Agriculture, Diffusion, and Development: Ripple Effects of the Neolithic Revolution

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Abstract. Are the Neolithic revolution's effects still impacting incomes across the world today? I find strong support for this proposition using new, country-specific estimates of the timing of agricultural transition. While support with my data is slightly weaker than with the coarser data of Hibbs and Olsson (2004), I provide evidence that the differences are due to how technological diffusion is accounted for. A correction for world migrations since 1500 significantly improves the fit. Transition year also helps to explain income in 1500 itself, and an alternative measure of pre-modern development, state history, has similar ability to predict income in 1500 and 1997.

Keywords: economic growth, agriculture, transition to agriculture, Neolithic Revolution.
JEL numbers: N50, O10, O40, Q10

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Introduction

The transition from reliance upon hunting and gathering to reliance upon agriculture was one of the great turning points in human history. Diamond (1998) provides evidence that differences among human societies with respect to the timing of the transition to agriculture led to differences in levels of technological development and social organization (including development of states) that persisted into the era of European expansion beginning in the 15th century, explaining why many non-European societies, especially those outside of Eurasia, could be colonized by European ones. To test the hypothesis that early agricultural development is associated with higher income today, Hibbs and Olsson (2004, hereafter HO) assembled data on biogeographic and geographic variation and on the estimated dates of transition in eight world macro-regions, showed that biogeography could predict the dates of transition to agriculture, and used the predicted dates of transition to predict 1997 incomes in 112 countries. They found that a remarkable 52% of the variation in 1997 incomes was explained by differences in predicted time since transition. Relatedly, Chanda and Putterman (forthcoming, 2005) found that an earlier start on agriculture (as represented by HO's data series) and a longer history of states predicts greater income in 1500 and more rapid economic growth between 1960 and 1998.

A limitation of HO's study is that the same date of transition is assigned to a large number of countries assumed to have obtained agriculture from the same source. For example, whereas archeological evidence suggests that agriculture was not established in what is now Britain until some 5,000 years later, HO's estimate for Mesopotamia is used by them not only for present-day Jordan and Turkey but also for Britain and Europe as a whole. This raises the question of whether it is the historical practice of agriculture in a country or the inheritance of an agro-technological tradition that matters, and if the latter, which modes of transmission—for example migration versus diffusion by borrowing—are relevant, and how should we account for multiple transmission paths?

In this paper, I investigate the empirical relationship between agricultural transition timing and recent income, extending the analysis in four directions. First, I re-estimate several of HO's regression equations using a new data set on the timing of

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* I wish to thank Arthur Hintermeister, Rahim Kassam-Adams, and especially Cary Anne Trainor for their assistance in compiling the agricultural transition data used here, Professors Hibbs and Olsson for providing their data set, Professor Hibbs for comments on a draft of the paper, Nilay Patel for the regression work reported here, my colleague David N. Weil for his suggestions regarding construction of the 1500 – 2000 population transition matrix, Yaheng Wang and Victoria Hsu for research going into that matrix, and the Chase Manhattan Undergraduate Research Assistant fund of the Department of Economics, Brown University, for support of Kassam-Adams, Trainor Patel, Wang and Hsu's work.

transition in individual countries, demonstrating that the explanatory power of the more country-specific series for year of agricultural transition is somewhat *lower* than that of HO's data, and that this is partly but not entirely due to their special treatment of Canada, the U.S., Australia and New Zealand, which they call "neo-Europes." Second, I combine the revised agricultural transition data with a new data set on global migration since 1500 (a rough marker for the epoch of European expansion) and show that the transition data perform better when adjusted to take migration into account. Third, I repeat HO's exercises substituting for years since transition a measure of the length of experience with large scale political structures (*statehist1500*). If the development of states is stimulated by agriculture and the accompanying sedentarism and population growth, *statehist1500* should act as an alternative measure of agricultural transition and the social and economic development it gives rise to, and it should perform similarly in the HO regressions. In fact, I find very similar results for *statehist1500* as for transition year, including the fact that its predictive power is similarly enhanced by an adjustment for post-1500 migration. Along the way, I confirm the high bi-variate correlation between *statehist1500* and transition year in the cross country data. Fourth, I check the ability of both HO's and my transition dates, as well as *statehist*, to predict income not of 1997 but of 1500, which I argue is a more direct test of Diamond's claim. I find that each of the two transition date series obtains a significant coefficient and explains up to 34% of the variance in estimated income in 1500, while *statehist1500* explains up to 46% of that variance. This appears to be the first statistical test of Diamond's claim using estimated income to represent level of development in 1500.

Overall, the results add to the evidence that differences in the timing of the transition to agriculture and accompanying social changes have been important determinants of the variation of income among countries today. They also indicate that history's influence on economic capabilities is not limited to the locations in which innovations first took place, because technologies and social capabilities can be transferred from one place to another, including by migrations such as the ones that have remade the globe since the 15th century encounter between the "Old" and "New" worlds.

The remainder of the paper consists of four sections, which in turn 1) retest HO's models using country-specific rather than region-specific transition dates, 2) test for the effects of migration, 3) explain incomes in 1500, and 4) examine the performance of state history as an alternative to transition year. Section 5 concludes the paper.

1. *Income as a function of region- versus country-specific transition year*

Have countries that made the transition to agriculture earlier tended to maintain their technological lead and to enjoy higher incomes than other countries even today? For this first exploration of that question using distinct estimates of the timing of transition for more than 100 countries, I begin by revisiting the approach adopted by HO (2004).

HO test the proposition, attributable to Diamond, that different geographic and biogeographic conditions in the Early Holocene period, some 12,000+ years ago, gave rise to differences in the timing of transitions to agriculture and animal husbandry, occurring in different regions between some 10,000 years ago in Mesopotamia and 4,900 years ago in sub-Saharan Africa. Supposing that technological progress has continued to build, in each society, upon the foundation set with that transition, and that differences in achieved technological level, although offset by population growth in earlier periods, gave rise to differences in standards of living following the industrial revolution (see Figure 1), they then focus on the baseline test equation

$$\ln y_n(1997) = \alpha + \beta(12{,}000 - t_n) \qquad (1)$$

where 12,000 is the number of years to the present from a starting date in the era of universal hunting and gathering, t_n is the year of transition in region n, hence the

Early Holocene ➔ Neolithic transition ➔ Industrial revolution ➔ Present day
10,000 B.C. 8,500 – 2,500 B.C. ≥ A.D. 1750 A.D. 2000

Figure 1. Model time-line, according to Hibbs and Olsson (2004).

expression in parentheses is the number of years since the transition. In augmented models, they allow for the possibility that geographic factors have also independently affected levels of development, and that the technological differences associated with the number of years since the agricultural transition affect levels of development both directly and via an affect on the quality of institutions (see Figure 2).

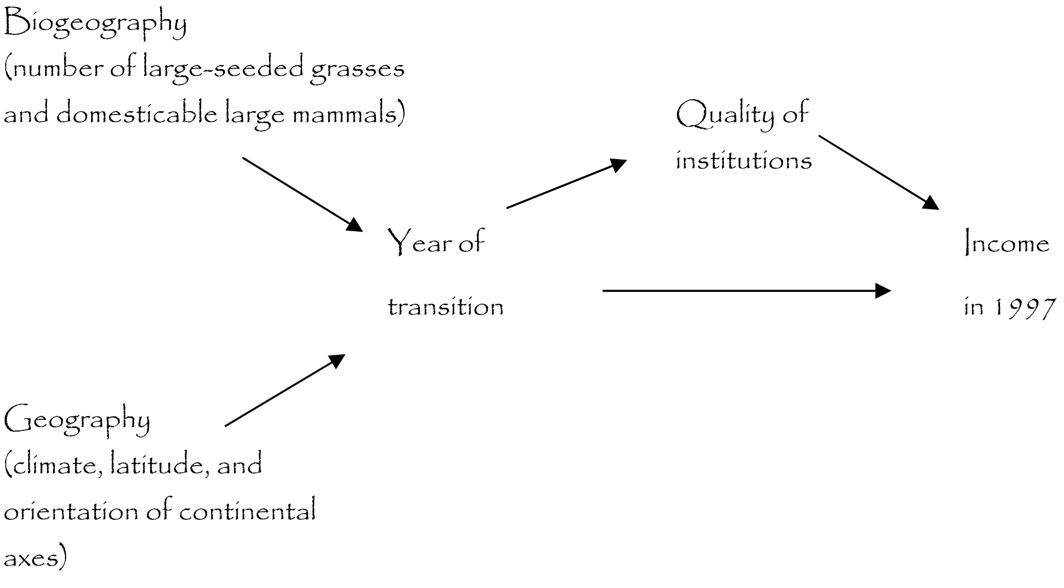

Figure 2. Causal flows according to Hibbs and Olsson (2004).

I focus on Table 3 in Hibbs and Olsson (2004), which presents a series of regression "experiments" testing the relationships shown in Figure 2. HO's years since transition measure is estimated for seven macro regions as a function of the number of indigenous large-seeded domesticable grains and the number of indigenous domesticable large animals, and is measured in thousands of years before the year 2000 (C.E.). Their geographic indicator is the average of three normalized constituent measures of (a) favorability of climate, (b) absolute latitude, and (c) ratio of east-west to north-south expanse of the continent to which the country belongs.[1] They measure quality of institutions by the average of five normalized constituent measures of (a) quality of bureaucracy, (b) rule of law, (c) government corruption, (d) risk of expropriation, and (e) risk of government repudiation of contracts, as rated in the International Country Risk Guide and used by Knack and Keefer (1995).

I begin with HO's second regression, which shows that the log of their geography indicator can explain 78% of the variance of the number of years since transition.[2] In Table 1, the first column reproduces HO's result.[3] As mentioned, HO assign their measures of biogeography for seven macro regions, and thus their predicted values of years since transition (henceforth YST), to 112 countries. For example, all sub-Saharan African countries in their sample share an estimated transition date of 4958 years before the present, while all North African, European and Middle Eastern countries share a transition date estimate of 9847 B.P.

Aided by research assistants, I investigated whether estimates of the date of agriculture were available on a more country-specific basis. When we were unable to identify any existing compilation of data meeting our needs, we undertook to assemble such data from the best sources available. Like HO, we used today's countries as observational units because our ultimate interest lies in studying possible impacts of early agricultural development on recent economic and other outcomes using an international sample of country-level observations. The results are available in Putterman and Trainor (2006). I denote HO's estimates YST-HO and our country-specific estimates YST-CS. Appendix 1 compares the two series for the 112 countries in HO's and the present study. Column 2 of Table 1 shows an estimated regression paralleling Column 1 but using YST-CS as dependent variable. The results are quite similar to Column 1, with only a slightly smaller positive coefficient on the explanatory variable. The t-statistic is also smaller, although the significance level remains very high.

Leaving discussion of the other columns of Table 1 for later, I turn to columns 1 and 2 of Table 2, which present a replication of HO's key test of equation (1), the relationship between YST-HO and the log of 1997 per capita income (column 1), and the corresponding estimate using YST-CS (column 2). Again, the results are qualitatively very similar, but the coefficient and t-statistic are somewhat smaller using the country-specific transition years, and a substantially smaller proportion of the variance is explained, according to the R-squared.

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[1] See Hibbs and Olsson (2004) for details. Diamond (1998) argues that continents extending mainly from west to east favor diffusion of agriculture, since there are fewer dramatic changes in climate as one traverses them than is the case for continents extending mainly from north to south.

[2] The relationship between biogeography and transition year is tested earlier in the paper and is then used to estimate predicted transition years. The first regression in their Table 3 tests for and finds a strong relationship also between biogeography and geography.

[3] In each case, I replicated the result independently, using their data.

Tables 3 and 4 contain estimates of HO's fifth and sixth regressions.[4] Column 1 of Table 3 replicates their equation explaining some 57% of the variance in 1997 income using the geography variable and level and square terms (i.e., a quadratic specification) for predicted years since transition. The transition year variables add 5% to the explanatory power of their regression two (that with geography alone), are significant at the 1 and 5% levels respectively, and suggest that income is increasing at a decreasing rate with the number of years since transition. Column 2, in which I substitute YST-CS, shows a first qualitative departure from HO's results: while the sign pattern on the level and square terms is the same, neither coefficient is in itself statistically significant, and the addition to explained variance is only about 3%. Columns 1 and 2 of Table 4, which replicate HO's sixth regression using their data and mine, respectively, produce similar results. In both variants, the new regression shows that adding the quality of institutions measure boosts the explanatory power of the regression—by an impressive 23% in HO's version. When YST-CS and its square are used, however, the coefficients on those variables are not statistically significant.

Finally, in column 1 of Table 5, I show a regression HO use to explore the relationship between years since transition and the quality of institutions. The result suggests that 38% of the variation in the latter variable can be explained by differences in the former. Column 2 re-estimates the regression using YST-CS. As with the other estimates, the country-specific series obtains a smaller estimated coefficient and smaller t-statistic and based on the adjusted R-squared it is only able to explain 5% of the variance in quality of institutions.

2. *The role of global migration post-1500*

Why do HO's transition year estimates have more predictive power in the regressions just discussed than do more country-specific values? One possibility is that having transitioned to agriculture at an earlier point in time is associated with higher income or faster growth today not because growing grain for thousands of years has imparted special powers to the land, but because it is associated with a lengthy development of human capabilities that are associated with the growth of civilizations, including the development of writing, metallurgy, specialization and trade, use of money and accounting, operation of large scale organizations, and the management of states.[5] If this is the case, then the fact that an agricultural society existed on one piece of territory but not on another thousands of years ago may be an imperfect predictor of the human capabilities present today, due to migrations of population and dissemination of ideas and practices over time. China, for example, had one of the world's earliest agricultures and perhaps its longest continuous civilization, but Japan, estimated to have been cultivating rice for only half as long, went on to assimilate essentially all of the human capability relevant to operating a complex economy and society that China had to offer (as well as a

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[4] Their fourth regression shows that by itself geography predicts some 52% of the variation in 1997 income.

[5] See Burkett *et al.*, 1999, Putterman, 2000, Bockstette *et al.*, 2002, Chanda and Putterman, 2004a, 2004b, 2005. See also Diamond, 2005.

little more, a little earlier, from sources geographically further away). A similar relationship may hold for Mesopotamia (YST-CS = 10,500) and England (YST-CS = 5,500). By contrast, Mexico's Yucatan peninsula, which had a burgeoning agrarian civilization at the time that Caesar commanded the Roman legions in Gaul, had returned to tropical vegetation by the time the Spaniards arrived in 1517.

Clearly, changes in the geographic incidence of human capabilities can occur for many reasons, including migration, exchange of ideas, colonization, and social decline (sometimes occasioned by climatic and environmental changes). What's remarkable is that there is as much persistence of the advantages conferred by differences in early agricultural starts as HO's regressions and our replications with more country-specific data suggest.

Crops and agricultural techniques, other technologies, and groups of human beings, have been spreading and migrating since the birth of agriculture—witness the spread of agriculture throughout the middle east, north Africa, and Europe from Mesopotamia, the gradual movement of the Bantu-speaking peoples and their crops out of what is now Cameroon into southern and eastern Africa beginning some four or five thousand years ago, the movement of Turkic-speaking peoples from central Asia to Anatolia, or the diffusion of Austronesian speakers and their crops throughout the Pacific and Indian Oceans. One of the largest and most rapid episodes of diffusion and migration was the one that accompanied the opening of overseas trading routes and colonization by western European nations beginning in the 15th Century. Influential papers by Acemoglu, Johnson and Robinson (2001, 2002) argue that the pattern of European colonization gave rise to institutions that determined which countries prospered and which stagnated after 1500. The spread of European languages and legal systems are identified as causes or good proxies for the causes of cross-country variation in income by Hall and Jones (1998) and La Porta, Lopez-de-Silanes, Shleifer and Vishny (1998).

HO acknowledge many of the factors just discussed, stating that their approach "says nothing about the complex dynamics of technology dispersal from the major original homelands of agriculture within (or across) the broad regions" and that "we know *ex post* that the technological leadership of the best endowed local homelands eventually eroded because of adverse human environmental impacts" (p. 3718). However, they make one crucial "correction" for the role of the colonial era: they assign the European/North African/Middle Eastern value for their biogeography variable to the U.S., Canada, Australia and New Zealand "[b]ecause the European food and technology package was wholly transferred by colonialists" in these cases. They admit that the "same transfer occurred by varying lesser degrees in some other former colonial nation states, but we were unable to calibrate this transfer; it is a source of imprecision in estimating the influence of biogeography on current national prosperity." In all, HO's assignment of biogeography to countries is subject to two sources of imprecision working in two opposite directions: on the one hand, they are "generous" in assigning the same biogeography to all of Europe as to Mesopotamia, and in going still further to assign it also to the four aforementioned "neo-Europes." On the other hand, they extend no such generosity to such countries as Uruguay and Argentina, although those countries and the "neo-Europes" have similar fractions of their populations descended from Europeans.

As a first step in exploring the impact of migration, I re-estimate each of the regressions above using the original HO biogeography values for the U.S., Canada, and Australia, rather than substituting as they do the European biogeography value (see Appendix 1). A special problem is that New Zealand's biogeography value is so low as to be inconsistent with HO's equation for predicting transition dates, so I assign it the value for Australia, which is the next lowest of the series. In column 3 of each table, I show the regressions with the transition year estimates from these "unadjusted HO biogeography values," noting the substantial declines in t-statistics and R-squares in all cases. Comparing column 1 with column 3 of each table suggests that accounting for the movement of technology by migration to the four "neo-Europes" leads to an improvement in the fit of HO's regressions to a degree rather impressive for a mere 4 of 112 observations.

While one might argue for extending European biogeography not only to the U.S. but also to Argentina and Uruguay, why stop there? Chile's population's ancestry is about 65% European, 35% Amerindian; Brazilians' ancestors are about 75% European, 20% African and 5% Amerindian. Instead of experimenting with differing cut-off levels of the European population share at which to apply HO's correction, a more rigorous approach is to correct for migration in proportion to its importance on a case-by-case basis. This is equivalent, conceptually, to inserting a new variable, "Movement of peoples," between the Year of transition and the Quality of institutions and Income of 1997 variables in Table 2.

I worked with research assistants to develop a matrix of global migration since 1500. Each cell in the matrix indicates the estimated proportion of the ancestors of the current permanent residents of 162 countries, identified by row headings, who lived the year 1500 in that same or any other one of those countries. For example, the entries for the United States estimate that 17% of current U.S. permanent residents' ancestors resided in what is now Germany, in 1500, that 1% resided in Russia, 1% in China, 1% in Senegal, and 3% in some part of what is now the United States, itself. Proportions of the ancestors of African-Americans, Afro-Brazilians, etc., brought to the Western Hemisphere as slaves are attributed to territories now comprising Senegal, Cameroon, Angola, and so forth, based on slave trade data.[6] Although the choice of 1500 was based upon considerations associated with European colonization, the same criteria are applied consistently around the world so that, for instance, the migration of Hmong people from southern China into what is now Laos is accounted for, as is movement of Crimean Tatars from what is now Ukraine into Turkey, movement of Hausa from Nigeria and Niger to Ghana, return of former slaves (some of them originally from Senegal, Angola, etc.) to Liberia, and so on.[7]

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[6] Eltis *et al*., eds., 1998.

[7] Of course, some guesswork is unavoidable; for example, some 60% of today's Mexicans are counted by most sources as "mestizo," and our sources lacked estimates of what proportion of their genes were contributed by indigenous and what proportion by European ancestors, so we made an educated guess,

In this section, I discuss a simple exercise conducted with the post-1500 migration matrix. Rather than assigning people of the U.S. whose ancestors migrated during the past few centuries from, say, Germany, the YST value of what is now the U.S., I assign them the value of Germany, doing the same for those of Chinese, Senegalese, Swedish and all other ancestries. This is similar to HO's procedure of assigning the U.S. and Canada the same value as Mesopotamia, but there are some differences. First, rather than fully replace the U.S. value with that of Germany or any other single country, I replace it with a weighted average of the values of all of the source countries of the U.S.'s population, including the U.S. itself. Second, I follow the same procedure for all countries, so that my method doesn't suffer from such inconsistencies as assigning the U.S. the value for Mesopotamia but assigning Argentina the value derived from ancient Inca farming. It accounts, too, for the African ancestors of many Haitians, the Indian ancestors of about half the citizens of Guyana, and so on—attempting, in fact, to cover any source country accounting for more than half of one percent of a country's ancestors. My migration-adjusted years since transition varaible is derived by simply multiplying the population shares of each source country in a country's row of the matrix by the years since transition value of the source country, and then summing these numbers.[8]

Results for re-estimates of the regression equations in Tables 1 – 5, with the new variable substituted for the original, are shown in each table's fourth column. It is immediately clear that the migration adjusted YST-CS variable achieves a better fit in each of the equations than does the unadjusted YST-CS, unadjusted for migration. In particular, the t-statistics for years since transition and its square are larger, as are the R-squared statistics for the equations, in the column 4 estimates with migration adjusted years since transition than in either the column 3 estimates with the "uncorrected" HO series or the column 2 estimates with my unadjusted country-specific series.

Finally, column 5 of each table uses the HO estimates of years since transition minus their adjustments for the "neo-Europes"—in other words, the values used in each table's column 3—but makes the same weighted average adjustment for post-1500 migration as does column 4. The results show improved predictive power for YST or for YST and its square relative to the column 3 estimates in all five tables, and in Tables 2 – 4, where YST or YST and its square are used to predict 1997 income, the new estimate outperforms all others, judging by the R-squared.

In general, HO's series, whether with their *ad hoc* correction for the four "neo-Europes" or with my more thorough correction for migration, perform much better than my country-specific series and somewhat better than my country-specific series with migration adjustment, in Tables 1 – 5. Why? A conjecture in line with the discussion of this section is that by ignoring differences in the timing of the agricultural transition

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treating the ancestors of Mexico's mestozos as being 2/3 indigenous. For more details about the construction of the matrix, see Putterman 2006b.

[8] Because we lack data on YST for a few of the matrix's smaller source countries, the shares of source countries providing data sometimes total less than 100%. In such cases, the available shares are simply re-weighted proportionately so as to add up to 1.

between, for example, England, Sweden and Iraq, or Japan, Korea and China, HO's values reflect both migrations and other kinds of diffusion of technology that my migration adjustments miss because their series implicitly accounts for migration and cultural diffusion that occurred prior to 1500 C.E.. Because the transition to agriculture occurred much later in Sweden and England than in Iraq, much later in Korea and Japan than in China, the model with my data predicts that Iraq and China will be the more economically advanced countries. It seems best not to view either set of estimates as the last word on the topic.

The clear messages in this set of estimates are that the timing of agricultural transitions have had surprisingly strongly persistent effects on current levels of income, and that migration and diffusion of technologies (including perhaps social ones) also need to be considered in any full accounting.

3. *1500: a more direct test of Diamond*

While HO's model predicting incomes in 1997 comes close to being a direct test of Diamond's (1998) hypothesis about the impact of early agriculture, Diamond uses differences in preconditions for agriculture and its diffusion to explain why Europeans colonized the Americas, Australia, Africa, etc. beginning in the 15th Century, not to predict current incomes. Thus, his predictions are more immediately relevant to differences in income around 1500 than to differences today.[9] Diamond's use of the timing of the transition to predict colonization in the late 15th Century and my use of the same variable to predict incomes of about that time are shown schematically in Figure 3.

The difference between predicting income in 1997 and predicting it in 1500 might be important, as Acemoglu et al. (2001, 2002) have warned. In this section, I re-estimate the relevant equations of HO (2004) but replace log of 1997 income with that of 1500 income. I use two series on income in 1500 from Chanda and Putterman (forthcoming). These are based on income estimates from Madisson (2001) and use either urbanization rates from Bairoch (1988) and Aceomoglu *et al*. (2002) or both those urbanization rates and population densities based on the historical population estimates of McEvedy and Jones (1978).[10] The relevant dependent variables are labeled $\mathrm{Ln}(y_{1500}{}^{u})$ and $\mathrm{Ln}(y_{1500}{}^{b})$, where the superscript u indicates that only urbanization is used to predict income and the superscript b indicates that both urbanization and population density are used.

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[9] Conceivably, differences in technological development and social systems may not have translated into differences in incomes in 1500, thanks to what is sometimes seen as the "Malthusian" nature of pre-modern growth (see for example Galor and Weil, 2000). But while most economists believe that income differences were smaller in 1500, such differences most likely existed and favored the more technologically advanced countries of the time, including those in Western Europe and China (see Maddison, 2001).

[10] Chanda and Putterman estimate the effects of urbanization and of urbanization and development on income in 1500 using 32 country-level observations derived from estimates in Maddison (2001), some of which are for regions that include several countries. Using the coefficients thereby obtained, they predict income in 1500 for a larger sample of 74 countries, using the urbanization measure only, and 72 countries, using both measures. Like Chanda and Putterman, we use the predicted values even for the 32 countries covered by Maddison's estimates.

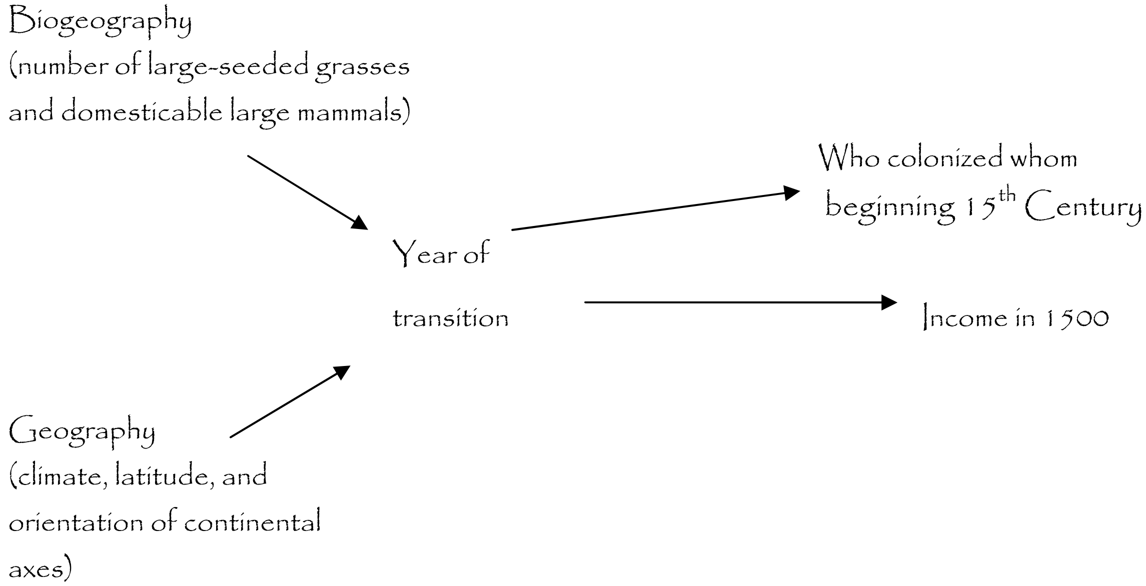

Figure 3. Causal flows according to Diamond (1998, upper right) and this paper (lower right).

Table 6 shows the estimates of the regressions paralleling those of Table 2, in which income is predicted by years since transition, only. In column 1, Ln(y_{1500}^{u}) is predicted by HO's series, including their "correction" for the neo-Europes. The explanatory variable has a positive coefficient significant at the 10% level, but only 6% of the dependent variable's variance is accounted for. In column 2, I use my country-specific values of years since transition with the same dependent variable, and the coefficient becomes significant at the 1% level, with R-squared of 0.15. Column 3's estimate substitute's the HO series without modifying the neo-Europe's, with results similar to column 2's. Since European migration to the neo-Europes had not yet occurred in 1500, this is clearly a preferable specification. In this case, my post-1500 migration adjustment is also uncalled for.

Columns 4, 5 and 6 repeat the exercises using Ln(y_{1500}^{b})as dependent variable. The results bear a similar relation to one another as those in columns 1 – 3, but in all cases the fit of the explanatory variable is better. Years since transition can explain about 33% of the variation of income among the 57 countries for which we have estimates. Although the number of countries covered is smaller than that in HO's exercises, the sample is nonetheless quite diverse, coming from every continent. The results are supportive of Diamond's hypothesis, although 2/3 of income variation remains unexplained.

Table 7 also shows six regressions using the same six combinations of dependent variable and transition data series as in Table 6, but the more elaborate specification of Table 3. Unlike in Table 3, the coefficient on geography is never significant here, and the level and square terms for YST are often insignificant as well. However, the significance of individual coefficients can be misleading since the three explanatory variables are correlated (see Table 1), and the R-squared statistics indicate some improvements in overall predictive power.

In sum, we are able to confirm a variant of Diamond's hypothesis at the historical cross-roads he focused on, although the fit is curiously less precise. Some of the difference may be attributable to the more imprecise estimates of income in 1500 than in 1997, but there is an intriguing possibility that it also reflects the fact that differences in living standards associated with differences in early development have actually been magnified, rather than being dampened, by the colonial era and the industrial revolution.[11]

4. *Agriculture and the state: an old story that still holds water*

Historians and archeologists have long recognized a connection between the rise of agriculture and the rise of states. When Europeans made their first landings on the island of New Guinea during the 16th through the 19th Centuries, they found neither a government nor a set of states vying for control of the large island. Anthropologists estimate that New Guinea, which during those centuries was populated by about a million people, is inhabited by tribes speaking as many as seven hundred different languages, none of which had ever formed a kingdom or empire. Large scale polities were also not found in Australia, Brazil, most of what is now the Congo, the southernmost parts of South America, and northernmost North America, Europe and Asia. And in general, it is agreed that such polities probably did not exist anywhere in the world before intensive cultivation of grains arose first in Mesopotamia, then in China and Egypt, eventually also in Mexico and Peru. In the archeological record, kingdoms and empires appear only after achievement of substantial population density over an area of some size, which tends to occur only hundreds or even thousands of years after establishment of settled agricultural villages. That the same pattern occurred independently and at different times in Mesopotamia, China, Mexico, Peru, and elsewhere, is striking.

Bockestette *et al*. studied a measure of the depth of countries' histories of supra-tribal polities and found it to be a strong predictor of economic growth during the period 1960 – 1995. They also found it to be correlated with various political and institutional measures and with the level of per capita income in 1995. While the measure's significance in predicting 1995 income *levels* (as opposed to post 1960 growth rates) is not robust to inclusion of some sets of controls, it adds significantly to the predictive power of the set of instruments that Hall and Jones use to predict "social infrastructure." Chanda and Putterman (2005) extend this work, studying both *statehist05*, which indexes the extent of indigenous state control over a present-day country's territory between 1 and 1950 C.E., and with *statehist1500*, which covers only the period 1 to 1500 C.E. (Both variables reduce the weight on past years using a discount rate of 5% per 50 years

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[11] As mentioned in footnote 8, income differences were lower in 1500, perhaps due to the "Malthusian" nature of agrarian growth. If the head start some regions gained from early agrarian development translated into a head start on industrialization as well, as casual empiricism suggests, and if industrialization initially magnifies income differences, then larger gradients of income with respect to YST would be expected in 1997 than in 1500.

before the present.) They find, among other things, that *statehist1500* is a good predictor of average income in countries as of 1500, and that it is highly correlated with HO's year of agricultural transition measure (for a global sample of 90 countries, the correlation is 0.73).[12]

In this section, I report the correlation between *statehist1500* and our country-specific years since transition variable, then discuss estimates of regressions paralleling those in Tables 2, 3, 6 and 7 but substituting *statehist1500* for years since transition. I also conduct a parallel exercise using the post-1500 migration matrix with *statehist1500* in place of YST.

The bi-variate correlation between *statehist1500* and our country-specific years since transition variable, in the sample of 149 countries for which both are available, is 0.634, significant with $p = < .001$. Table 8 provides estimates paralleling those of Tables 2 and 6, while Table 9 does the same for Tables 3 and 7. Because *statehist1500* takes a unique value for each country, like YST-CS, the estimates in columns 1 and 2 of Table 8 can be compared to those in columns 2 and 4 of Table 2. Like the coefficients on YST-CS, those on *statehist1500* are both significant at the 0.1% level. As with YST-CS, the migration adjustment considerably improves the ability to predict 1997 income (see Column 2). The percentage of the variance in 1997 income explained by *statehist1500* plus the migration adjustment is an impressive 34%. Columns 3 and 4 of Table 8 can be compared to columns 2 and 4 of Table 6. Again the coefficients on *statehist1500* like those on YST-CS are significant at the 0.1% level, and the percentage of variance in 1500 C.E. income explained is even higher when using *statehist1500*, reaching 46% in column 4. Post-1500 migration adjustments are omitted when prediction 1500 income, since they have no bearing on the dependent variable in that case.

Table 9 bears the same relationship to Tables 3 and 7 as Table 8 does to Tables 2 and 6. Results for *statehist1500* and its square resemble those for *YST-CS* and its square, but the percentage of the variance of 1500 C.E. income that is explained using *statehist1500* is noticeably larger.

The results of these exercises suggest that *statehist1500* has at least as much power to predict recent incomes as does YST, and that taking account of migration improves the fit for *statehist1500* as it does for the transition measure. The slightly better performance of *statehist1500* in some regressions may be explained by the fact that unlike YST, *statehist1500* takes into account developments long after the initial appearance of agriculture.[13] In this respect, *statehist*'s superiority resembles that of YST-

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[12] For this correlation, see Chanda and Putterman (2004a). Statehist has also been tested and found to be a powerful instrument in studies by Aghion and Howitt (2005) and Bardhan (2005), among others. The *statehist* data and a description of how they are calculated are available at www.econ.brown.edu/fac/Louis%5FPutterman

[13] A closer analogue to YST than *statehist* would be one that estimates the time elapsed since the *first* state appeared on a territory. That information is unavailable in the statehist data set, which estimates state presence back to 1 C.E. only. *Statehist* measures the accumulated experience with states during the years since that time.

HO, which reflects diffusion of agriculture in contrast to YST-CS, which only considers agriculture's local start date.

5. *Conclusions*

The exercises presented here reconfirm Hibbs and Olsson's finding of a remarkable amount of persistence of the effects of early Neolithic transitions on levels of economic development in recent times. Rather than improving upon the performance of HO's less country-specific measures of years since transition, however, my country-specific YST series is less successful at predicting recent income. My exercises using post-1500 migration data support the conjecture that the difference is due to the fact that development is related not so much to when agriculture began on a country's territory as such as to how old a tradition of agricultural and other technologies and social capacities the country has inherited through channels of diffusion that include but are probably not limited to migration.

Estimated income differences in 1500 can also be predicted by YST, as Diamond (1998) implies. But the predictive power is somewhat lower, perhaps partly due to less accurate income numbers, but partly to the smaller sample size and the fact that income gaps widened after 1500.

An alternative measure of an early start in technological and economic development, *statehist*, generates results similar to YST, and *statehist*'s prediction of 1997 income is likewise improved by a post-1500 migration adjustment. Like HO's YST series, *statehist* reflects development since the initial agricultural transitions, and this helps it to perform better than the "more accurate" YST-CS series in several regressions.

References

Aghion, Philippe, and Peter Howitt, 2005, "The Effect of Financial Development on Convergence: Theory and Evidence," *Quarterly Journal of Economics* 120: 173-222.

Bairoch, Paul, 1988, Cities and Economic Development: From the Dawn of History to the Present, University of Chicago Press.

Bardhan, Pranab, 2005, "Institutions Matter, But Which Ones?" *Economics of Transition* 13 (3): 499-532.

Bockstette, Valerie, Areendam Chanda and Louis Putterman, 2002, "States and Markets: The Advantage of an Early Start," *Journal of Economic Growth* 7: 347-69, 2002.

Burkett, John P., Catherine Humblet and Louis Putterman, 1999, "Pre-Industrial and Post-War Economic Development: Is There a Link?" with John P. Burkett and Catherine Humblet, *Economic Development and Cultural Change,* 47 (3): 471-95.

_________________________________, 2004b, "The Quest for Development: What Role Does History Play?" *World Economics* 5 (2): 1-31.

_________________________________, 2005, "State Effectiveness, Economic Growth, and the Age of States," pp. 69-91 in Matthew Lange and Dietrich Rueschemeyer, eds., *States and Development: Historical Antecedents of Stagnation and Advance* Basingstoke, England.

Chanda, Areendam and Louis Putterman, forthcoming, "Early Starts, Reversals and Catch-up in the Process of Economic Development," Scandinavian Journal of Economics (in Press).

Diamond, Jared, 1998, *Guns, Germs and Steel: The Fates of Human Societies.* New York: W. W. Norton.

Diamond, Jared, 2004, "Economics: The Wealth of Nations," *Nature* 429 (no. 6992): 616-7 (June 10).

Eltis, David, Stephen Behrendt, David Richardson, and Herbert Klein, eds., 1999, *The Trans-Atlantic Slave Trade: a database on CD-ROM*. Cambridge: Cambridge University Press.

Galor, O. and D. Weil, 2000, "Population, technology and growth: From the Malthusian regime to the demographic transition and beyond," *American Economic Review*, 90, 806-28.

Hibbs, Douglas A., and Ola Olsson, 2004, "Geography, biogeography, and why some countries are rich and others are poor," *Proceedings of the National Academy of Sciences* 101: 3715-3720.

Hibbs, Douglas A., and Ola Olsson, 2005, "Biogeography and long-run economic development," *European*

Knack, Stephen and Philip Keefer, 1995, "Institutions and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures," *Economics and Politics* 7: 207-25.

La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert Vishny, "Law and Finance," *Journal of Political Economy* 106 (6): 1113-55.

Maddison, Angus, 2001, *The World Economy: A Millenial Perspective*, OECD

McEvedy, Colin and Richard Jones, 1978, *Atlas of World Population History.* New York: Facts on File.

Putterman, Louis, 2000, "Can an Evolutionary Approach to Development Predict Post-War Economic Growth?" *Journal of Development Studies* 36(3): 1-30.

Putterman, Louis, with Cary Anne Trainor, 2006a, "Agricultural Transition Year Country Data Set," available at www.econ.brown.edu/fac/Louis%5FPutterman.

Putterman, Louis, 2006b, "World Migration Matrix, 1500 – 2000," available at www.econ.brown.edu/fac/Louis%5FPutterman.

Dep. Var. Indep. Var.	YST-HO	YST-CS	YST-HO w/o “neo-Europes” adjustment	YST-CS w/ post-1500 migration adjustment	YST-HO† w/ post-1500 migration adjustment
Ln(geography)	4.711 (0.235) $p < 0.001$	3.593 (0.409) $p < 0.001$	4.233 (0.443) $p < 0.001$	3.132 (0.419) $p < 0.001$	4.240 (0.262) $p < 0.001$
Constant	-10.757 (0.911) $p < 0.001$	-9.516 (1.588) $p < 0.001$	-9.237 (1.719) $p < 0.001$	-7.079 (1.626 $p < 0.001$	-8.587 (1.018) $p < 0.001$
# Obs.	112	112	112	112	112
R-squared	0.79	0.41	0.45	0.34	0.70

Table 1. Variants of Hibbs-Olsson regression 2.

† Series constructed by taking years-since-transition values without “neo-Europes” adjustment, as in Column 3, then adjusting for post-1500 migration as in Column 4.

Dep. Var. Indep. Var.	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1997})
YST-HO	0.382 (0.035) $p < 0.001$				
YST-CS		0.171 (0.045) $p < 0.001$			
YST-HO w/o “neo-Europes” adjustment			0.192 (0.039) $p < 0.001$		
YST-CS w/ migration adjustment				0.250 (0.044) $p < 0.001$	
YST-HO† w/ migration adjustment					0.430 (0.034) $p < 0.001$
Constant	5.131 (0.271) $p < 0.001$	7.223 (0.222) $p < 0.001$	6.603 (0.292) $p < 0.001$	6.715 (0.239) $p < 0.001$	4.624 (0.272) $p < 0.001$
# Obs.	112	112	112	112	112
R-squared	0.52	0.12	0.18	0.23	0.60

Table 2. Variants of Hibbs-Olsson regression 3.

† Series constructed by taking years-since-transition values without “neo-Europes” adjustment, as in Column 3, then adjusting for post-1500 migration as in Column 4.

Dep. Var. Indep. Var.	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1997})
Ln(Geography)	1.335 (0.387) $p = 0.001$	2.434 (0.235) $p < 0.001$	1.946 (0.372) $p < 0.001$	1.829 (0.222) $p < 0.001$	1.123 (0.338) $p = 0.001$
YST-HO	1.797 (0.627) $p = 0.005$				
(YST-HO)^2	-0.110 (0.043) $p = 0.011$				
YST-CS		0.031 (0.118) $p = 0.792$			
(YST-CS)^2		-0.014 (0.011) $p = 0.212$			
YST-HO w/o “neo-Europes” adjustment			-0.131 (0.084) $p = 0.122$		
(YST " ")^2			0.010 (0.009) $p = 0.271$		
YST-CS w/ migration adjustment				0.407 (0.136) $p = 0.003$	
(YST " ")^2				-0.033 (0.012) $p = 0.006$	
YST-HO† w/ migration adjustment					1.639 (0.547) $p = 0.003$
(YST " ")^2					-0.095 (0.039) $p = 0.016$
Constant	-3.912 (0.2574) $p = 0.131$	-1.231 (0.837) $p = 0.144$	0.825 (1.347) $p = 0.541$	-0.133 (0.778) $p = 0.864$	-2.961 (2.456) $p = 0.231$
# Obs.	112	112	112	112	112
R-squared	0.58	0.56	0.54	0.56	0.64

Table 3. Variants of Hibbs-Olsson regression 5.

† Series constructed by taking years-since-transition values without “neo-Europes” adjustment, as in Column 3, then adjusting for post-1500 migration as in Column 4.

Dep. Var. Indep. Var.	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1997})
Ln(Geography)	0.527 (0.276) $p = 0.059$	0.953 (0.253) $p < 0.001$	0.703 (0.314) $p = 0.027$	0.602 (0.210) $p = 0.005$	0.318 (0.244) $p = 0.196$
YST-HO	2.488 (0.435) $p < 0.001$				
(YST-HO)^2	-.162 (0.030) $p < 0.001$				
YST-CS		0.039 (0.092) $p = 0.672$			
(YST-CS)^2		-0.004 (0.008) $p = 0.623$			
YST-HO w/o "neo-Europes" adjustment			-0.014 (0.065) $p = 0.833$		
(YST " ")^2			0.004 (0.007) $p = 0.551$		
YST-CS w/ migration adjustment				0.255 (0.102) $p = 0.014$	
(YST " ")^2				-0.015 (0.009) $p = 0.096$	
YST-HO† w/ migration adjustment					1.875 (0.377) $p < 0.001$
(YST " ")^2					-0.115 (0.027) $p < 0.001$
Inst. Qual.	0.037 (0.003) $p < 0.001$	0.035 (0.004) $p < 0.001$	0.036 (0.004) $p < 0.001$	0.036 (0.004) $p < 0.001$	0.034 (0.003) $p < 0.001$
Constant	-5.129 (1.772) $p = 0.005$	2.077 (0.760) $p = 0.007$	2.928 (1.048) $p = 0.006$	2.634 (0.647) $p < 0.001$	-2.488 (1.691) $p = 0.144$
# Obs.	112	112	112	112	112
R-squared	0.80	0.74	0.74	0.76	0.83

Table 4. Variants of Hibbs-Olsson regression 6.

† Series constructed by taking years-since-transition values without "neo-Europes" adjustment, as in Column 3, then adjusting for post-1500 migration as in Column 4.

Dep. Var. / Indep. Var.	Inst. Qual.	Inst. Qual.	Inst. Qual.	Inst. Qual.	Inst. Qual.
YST-HO	5.609 (0.680) $p < 0.001$				
YST-CS		1.883 (0.802) $p = 0.021$			
YST-HO w/o “neo-Europes” adjustment			2.336 0.697 $p = 0.001$		
YST-CS w/ migration adjustment				2.579 (0.816) $p = 0.002$	
YST-HO† w/ migration adjustment					5.651 (0.733) $p < 0.001$
Constant	19.726 (5.267) $p < 0.001$	53.163 (3.949) $p < 0.001$	44.771 (5.269) $p < 0.001$	48.441 (4.473) $p < 0.001$	17.424 (5.904) $p = 0.004$
# Obs.	112	112	112	112	112
R-squared	0.38	0.05	0.09	0.08	0.35

Table 5. Variants of Hibbs-Olsson regression 8.

† Series constructed by taking years-since-transition values without “neo-Europes” adjustment, as in Column 3, then adjusting for post-1500 migration as in Column 4.

Dep. Var. / Indep. Var.	$\text{Ln}(y_{1500}^{u})$	$\text{Ln}(y_{1500}^{u})$	$\text{Ln}(y_{1500}^{u})$	$\text{Ln}(y_{1500}^{b})$	$\text{Ln}(y_{1500}^{b})$	$\text{Ln}(y_{1500}^{b})$
YST-HO	0.022 (0.012) $p = 0.066$			0.042 (0.015) $p = 0.005$		
YST-CS		0.029 (0.008) $p = 0.001$			0.054 (0.010) $p < 0.001$	
YST-HO w/o "neo-Europes" adjustment			0.022 (0.007) $p = 0.002$			0.042 (0.008) $p < 0.001$
Constant	6.148 (0.099) $p < 0.001$	6.191 (0.043) $p < 0.001$	6.158 (0.055) $p < 0.001$	5.962 (0.124) $p < 0.001$	6.048 (0.050) $p < 0.001$	5.992 (0.064) $p < 0.001$
# Obs.	57	65	57	57	65	57
R-squared	0.06	0.15	0.17	0.13	0.33	0.34

Table 6. Predicting 1500 income by years since transition.

† Series constructed by taking years-since-transition values without "neo-Europes" adjustment, as in Column 3, then adjusting for post-1500 migration as in Column 4.

Dep. Var. Indep. Var.	$\text{Ln}(y_{1500}^{u})$	$\text{Ln}(y_{1500}^{u})$	$\text{Ln}(y_{1500}^{u})$	$\text{Ln}(y_{1500}^{b})$	$\text{Ln}(y_{1500}^{b})$	$\text{Ln}(y_{1500}^{b})$
Ln(Geography)	-0.002 (0.106) $p = 0.983$	0.034 (0.065) $p = 0.606$	-0.028 (0.082) $p = 0.733$	0.055 (0.135) $p = 0.686$	0.038 (0.075) $p = 0.617$	-0.082 (0.091) $p = 0.370$
YST-HO	-0.490 (0.332) $p = 0.146$			-0.223 (0.424) $p = 0.601$		
$(\text{YST-HO})^2$	0.033 (0.022) $p = 0.138$			0.016 (0.028) $p = 0.557$		
YST-CS		0.057 (0.032) $p = 0.085$			0.093 (0.037) $p = 0.017$	
$(\text{YST-CS})^2$		-0.003 (0.003) $p = 0.322$			-0.004 (0.004) $p = 0.257$	
YST-HO w/o "neo-Europes" adjustment			0.002 (0.015) $p = 0.917$			0.001 (0.017) $p = 0.05$
$(\text{YST " "})^2$			0.002 (0.002) $p = 0.179$			0.005 (0.002) $p = 0.015$
Constant	8.069 (1.437) $p < 0.001$	6.009 (0.252) $p < 0.001$	6.269 (0.304) $p < 0.001$	6.772 (1.835) $p = 0.001$	5.836 (0.290) $p < 0.001$	6.307 (0.338) $p < 0.001$
# Obs.	57	57	57	57	57	57
R-squared	0.11	0.18	0.20	0.15	0.36	0.42

Table 7. Predicting 1500 income by geography and years since transition.

† Series constructed by taking years-since-transition values without "neo-Europes" adjustment, as in Column 3, then adjusting for post-1500 migration as in Column 4.

Dep. Var. Indep. Var.	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1500}^{u})	Ln(y_{1500}^{b})
Statehist1500	1.132 (0.327) $p = .001$		0.239 (0.047) $p < 0.001$	0.385 (0.054) $p < 0.001$
Statehist1500 w/ migration adjustment		2.348 (0.314) $p < 0.001$		
Constant	7.596 (0.154) $p < 0.001$	6.949 (0.161) $p < 0.001$	6.226 0.025 $p < 0.001$	6.146 (0.029) $p < 0.001$
# Obs.	105	110	64	64
R-squared	0.10	0.34	0.30	0.46

Table 8. Predicting income of 1997 and 1500 with *statehist1500*.

Dep. Var. Indep. Var.	Ln(y_{1997})	Ln(y_{1997})	Ln(y_{1500}^{u})	Ln(y_{1500}^{b})
Ln(Geography)	2.112 (0.230) $p < 0.001$	1.550 (0.210) $p < 0.001$	-0.017 (0.058) $p = 0.764$	-0.010 (0.065) $p = 0.876$
Statehist1500	-1.167 (0.951) $p = 0.223$		0.663 (0.219) $p = 0.004$	0.937 (0.245) $p < 0.001$
(Statehist1500)^2	1.256 (1.099) $p = 0.255$		-0.524 (0.261) $p = 0.05$	-0.673 (0.292) $p = 0.025$
Statehist1500 w/ migration adjustment		2.316 (0.918) $p = 0.013$		
(statehist1500 w/ adjustment)^2		-1.379 (1.022) $p = 0.180$		
Constant	-0.068 (0.834) $p = 0.935$	1.352 (0.741) $p = 0.071$	6.274 (0.221) $p < 0.001$	6.157 (0.248) $p < 0.001$
# Obs.	105	110	56	56
R-squared	0.52	0.58	0.34	0.51

Table 9. Predicting income of 1997 and 1500 with geography and *statehist1500*.

Appendix 1. Years since transition according to Hibbs and Olsson and country-specific values.

Country	YST-HO	YST-CS
Argentina	6,151	3,800
Australia	9,847	400
Austria	9,847	6,500
Bangladesh	9,263	5,500
Belgium	9,847	5,500
Belize	5,882	3,300
Benin	4,958	3,100
Bolivia	6,151	4,000
Botswana	4,958	1,000
Brazil	6,151	3,500
Bulgaria	9,847	7,500
BurkinaFaso	4,958	2,900
Burundi	4,958	3,500
Cameroon	4,958	3,000
Cape Verde	4,958	538
Canada	9,847	1,500
CAfricanRepublic	4,958	3,000
Chad	4,958	2,700
Chile	6,151	4,000
China	9,263	9,000
Colombia	6,151	3,400
Comoros	4,958	2,000
CongoRep	4,958	3,000
CostaRica	5,882	2,500
Cote d'Ivoire	4,958	3,500
Czech Republic	9,847	6,500
Denmark	9,847	5,500
DomRepublic	5,882	1,500
Ecuador	6,151	4,000
Egypt	9,847	7,200
ElSalvador	5,882	3,000
Equatorial Guinea	4,958	3,000
Ethiopia	4,958	4,000
Finland	9,847	3,500
France	9,847	7,500
Gambia	4,958	3,000
Germany	9,847	6,000
Georgia	9,847	8,000
Ghana	4,958	3,500
Greece	9,847	8,500
Guatemala	5,882	3,500
Guinea	4,958	3,250
GuineaBissau	4,958	3,000
Haiti	5,882	1,000
Honduras	5,882	3,000
HongKong	9,263	5,000
Hungary	9,847	7,400
India	9,263	8,500
Indonesia	8,194	4,000
Ireland	9,847	5,000
Israel	9,847	10,500
Italy	9,847	8,000
Jamaica	5,882	1,000
Japan	9,263	4,500
Jordan	9,847	10,500
Kenya	4,958	3,500
KoreaRep	9,263	4,500
LaosPDR	9,263	6,000
Latvia	9,847	3,700
Lesotho	4,958	1,500
Luxembourg	9,847	5,500
Madagascar	4,958	2,000
Malawi	4,958	1,800
Malaysia	9,263	4,500
Mali	4,958	3,000
Malta	9,847	7,600
Mauritania	4,958	3,500
Mauritius	4,958	362
Mexico	5,882	4,100
Mongolia	9,263	5,000
Morocco	9,847	3,500
Mozambique	4,958	1,400
Namibia	4,958	1,250
Nepal	9,263	6,000
Netherlands	9,847	6,000
NewZealand	9,847	800
Niger	4,958	4,000
Norway	9,847	5,000
Pakistan	9,847	9,000
Panama	5,882	2,400
PapuaNewGuinea	8,194	4,000
Paraguay	6,151	4,000
Peru	6,151	4,300
Philippines	8,194	5,000
Poland	9,847	6,000
Portugal	9,847	6,500
Romania	9,847	7,500
Rwanda	4,958	2,500
Senegal	4,958	3,000
SierraLeone	4,958	3,250
Singapore	9,263	4,500
SlovakRepublic	9,847	6,500
SouthAfrica	4,958	1,700
Spain	9,847	7,200
SriLanka	9,263	5,000
Sudan	4,958	5,000
Swaziland	4,958	1,500
Sweden	9,847	5,500
Switzerland	9,847	5,500
Syria	9,847	10,500
Taiwan	9,263	5,500
Tanzania	4,958	2,500
Thailand	9,263	5,500
Togo	4,958	3,100
Tunisia	9,847	4,500
Turkey	9,847	10,000

Uganda	4,958	3,500	Uruguay	6,151	3,600
UK	9,847	5,500	Zambia	4,958	1,800
USA	9,847	3,500	Zimbabwe	4,958	1,400

Note: Assumes present = 2000 C.E. HO values computed using equation (3) in Hibbs and Olsson, 2004. The value for Europe/Middle East/N. Africa (9,847) is substituted for the original values for Canada, the U.S., Australia and New Zealand. Those original values are 4,958, 4,958 and -3,505 for the first three countries. The biogeography value for New Zealand is too low to generate a YST value using equation (3).