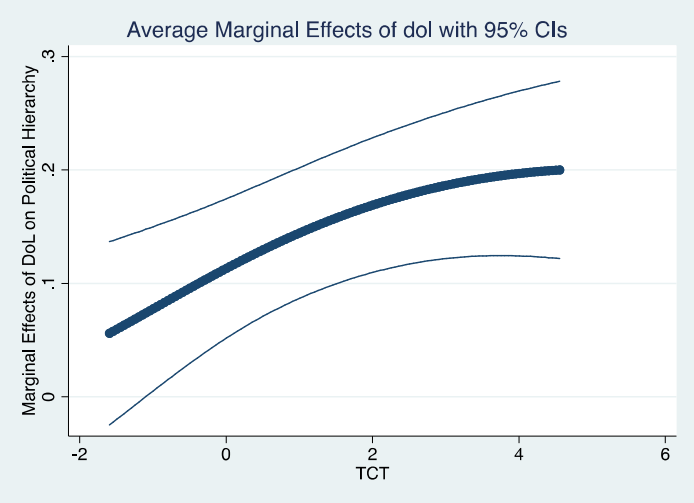
The second figure illustrates the magnitude of the effect of Division of Labor on Political Hierarchy across the observed values of TCT in our Least-Square model. I reject the null hypothesis that Division of Labor significantly increases Economic Stratification across the full range of TCT. At the minimum value of TCT (-1.592768) the coefficient is .1988343 and is significant (p= 0.003). At the maximum value of TCT (4.569) the coefficient is .55434 and is significant as well (p= .000). This represents a 178.795% increase in the effect of Division of Labor on Economic Stratification across the moderating variable. The effect of Division of Labor on Political Stratification is 180% bigger for societies with more cost efficient TCT.

Figure 3. Marginal Effects of Division of Labor on ***Economic Stratification*** *across Observed Range of Information Systems and Transportation (Table 3 Model 6)*



The third figure illustrates the marginal effect of Division of Labor on Economic Stratification across the observed values of TCT in our logistic model. I fail to reject the null hypothesis that Division of Labor significantly increases Economic Stratification across the full range of TCT. Though not statistically significant (p= 0.360), at its minimum value, TCT (-1.592768) has a coefficient of .2622393. Significance is gained when TCT has a value of -.792768. At its maximum value (4.569) the coefficient is 2.363681 and is significant (p= .003). This represents an overall change of 801.345% in the effect of division of labor on economic stratification from the minimum to the maximum of TCT.

Figure 4. Marginal Effects of Division of Labor on ***Political Hierarchy*** *across Observed Range of Information Systems and Transportation (Table 3 Model 8)*



The fourth figure illustrates the magnitude of the effect of Division of Labor on Political Hierarchy across the full range of TCT. I fail to reject the null hypothesis that Division of Labor significantly increase Political Hierarchy across the full range of TCT. Though non significant (p= .163), at the minimum value of TCT (-1.592768) the coefficient is .4200927. Significance is gained when TCT has a value of -1.092768. At the maximum value of TCT (4.569), on the other hand, the coefficient is 1.843041 and is statistically significant (p= .027). This represents a 338.722% overall increase in the effect of division of labor on political hierarchy, as the ability to exchange information and resources, through TCT, increases.

On average, societies with high division of labor have high political hierarchy and economic stratification. Additionally, the analysis of the marginal effects enables us to see the magnitude of the effect that the ability to exchange information and

resources has on the effect of division of labor on both economic stratification and political hierarchy. Russian (Russia), Balinese (Indonesia), Javanese (Indonesia) and Irish (Ireland) societies represent the most hierarchically organized and stratified societies, having the highest division of labor and TCT.

There are, however, some societies that do not fit the pattern. Outliers such as the Riffian (Morocco) and Zuni (New Mexico) societies, have a high division of labor but very little stratification or hierarchy. On the other hand, there are no societies without division of labor that have more than 2 economic classes or administrative levels. Lower levels of TCT seem to not affect the main relationship. For example, small-scale societies such as the Thonga, North Paiute and Alleut have too little TCTs for it to have a significant moderating effect on the main relationship.

CONCLUSION

In this article I contribute to both theory building, by synthesizing Spencer's Theory of Societal Evolution with perspectives on the role of technology in power relations, and empirical analyses of stratification, by testing the hypotheses derived from the integration of these approaches. First, I articulate macro-level mechanisms by which division of labor causes inequality, second, the macro-level mechanisms by which TCTs promote or impede this inequality and third I empirically evaluate two divergent positions on the effect of TCTs on inequality.

To summarize, we find support for both hypotheses derived from the Spencerian Theory – as the degree of division of labor increases so does political hierarchy and economic stratification. Small-scale societies with lower degrees of social division of labor tended to also have lower levels of economic stratification and political hierarchy. Conversely, those with higher degrees of social division of labor tended to also have higher levels of economic stratification and political hierarchy. Our findings suggest that division of labor and stratification "coevolves in predictable ways" (Turchin et al. 2018; also see Turchin 2009).

Moreover, some support is found for both hypotheses derived from the Techno-pessimist perspective – that TCTs have a positive moderating effect on the relationship between division of labor and economic stratification. Conversely, no support is found for hypotheses derived from the Techno-optimist – that TCTs have a negative moderating effect on the relationship between economic stratification and occupational specialization. The magnitude of this moderating effect appears rather substantial although lower levels of TCTs do not have a significant effect on the main relationship. The effects of division of labor in small-scale societies are orders of magnitude greater in societies like the Burmese, Romans and Russians, that have advanced TCTs, than they are in societies like the Gond, Tallensi or Toda. I find that those innovations in TCTs have historically tended towards increasing the "positional advantage" of groups with already existing resources and decision-making power.

The interactions involving Political Hierarchy fell just short of significance at conventional thresholds while the interaction involving Economic Stratification appears to produce the largest gains per unit increase in TCTs. Our findings are consistent with the Techno-pessimist hypotheses that posit that the improvements of technological innovation have historically disproportionately benefited the top strata of society at the expense of the lower. Additionally, lower levels of TCT have no significant effect the main relationships between Division of Labor and both Economic Stratification and Political Hierarchy. Innovations that allowed the transmission of more complex information faster and more reliably as well as those that allow the exchange of more resources faster and more reliably seem to have increased the amount of inequality between societal sub-groups. This implies that technologies are either asymmetrically diffused and/or their adoption patterns are unequal leading to the reproduction the structure of information and resource exchange.

Economic and political power, accrued through control over the regulatory and distributive functions, shapes a group's (Grimes 2017) ability affect the overall structure of the operative functions. This ability to affect the system implies the choice of altering or reproducing the structure, and therefore the possibility of realizing one's interests. Power, prestige and wealth are seen as inevitably being concentrated in an elite like Mill's (1956) "warlords, corporate and statesman", or Marx's "bourgeoisie". Through the control technologies required to interact,

individuals are able to manipulate the structure of interaction: power begets power. Technologies are not neutral and are imbued by power (Feenberg 1991).

Finally, future work can address some of the limitations of this study. First, the measurement of our key variables could be improved with alternative coding schemes[6]. Other than the categorical nature of my key variables, what makes them difficult to manipulate is the coding scheme. For example, it is difficult to interpret the coding scheme for both the variables included in the TCT index. Second, political hierarchy could be used as a measure of the strength of institutions for coordination and control, which would mediate the relationship between division of labor and economic stratification. Third and finally, because our indicators are synchronous estimates (cross-sectional) rather than measurements of change over time, it is difficult to establish a causal order and therefore to eliminate the possibility of reverse causation. This could be solved by the use of longitudinal data.

[6] A more suited operationalization of Economic Stratification would be a Gini index, measuring the income or wealth distribution among a population. The number of economic classes is also an adequate measure of economic stratification.
The number of intermediaries between the lowest and highest decision-makers is, for our purpose, an adequate operationalization of Political Hierarchy as it describes the compounding.
A more suited operationalization of Division of Labor would simply be the number of different occupational specialization or occupational sectors, measuring the number of occupational groups with which diverging interests and interdependence emerges.
A more suited operationalization of the Communication Technology variable would be the energy cost per unit of weight per unit of time that the society is able to move.
A more suited operationalization of the Transport Technology variable would be the energy cost per unit of volume per unit of time that the society is able to transmit.

REFERENCES

Atkinson Q. D., Sheehan O., Watts J., Gray R.D. 2018. Coevolution of landesque capital intensive agriculture and sociopolitical hierarchy. Proc. Natl. Acad. Sci. USA. Apr 3; 115(14): 3628-3633. Doi: 10.1073/pnas.1714558115.

Dunbar, R.I.M. June 1992. "Neocortex size as a constraint on group size in primates". Journal of Human Evolution. 22 (6): 469–493. doi:10.1016/0047-2484(92)90081-J.

Dunbar, R.I.M. 1993. "Coevolution of neocortical size, group size and language in humans". Behavioral and Brain Sciences. 16 (4): 681–735. doi:10.1017/s0140525x00032325.

Eff, E. A, 2004. "Does Mr. Galton Still Have a Problem? Autocorrelation in the Standard Cross-Cultural Sample". World Cultures 15(2):153-170.

Eff, E. A, & Dow, M. M. 2009. How to Deal with Missing Data and Galton's Problem in Cross-Cultural Survey Research: A Primer for R. Structure and Dynamics, 3(3). Retrieved from https://escholarship.org/uc/item/7cm1f10b

Flannery, K., & Marcus, J. 2012. The Creation of Inequality: How Our Prehistoric Ancestors Set the Stage for Monarchy, Slavery, and Empire. Cambridge, Massachusetts; London, England: Harvard University Press. Retrieved from http://www.jstor.org/stable/j.ctt2jbvjr

Feenberg, Andrew. 1991. Critical theory of technology. Oxford University Press.

Gilman, A., Robert McC. Adams, Anna Maria Bietti Sestieri, Cazzella, A., Henri J. M. Claessen, Cowgill, G., Crumley, C., Earle, T., Gallay, A., Harding, A. F., Harrison, R. J.,
Hicks, R., Kohl, Philip L., Lewthwaite, James, Schwartz, Charles A., Shennan, Stephen J., Sherratt, Andrew, Maurizio T., Wells, P. 1981. The Development of Social Stratification in Bronze Age Europe [and Comments and Reply]. Current Anthropology, 22(1), 1-23. Retrieved from http://www.jstor.org/stable/2742414

Grimes, Peter. 2017. Evolution and World-Systems: Complexity, Energy, and Form. Journal of World-System Research. ISSN: 1076-156X | Vol. 23 Issue 2 | DOI 10.5195/JWSR.2017.728 jwsr.org

Gavrilets, Sergey & Fortunato, Laura. 2014. A solution to the collective action problem in between-group conflict with within-group inequality. Nature Communications volume 5, Article number: 3526.

Hård, M. 1993. Beyond Harmony and Consensus: A Social Conflict Approach to Technology. Science, Technology, & Human Values, 18(4), 408–432. https://doi.org/10.1177/016224399301800402

Henrich, Joseph, and Robert Boyd. 2008. "Division of Labor, Economic Specialization, and the Evolution of Social Stratification." Current Anthropology, vol. 49, no. 4, pp. 715–724. JSTOR, JSTOR, www.jstor.org/stable/10.1086/587889.

Mathew, Sarah and Robert Boyd. 2011. "Punishment sustains large-scale cooperation in pre-state warfare". Proceedings of the National Academy of Sciences Jul 2011, 108 (28) 11375-11380; DOI: 10.1073/pnas.1105604108.

Murdock, George P.; White, Douglas R. 2006. Standard Cross-Cultural Sample. UC Irvine. Social Dynamics and Complexity

Murdock, G., & Provost, C. (1973). Factors in the Division of Labor by Sex: A Cross-Cultural Analysis. Ethnology, 12(2), 203-225. doi:10.2307/3773347

Nolan, P., & Lenski, G. 1996. Technology, Ideology, and Societal Development. Sociological Perspectives, 39(1), 23–38. https://doi.org/10.2307/1389341

Ruyle, Eugene E. 1973. Slavery, Surplus, and Stratification on the Northwest Coast: The Ethnoenergetics of an Incipient Stratification System. Current Anthropology, Vol. 14, No. 5., pp. 603-63 1.

Spencer, Herbert. 1862. First Principles. Adamant Media Corporation.

Spencer, Herbert. 1898. The Principles of Sociology. Taylor & Francis; Vol. 2. Part 2.

Turchin, Peter. 2009. Evolution of Complex Hierarchical Societies. Social Evolution & History. Volume 8, Number 2 / September 2009 https://www.sociostudies.org/journal/articles/140588/

Turchin, Peter. 2009. Long-Term Population Cycles in Human Societies. Annals of the New York Academy of Sciences Volume 1162, Issue 1. https://doi.org/10.1111/j.1749-6632.2009.04447.x

Turchin, Peter; Currie, Thomas E.; Turner, Edward A. L.; Sergey Gavrilets. 2013. War, space, and the evolution of Old World complex societies. Proceedings of the National Academy of Sciences Oct 2013, 110 (41) 16384-16389; DOI: 10.1073/pnas.1308825110

Turchin, Peter et al. 2017. Quantitative historical analysis uncovers a single dimension of complexity that structures global variation in human social organization. National Academy of Sciences. https://doi.org/10.1073/pnas.1708800115

Turner, Johnathan H. 2012. Contemporary Sociological Theory. SAGE Publications, Inc.

Turner, Johnathan. 1985. Herbert Spencer: A Renewed Appreciation. SAGE Publications, Inc; 1 edition.

APPENDIX 1.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Economic Stratification	175	2.451429	1.449013	1	5
Political Stratification	172	2.034884	1.112898	1	4
Division of Labor	175	3.097143	1.421001	1	5
Information Systems	175	2.36	1.466719	1	5
Transport	174	1.770115	1.160039	1	5
TCT	173	-.0025073	1.764571	-1.592768	4.569625
Population Size	174	3.45977	1.705514	1	8

Table 2. Least Square Regression of Economic Stratification and Political Hierarchy on Division of Labor,TCT and Population Size, with and without the Interaction of Division of Labor and Information Systems/Transport

	(1)	(2)	(3)	(4)
	Political Hierarchy	Political Hierarchy	Economic Stratification	Economic Stratification
Division of Labor	0.260***	0.291***	0.254***	0.334***
	(0.058)	(0.058)	(0.073)	(0.070)
TCT	0.202***	-0.040	0.333***	-0.305
	(0.045)	(0.136)	(0.049)	(0.165)
Division of Labor *		0.058		0.152***
TCT		(0.030)		(0.036)
Population Size	0.126**	0.118**	0.181***	0.156***
	(0.043)	(0.042)	(0.048)	(0.046)
Intercept	0.809***	0.666***	1.039***	0.667**
	(0.171)	(0.197)	(0.216)	(0.234)
N	170	170	173	173
R-sq	0.460	0.468	0.493	0.526
F	(3, 166)= 70.17***	(4, 165)= 53.82***	(3, 169)= 74.42***	(4, 168)= 53.82***

Note: p< .05; p< .01; p<.001

Table 3. Logistic Regression of Economic Stratification and Political Hierarchy on Division of Labor,TCT and Population Size, with and without the Interaction of Division of Labor and Information Systems/Transport

	(5)	(6)	(7)	(8)
	Political Hierarchy	Political Hierarchy	Economic Stratification	Economic Stratification
Division of Labor	0.699**	0.788**	0.678*	0.805**
	(0.257)	(0.260)	(0.265)	(0.258)
TCT	0.405**	-0.551	0.486***	-0.929
	(0.142)	(0.681)	(0.134)	(0.616)
Division of Labor *		0.231		0.341*
TCT		(0.157)		(0.146)
Population Size	0.322*	0.303*	0.252	0.222
	(0.144)	(0.138)	(0.132)	(0.134)
Intercept	-4.508***	-4.925***	-4.487***	-5.083***
	(0.883)	(1.000)	(0.972)	(0.976)
N	170	170	173	173
R-Square	0.348	0.358	0.367	0.387
Wald Chi-Square	(3)= 48.03***	(4)= 44.89***	(3)= 44.42***	(4)= 40.77***

Note: p< .05; p< .01; p<.001

APPENDIX 2.

Figure 1.
Marginal Effects of Division of Labor on **Economic Stratification** across Observed Range of Information Systems and Transportation (Table 2 Model 2)

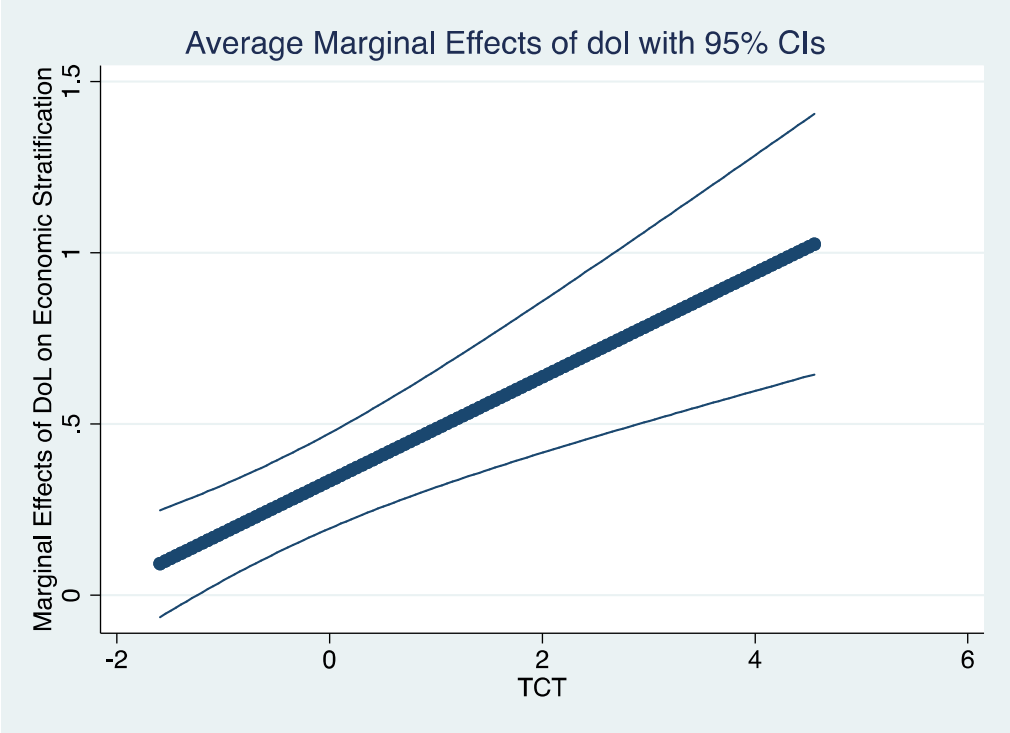


Figure 2.
Marginal Effects of Division of Labor on **Political Hierarchy** across Observed Range of Information Systems and Transportation (Table 2 Model 4)

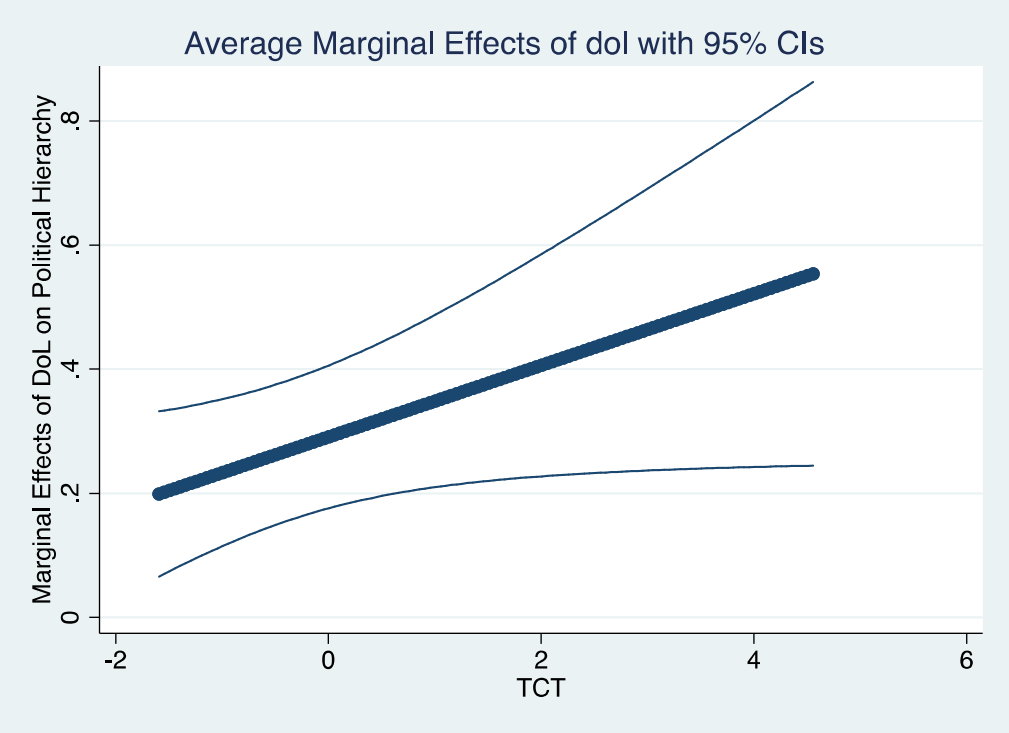


Figure 3.
Marginal Effects of Division of Labor on **Economic Stratification** across Observed Range of Information Systems and Transportation (Table 3 Model 6)

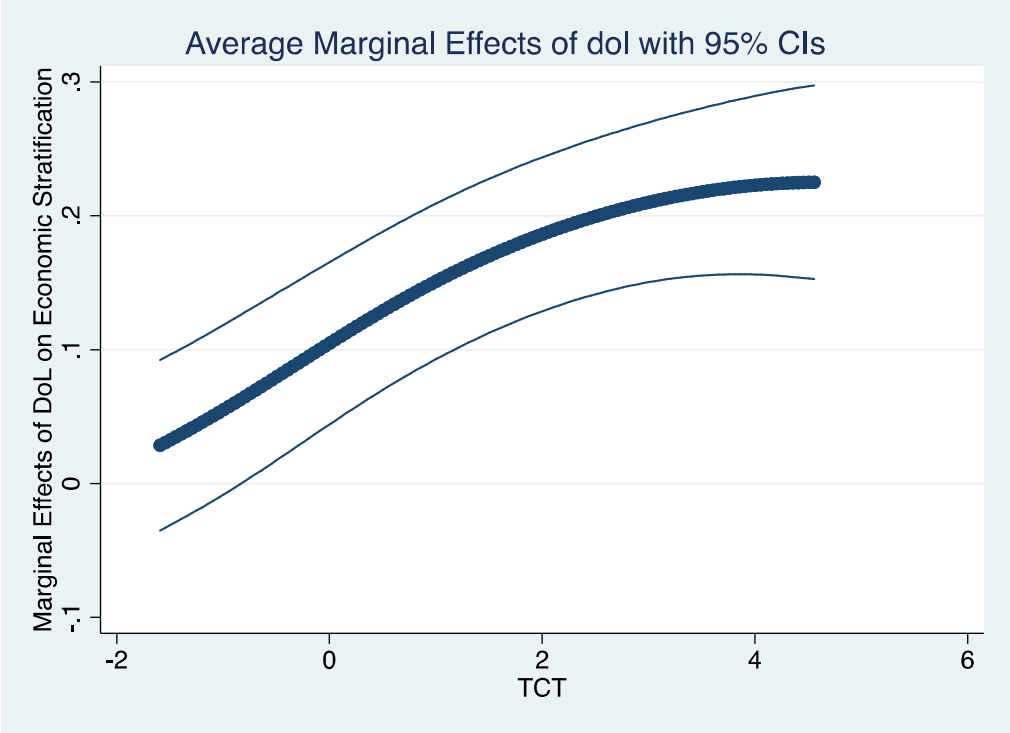


Figure 4.
Marginal Effects of Division of Labor on **Political Hierarchy** across Observed Range of Information Systems and Transportation (Table 3 Model 8)