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Biogeographical conditions, the transition to agriculture and long-run growth

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Biogeographical Conditions, the Transition to Agriculture and Long-Run Growth

by

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Abstract

We use new data on the timing of the transition to agriculture, developed by Putterman and Trainor (2006), to test the theory of Diamond (1997) and Olsson and Hibbs (2005) that an earlier transition is reflected in higher incomes today. Our results confirm the theory, even after controlling for institutional quality and other geographical factors. The date of transition is correlated with prehistoric biogeography (the availability of wild grasses and large domesticable animal species). The factors conducive to high per capita incomes today are good institutions, an early transition to agriculture, access to the sea and a low incidence of fatal malaria. Geographical influences have been at work in all of these proximate determinants of per capita income.

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Keywords: agriculture, geography, growth, institutions



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1) Introduction

What explains why some countries are rich today and some poor? Research has established that the most important factor is the quality of a country's institutions (Acemoglu *et al.*, 2001; Hall and Jones, 1999; Rodrik *et al.*, 2004). Acemoglu *et al.* (2001) argue that better institutions evolved where Europeans chose to settle, which tended to be in areas where their mortality rate was lower. Using settlers' mortality as an instrument for institutional quality, they show that geography, as measured by latitude, has no independent effect on per capita incomes, once institutional quality is controlled for.

This view has been challenged by Sachs (2003) and Olsson and Hibbs (2005). Sachs shows that geographical factors remain significant if they are represented by an index of the risk of fatal malaria rather than by latitude. Rodrik *et al.* (2004) confirm this result, although in their view its significance is limited because malaria risk ceases to be statistically significant once a dummy for sub-Saharan Africa is included.

Our particular focus here is the contribution of Olsson and Hibbs (2005) [OH]. Inspired by the work of Diamond (1997), OH argue that countries endowed with favourable biogeography in prehistoric times, as indicated by a greater variety of domesticable large animals and wild grasses suitable for cultivation, made the transition to agriculture at an earlier date. An early transition gave these countries a lead in economic development that they have never entirely lost, contrary to the "reversal of fortune" argument of Acemoglu *et al.* (2002).¹ Although catching up with and overtaking other countries is possible, OH argue (p. 927) that "regions with a well-endowed natural environment, which consequently made the transitions to agriculture and industry comparatively early, should other things equal have higher per capita today than more poorly endowed regions where the transitions came later." They develop an index of biological conditions conducive to agriculture, and in the empirical section of their paper they show that this is strongly positively correlated with current per capita GDP and the date of transition to sedentary agriculture.²

¹ To be precise, Acemoglu *et al.* (2002) argue that the reversal of fortune applies only to ex-colonies and not to all countries. We return to this point later.

² Their index of biological conditions is the first principal component of two variables: the number of wild grasses with a mean kernel weight exceeding 10mg known to exist in prehistory, and the number of domesticable mammal species weighing more than 45g known to exist in prehistory.

This hypothesis suggests that geography works through history, by setting favoured countries on the path to development earlier. A limitation of OH's empirical work is that their dating of the transition to agriculture, which is based on Diamond (1997), is very imprecise and estimated only down to the regional level, as we discuss further below. Recently much more detailed estimates of the timing of this transition have been provided by Putterman and Trainor (2006), and these estimates differ quite substantially from those used by OH. Since the timing of the transition to sedentary agriculture is the crucial link in the Diamond-Olsson-Hibbs thesis, it is important to establish whether their theory is supported by the new data.

This is the issue which we address in this paper. First, we test whether the strong correlation between prehistoric biogeographical conditions and transition dates still holds with the Putterman-Trainor data. Then we test the second link in the argument, that current per capita income is correlated with the timing of the agricultural transition (OH do not actually test this, but only the correlation between prehistoric biogeography and current income). Third, we incorporate institutional quality along the lines of previous work, and we show that the time elapsed since the agricultural transition is a significant determinant of current per capita income even after controlling for institutions and other geographical variables. Fourth, we show that adding prehistoric biogeographical conditions to the regression does not improve the fit, indicating that the date of the agricultural transition is not simply acting as a proxy for some omitted geographical variable. In short, our findings are favourable to the Diamond-OH hypothesis. Finally, we consider whether the date of the agricultural transition is less significant for countries that were colonies for many centuries, as is implied by Acemoglu *et al.*'s (2002) argument that poorer colonies have overtaken initially richer ones because of their more "European" institutions.

The paper is organized in the following way. In Section Two we discuss the new data on the transition to sedentary agriculture and test the correlation of transition dates with biogeographical conditions at the time. In Section Three we introduce the model and data that we use to test the relationship between the date of the agricultural transition and current per capita income. Because of possible endogeneity of some of the independent variables, in Section Four we describe our empirical strategy in some detail. Section Five shows the main empirical results, whose robustness is tested in Section Six. In Section

Seven we consider the evidenc for a “reversal of fortune” amongst early colonies. The paper ends with a short conclusion.

2) Transition to Agriculture and Biogeography

The starting point of our paper is the availability of new data on the transition from a hunter-gatherer existence to sedentary agriculture. Putterman and Trainor (2006) have produced detailed estimates of the timing of the transition to sedentary agriculture in 163 countries, using as the criterion the point at which the calorific intake from domesticated plants and animals is estimated first to have exceeded 50%. These estimates are a great improvement on those used by OH, who ascribe the transition in 112 countries to one of only six dates, ranging from 9847 years ago (all of Europe) to 4960 years ago (all African countries). Moreover in the OH data “neo-European” countries (Australia, Canada, New Zealand and the USA) are rather arbitrarily ascribed the European transition date.

Table 1 shows some basic statistics relating to Putterman and Trainor’s estimates. As is well known, the earliest transition took place in the Middle East, on average almost 9000 years ago. African and Latin American countries experienced the most recent transition, almost 3000 years ago. The average West European and Asian country made the transition almost 5,500 years ago.

Table 1: Descriptive Statistics for the Transition to Agriculture

| Continent | Mean | Std. Dev. | Min | Max |
|----------------------|------|-----------|------|-------|
| Africa | 3001 | 1170 | 1000 | 7200 |
| Latin America | 3043 | 1078 | 800 | 4300 |
| Asia | 5600 | 1487 | 4000 | 9000 |
| Eastern Europe | 6500 | 1282 | 3700 | 8000 |
| Western + New Europe | 5450 | 2389 | 400 | 10000 |
| Middle East | 8820 | 1303 | 7500 | 10500 |

Notes: years before the present (source: Putterman and Trainor, 2006). New Europe is Australia, Canada, New Zealand and USA.

Table 2 compares the transition dates estimated by OH and Putterman and Trainor (2006) [PT]. Descriptive statistics for the OH measure of prehistoric biogeographical conditions are also shown. The mean year of the transition according to PT was 4800 years ago (4336 years ago for the countries covered by HO), compared to 7420 according to OH. The standard deviation are respectively 2440 and 2208.

Table 2: Descriptive Statistics for Transition Dates

| Variable | Countries | Mean | Std. Dev. | Min | Max |
|---|-----------|-------|-----------|-------|-------|
| Agricultural Transition (PT) | 163 | 4808 | 2440 | 362 | 10500 |
| Agricultural Transition (PT estimates; OH sample) | 108 | 4335 | 2325 | 362 | 10500 |
| Agricultural Transition (OH) | 112 | 7420 | 2208 | 4959 | 9846 |
| Prehistoric biogeography (OH) | 112 | 47.48 | 39.65 | 12.35 | 100 |

Notes: Agricultural transition is the years elapsed since the estimated date of transition; prehistoric biogeography is a measure of the number of species of domesticable large animals and wild plants. PT – Putterman and Trainor (2006); OH – Olsson and Hibbs (2005).

Table 3: Correlation Matrix

| | ln Agric (PT) | ln Agric (HO) | ln Biogeography |
|-----------------------------------|---------------|---------------|-----------------|
| ln Agricultural T. (PT) | 1 | | |
| ln Agricultural T. (Hibbs-Olsson) | 0.5767 | 1 | |
| ln Biogeography (Hibbs-Olsson) | 0.5468 | 0.9666 | 1 |

Table 3 shows the pairwise correlation between biogeography and the date of the transition to agriculture. The correlation between the OH and PT transition dates is only 0.58, which reflects the much more detailed character of PT's estimates. The correlation between the transition date and the index of biogeography is extremely high for the OH data, at 0.97, and rather lower for the PT data (0.55), but this is still highly significant ($t=6.66$). Thus the first stage of the OH hypothesis, that the agricultural transition was favoured by the availability of domesticable large animals and cultivable wild plant species, is still supported by the PT transition data.

3) Data and Model

The hypothesis which we wish to test in this paper is whether an earlier transition to agriculture has caused a lasting advantage in per capita income, once controls for the other deep determinants of the current level of development – the quality of institutions, geographical factors, and trade integration - are entered in the model. To put it another way, does the inclusion of the timing of the agricultural transition enable us to improve on the models estimated by Rodrik *et al.* (2004), who conduct rigorous econometric tests of the competing hypotheses?

The model which we estimate for a cross-country sample can be written as:

$$\text{Log}(y) = \alpha + \beta_1 AT + \beta_2 GEO + \beta_3 QI + \beta_4 TR + v \quad (1)$$

where AT represents the timing of the transition to sedentary agriculture, GEO represents one or more geographical factors, QI is a measure of the quality of institutions, TR represents openness to international trade, and y is income per capita on a purchasing power parity basis for the year 2000, estimates for which come from the World Bank's *World Development Indicators*. Equation (1) is similar in form to that estimated by Rodrik *et al.* (2004), but with the addition of the agricultural transition variable.

The variable AT is our measure of how long ago the transition to agriculture was estimated to occur, so a higher value represents an earlier transition. More precisely the variable is equal to the logarithm of the cumulative number of years before 2000 C.E. (A.D.) at which countries are supposed to have made the transition, as estimated by Putterman and Trainor (2006).

Geographical variables that have been used in cross-country growth analysis include a dummy for access to the sea, the proportion of a country that lies within the tropics, exposure to the risk of fatal malaria, latitude and European settlers' mortality (introduced by Acemoglu *et al.*, 2001). Geographical variables have a dual function in equations like (1), because at least one of them is invariably used as an instrument for institutional quality. Acemoglu *et al.* (2001) and Rodrik *et al.* (2004) use settlers' mortality for this purpose.

We replace settlers' mortality with latitude, since tests show that it is a superior instrument;³ the use of latitude as an instrument also avoids truncation of the sample through lack of settlers' mortality data for some countries. The geographical variables included in the regression are the risk of fatal malaria (the contribution of regionally dominant vector mosquitoes to the potential transmission intensity of malaria) as used by Sachs (2003) and a measure of access to the sea (the ratio of a country's continental shelf area⁴ to its surface area), which is similar to a dummy for sea access but allows for more variation across countries. Data on the continental shelf area are provided by Pruett and Cimino (2000) and published by the UNEP.

To proxy institutions we use two alternative indices. The first one is an index of property rights protection from Gwartney and Lawson (2006), as published by the Fraser Institute. The second measure, which is available for considerably more countries, is an index of the rule of law⁵ supplied by Kaufmann *et al.* (2005) and published by the World Bank. Finally, trade as a ratio of GDP at current prices is used as a measure of the openness of the country. Data are collected from Heston and Summers (2006) (PWT 6.2).

4) Empirical Strategy

Although in equation (1) geographical factors and the elapsed time since the transition to agriculture can reasonably be considered exogenous to current per capita income, the same cannot be said for institutions and trade integration. The problem is to find plausible instruments for these variables. Like Rodrik *et al.* (2004), we use the predicted trade shares estimated by Frankel and Romer (1999) [FR] as an instrument for openness to international trade. As already mentioned, we use latitude as an instrument for institutional quality.

³ Settlers' mortality tends to fail the Stock-Yogo test for weak instruments, implying that it is insufficiently correlated with institutional quality.

⁴ The shelf area is defined as "the extended perimeter of each continent and associated coastal plain, which is covered during interglacial periods such as the current epoch by relatively shallow seas (known as shelf seas) and gulfs. The shelf usually ends at a point of increasing slope (called the shelf break). The sea floor below the break is the continental slope. broad, relatively shallow submarine platform that forms a border to a continent"(Wikipedia).

⁵ "Rule of law combines several indicators that measure the extent to which agents have confidence in and abide by the rules of society. These include perceptions of the incidence of both violent and non-violent crime, the effectiveness and predictability of the judiciary, and the enforceability of contracts" (Kaufmann *et al.*, 2005).

Table 4: Pairwise Correlation Matrix

| | Open | Law | P. Rights | Agric. T | Shelf A. | Latit. | F.&R. Trade | Temper | Frost | Eurofrac | Wet |
|-----------------|---------|---------|-----------|----------|----------|---------|----------------|---------|---------|----------|--------|
| Openness | 1.0000 | | | | | | | | | | |
| Rule of Law | 0.2791 | 1.0000 | | | | | | | | | |
| Prop. Rights | 0.2787 | 0.8919 | 1.0000 | | | | | | | | |
| Agric. Transit. | 0.0856 | 0.0286 | 0.1141 | 1.0000 | | | | | | | |
| Shelf Area | 0.1664 | -0.0344 | 0.1328 | -0.0781 | 1.0000 | | | | | | |
| Latitude | 0.0991 | 0.5025 | 0.6611 | 0.3951 | -0.1326 | 1.0000 | | | | | |
| F.& R. Trade | 0.5625 | 0.1741 | 0.1770 | 0.0650 | 0.1921 | -0.0318 | 1.0000 | | | | |
| Temperature | -0.0672 | -0.3737 | -0.5415 | -0.3185 | 0.1223 | -0.8651 | 0.1714 | 1.0000 | | | |
| Frost Days | 0.0480 | 0.3042 | 0.4949 | 0.3115 | -0.0929 | 0.8140 | -0.1859 | -0.9526 | 1.0000 | | |
| Euro-Fraction | -0.0246 | 0.3437 | 0.1610 | -0.3337 | -0.0463 | -0.0369 | -0.0085 | 0.0415 | -0.0759 | 1.0000 | |
| Wet Days | 0.2613 | 0.1988 | 0.0748 | -0.1303 | 0.0753 | -0.0121 | 0.1223 | -0.1491 | 0.1188 | 0.3080 | 1.0000 |

In Table 4 we show the pairwise correlation between presumed endogenous variables and some of the possible instruments. Latitude has a stronger correlation with property rights and rule of law than any other variable. Measures of the share of population speaking English or other European languages (introduced by Hall and Jones, 1999, and used by Rodrik *et al.*, 2004, in some regressions) do not have a particularly large correlation with institutions. The FR predicted trade share is significantly correlated with trade openness. Consequently we use latitude as the main instrument for institutions and the FR predicted trade share as an instrument for integration. We show below that these variables pass the Stock-Yogo (2005) test for weak instruments. In the first-stage regressions, measures of institutions and trade integration are regressed on all the exogenous variables, and as a consequence our first stage regressions can be written as:

$$INST_i = \theta_i + \delta_1 Agric._i + \delta_2 Geo_i + \delta_3 FR. Trade_i + \delta_4 Latitude._i + \mu_i \quad (2)$$

$$OPEN_i = \eta_i + \lambda_1 Agric._i + \lambda_2 Geo_i + \lambda_3 FR. Trade_i + \lambda_4 Latitude._i + \varepsilon_i \quad (3)$$

5) Results

Table 5 reports ordinary least squares (OLS) results for equation (1), using property rights (Model 1) and the rule of law (Model 2) as the measure of institutional quality. The sample size is considerably larger when rule of law is used, but the results are fairly similar.

Institutional quality is easily the most significant variable, particularly in Model 2. An earlier transition to agriculture (AT) is associated with a higher current per capita income, and the effect is significant at the 0.01 level. In Models 3 and 4 we add fatal malaria risk as an explanatory variable. This index (originally called malaria ecology) was developed by Kizsewski *et al.* (2004) and measures “*the contribution of regionally dominant vector mosquitoes to the potential transmission intensity of malaria*”. It is not simply a measure of the probability of dying of malaria (which is likely to be affected by the quality of medical and other public services and therefore by per capita income), but attempts to capture the exogenous environmental component of this (Sachs, 2003, uses it as an instrument for malaria fatalities). Fatal malaria risk is highly (negatively) significant, and its inclusion reduces the estimated magnitude of the AT effect, although AT is still significant at the 5% level.

However, because OLS is not consistent in the presence of endogenous variables, we run the augmented Durbin-Wu-Hausman test to check whether institutions and trade are truly endogenous, using latitude and FR trade shares as the potential instruments. In this test, residuals from the first stage of two-stage least squares (2SLS) estimation are added to the OLS equations shown in Table 5, and the null of exogeneity is rejected if the fit significantly improves. The results suggest that there is a problem of endogenous regressors in all models except Model 4.

Accordingly in Table 6, we show the 2SLS estimates of the same equations, treating both institutions and openness as endogenous. Panel A of Table 6 shows the second-stage results, and Panel B shows the first-stage regressions for each endogenous variable, which indicate that latitude and FR trade shares are very strong instruments for institutional quality and trade openness respectively.

Table 5: OLS Estimates for the Income Level Model

| Dependent Variable: ln per capita Income (2000) PPP adjusted | | | | |
|--|---------------------|---------------------|-----------------------|-----------------------|
| ESTIMATION METHOD: OLS | COEFFICIENTS | | | |
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Institutional Quality (Property Rights) | 0.463*** (14.95) | | 0.382*** (13.00) | |
| Institutional Quality (Rule of Law) | | 0.978*** (22.98) | | 0.881*** (20.86) |
| Log Agricultural Transition Date | 0.295*** (3.47) | 0.245*** (3.83) | 0.190** (2.10) | 0.154** (2.37) |
| Shelf area/Surface Area | 0.0357** (2.03) | 0.0369*** (4.08) | 0.0568** (2.41) | 0.0494*** (2.68) |
| Log Openness | 0.222* (1.78) | 0.147 (1.49) | 0.285** (2.42) | 0.124 (1.36) |
| Malaria Risk | | | -0.0619*** (-8.44) | -0.0436*** (-7.03) |
| Constant | 2.544*** (2.72) | 5.782*** (8.01) | 3.820*** (4.20) | 6.793*** (9.76) |
| Endogeneity Test for Inst and Open. (p-values) | 0.0010 | 0.0338 | 0.0889 | 0.2369 |
| Endogeneity Test for Institutions (p-values) | | | | 0.1795 |
| Endogeneity Test for Openness (p-values) | | | | 0.2333 |
| Observations | 110 | 145 | 108 | 142 |
| Root MSE | 0.685 | 0.604 | 0.580 | 0.547 |
| R-squared | 0.67 | 0.74 | 0.77 | 0.79 |

1) Breusch-Pagan / Cook-Weisberg test for heteroscedasticity: $H_0 =$ Constant variance (p-values): 0.0018 for Model 1; 0.0000 for Model 2; 0.1113 for Model 3; and 0.0010 for Model 4.

2) Robust t-statistics in parentheses; *significant at 10%; **significant at 5%; *** significant at 1%

3) The endogeneity test is the Durbin-Wu-Hausman test of the significance of the first-stage residuals in the augmented OLS regression.

Table 6: 2SLS Estimates

| Dependent Variable: ln 2000 per capita income at PPP | | | | |
|--|--|---------------------|-----------------------|-----------------------|
| Independent variables | Model 1 | Model 2 | Model 3 | Model 4 |
| Institutional Quality (Property Rights) | 0.573*** (12.15) | | 0.443*** (10.38) | |
| Institutional Quality (Rule of Law) | | 1.172*** (12.74) | | 0.973*** (9.95) |
| Log Agricultural Transition Date | 0.269*** (3.17) | 0.171** (2.48) | 0.187** (2.12) | 0.134** (2.01) |
| Shelf Area/Surface Area | 0.0486** (2.17) | 0.0492*** (3.73) | 0.0639** (2.20) | 0.0506** (2.22) |
| Log Openness | -0.160 (-0.70) | -0.230 (-1.13) | 0.0082 (0.04) | -0.100 (-0.56) |
| Fatal Malaria Risk | | | -0.0553*** (-7.09) | -0.0392*** (-5.40) |
| Constant | 3.743*** (3.33) | 7.959*** (7.81) | 4.648*** (4.42) | 7.885*** (8.51) |
| Observations | 100 | 120 | 98 | 117 |
| Cragg-Donald F statistic | 25.94 | 41.77 | (24.90) | (25.60) |
| Stock-Yogo Critical Values for CD Statistic | (7.03) | (7.03) | 7.03 | 7.03 |
| Anderson canon. statistic ² | 43.58 | 37.88 | 42.39 | 44.38 |
| Hansen J statistic | 0.0000 | 0.000 | 0.0000 | 0.000 |
| Root MSE | 0.73 | 0.64 | 0.59 | 0.56 |
| R-Squared | 0.62 | 0.72 | 0.75 | 0.79 |
| Excluded Instruments | Latitude & Frankel-Romer trade shares. | | | |

1) The Anderson canon. corr. LR statistic is a likelihood-ratio test of whether the equation is identified. Under the null the model is under-identified. Test not robust to heteroscedasticity.

2) The Hansen J statistic is a test of overidentifying restrictions. The joint null hypothesis is that the instruments are valid instruments, and that the excluded instruments are correctly excluded from the estimated equation.

3) The figures in parentheses are robust *t*-statistics; *, **, ***: significant at 10, 5, and 1% respectively

Panel B: Firs- Stage Regressions

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 1 | Model 2 | Model 3 | Model 4 |
|-------------------------|----------------------|--------------------|---------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | Property Rights | Rule of Law | Property Rights | Rule of Law | Openness | | | |
| Agricultural Transition | -0.593*** (-2.71) | -0.153 (-1.29) | -0.546** (-2.01) | -0.101 (-0.72) | -0.015 (-0.27) | -0.035 (-0.68) | -0.008 (-0.12) | -0.035 (-0.59) |
| Continental Shelf area | 0.035 (1.60) | 0.031* (1.91) | 0.077 (0.89) | 0.090* (1.75) | 0.038*** (4.41) | 0.037*** (4.21) | 0.0428* (1.86) | 0.038* (1.70) |
| FR . Trade Share | 0.403** (2.02) | 0.240** (2.37) | 0.409** (2.06) | 0.234** (2.22) | 0.429*** (7.57) | 0.431*** (8.71) | 0.433*** (7.47) | 0.440*** (8.31) |
| Latitude | 0.088*** (9.55) | 0.043*** (8.97) | 0.086*** (8.44) | 0.040*** (7.56) | 0.002 (0.51) | 0.003 (1.08) | 0.013 (0.37) | 0.0016 (0.48) |
| Malaria Risk | | | -0.0067 (-0.43) | -0.013* (-1.91) | | | -0.0004 (-0.06) | -0.0062 (-1.02) |
| Constant | 7.359*** (3.96) | -0.430 (-0.42) | 7.016*** (3.03) | -0.716 (-0.59) | 3.076*** (7.30) | 3.214*** (7.83) | 3.017*** (5.82) | 3.251*** (6.66) |
| Partial R-squared | 0.54 | 0.50 | 0.47 | 0.41 | 0.35 | 0.36 | 0.35 | 0.36 |
| Shea Partial R-squared | 0.54 | 0.46 | 0.47 | 0.38 | 0.36 | 0.33 | 0.35 | 0.33 |

The figures in parentheses are robust *t*-statistics; *, **, ***: significant at 10, 5, and 1% respectively

Various test statistics indicate the adequacy of the instruments in Table 6. The Anderson statistic rejects the hypothesis of under-identification, while the Hansen J-statistic indicates

that the null of exact identification cannot be rejected. The Cragg-Donald F-statistic exceeds Stock and Yogo (2005) critical values for two endogenous variables, which confirms that instruments and endogenous variables are strongly correlated, providing consistent estimates in the second stage. The Shea partial R-squareds are also similar to the standard partial R-squareds from the first-stage regressions, which indicates that the instrument vectors are relatively uncorrelated.⁶

Compared to OLS estimates, the proxy for trade integration is the only variable which completely loses significance in the 2SLS models, although it keeps its sign. Our proxy for the elapsed time since the transition to agriculture is significant at a 1% level in Model 1 and at 5% in Models 2 to 4. Its coefficient suggests that a transition to agriculture 10% earlier is associated with a per capita income between 1.3% (Model 4) and 2.7% (Model 1) higher today. Although this sounds quite a small effect, it must be remembered that the dispersion of transition dates across countries is very wide.

The first-stage regressions (reported in Panel B) suggest a negative correlation between institutional quality and the transition to agriculture (significant for property rights but not rule of law). This negative correlation is consistent with Acemoglu *et al's* (2002) argument that the colonisation process resulted in a “reversal of fortune”, with poorer and less populated regions absorbing more European settlers and therefore having more “European” institutions. We return to this point later.

6) Further Analysis

The results in Tables 5 and 6 support the Diamond-OH hypothesis that an earlier transition to agriculture is associated with higher per capita incomes today. Since, as we have already seen, the timing of the transition to agriculture is correlated with prehistoric biogeography, this result may just reflect some omitted geographical influences. To test this, in Table 7 we add the OH prehistoric biogeography variable to the regression. If the true explanation for our previous results is an omitted geographical effect, it should outperform the agricultural transition variable.

⁶ If they were highly correlated, they would effectively little better than one instrument, in which case the model would be underidentified (Shea, 1996).

In Models 1 and 2 of Table 7 we first estimate a parsimonious version of Models 2 and 4 of Table 6, omitting the insignificant trade variable, which increases the number of observations, particularly in the case of the rule of law (to 143 instead of 120, and to 109 rather than 100 for property rights). The agricultural transition variable now has a slightly larger coefficient (and t -statistic) than in the equivalent regressions in Table 6. This is our reference model for the remainder of the paper.

When we add prehistoric biogeography (Models 3 and 4 of Table 7), its coefficient is statistically insignificant and negative, while the AT coefficient even becomes more positive. This suggests that the effect of prehistoric biogeography on current income does indeed work through the timing of the transition to sedentary agriculture, as the Diamond-OH hypothesis suggests.

Table 7: Adding Prehistoric Biogeography

| Dependent Variable: ln 2000 per capita GDP (PPP) | | | | |
|--|-----------------------|-----------------------|-----------------------|-----------------------|
| ESTIMATION METHOD: 2SLS | Model 1 | Model 2 | Model 3 | Model 4 |
| Institutional Quality (Property Rights) | 0.450*** (9.82) | | 0.509*** (5.09) | |
| Institutional Quality (Rule of Law) | | 1.032*** (8.66) | | 1.092*** (5.10) |
| Log Agricultural Transition Date | 0.208** (2.43) | 0.152** (2.31) | 0.305** (2.25) | 0.240* (1.87) |
| Shelf Area / Surface Area | 0.0654*** (2.84) | 0.0337 (1.48) | 0.0691*** (2.84) | 0.0494** (2.16) |
| Fatal Malaria Risk | -0.0551*** (-6.84) | -0.0375*** (-4.95) | -0.0582*** (-6.65) | -0.0386*** (-5.00) |
| Log Prehistoric Biogeography | | | -0.159 (-0.79) | -0.131 (-0.66) |
| Constant | 4.476*** (5.65) | 7.332*** (12.95) | 3.852*** (3.58) | 6.976*** (11.21) |
| Cragg-Donald F statistic | 57.70 | 33.00 | 17.14 | 11.53 |
| Stock-Yogo Critical Values for CD Statistic | (7.03) | (7.03) | (7.03) | (7.03) |
| Anderson LR statistic | 48.11 | 30.66 | 16.71 | 11.57 |
| Hansen J statistic | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Endogeneity test (p-values) | 0.2831 | 0.1909 | 0.4383 | 0.5121 |
| Root MSE | 0.59 | 0.55 | 0.60 | 0.53 |
| R-Squared | 0.75 | 0.78 | 0.76 | 0.82 |
| Observations | 109 | 143 | 89 | 106 |

Instrument: Latitude

1) See Notes to Table 6. Prehistoric Biogeography data are only available for 112 countries.

4) The figures in parentheses are robust t -statistics; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

We now perform some additional robustness checks. In Table 8 we use additional controls. First we include a dummy for oil producers. Many oil producers are located in the Middle East, the region with the earliest transition to agriculture, so it is possible that the positive effect of the transition to agriculture really captures the effect of oil producers.⁷

A second possibility is that AT is capturing the negative effect of ethnic diversity. Several authors, such as Easterly and Levine (1997), find a negative effect of ethnic diversity on growth, and African countries, which mostly had a late transition to agriculture, also tend to have high ethnic diversity. We use the ethno-linguistic fractionalization index of Fearon and Laitin (2003).

The third possibility that we entertain is that AT is just reflecting regional effects. To control for this we add dummy variables for Latin American and Africa countries.

Table 8 shows the results, first for property rights (Models 1 to 3), and then for the rule of law (Models 4 to 6). The dummy for oil producers has a significant positive coefficient, but the AT coefficient remains significantly positive (Models 1 and 4). Ethnic fractionalization is marginally significant for property rights and has a negative coefficient. The Latin America dummy is positive and significant, and the Africa dummy is negative and insignificant. With the regional dummies AT remains significant at the 5% level (Models 3 and 6). Only in Model 5 (ethnic fractionalization; rule of law) does AT cease to be significant at the 5% level, and ethnic fractionalization is highly insignificant in this regression, which suggests that this is the result of multicollinearity.

In summary, the finding that the agricultural transition date is positively correlated with current per capita incomes seems to be robust.

⁷ We use data from the International Energy Agency to identify oil producers.

Table 8: Robustness Checks

| Dependent Variable: ln 2000 Per Capita GDP (PPP) | | | | | | |
|--|----------------------|----------------------|---------------------|----------------------|----------------------|---------------------|
| ESTIMATION METHOD: 2SLS | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
| Institutional Quality (Property Rights) | 0.463*** (10.57) | 0.430*** (9.02) | 0.504*** (6.53) | | | |
| Institutional Quality (Rule of Law) | | | | 1.082*** (9.12) | 1.019*** (8.01) | 1.296*** (9.44) |
| Log Agricultural Transition Date | 0.192** (2.16) | 0.175** (2.12) | 0.200** (1.96) | 0.147** (2.01) | 0.139* (1.92) | 0.247** (2.21) |
| Shelf Area / Surface Area | 0.0656*** (2.79) | 0.0684*** (2.88) | 0.0633*** (3.03) | 0.0293 (1.19) | 0.0334 (1.44) | -0.122 (-1.38) |
| Malaria Intensity | -0.051*** (-5.96) | -0.044*** (-4.57) | -0.0226* (-1.76) | -0.032*** (-4.14) | -0.035*** (-4.71) | -0.00895 (-0.89) |
| Oil Producers | 0.300** (2.04) | | | 0.317** (2.34) | | |
| Ethnic Fractionalization | | -0.550* (-1.84) | | | -0.163 (-0.58) | |
| Latin America Dummy | | | 0.400* (1.69) | | | 0.712*** (3.14) |
| Africa Dummy | | | -0.460 (-1.63) | | | -0.160 (-0.73) |
| Constant | 4.445*** (5.39) | 5.030*** (6.39) | 4.154*** (3.248) | 7.292*** (11.61) | 7.498*** (11.60) | 6.433*** (6.51) |
| Cragg-Donald F statistic | 55.15 | 56.38 | 22.93 | 32.23 | 31.83 | 38.17 |
| Stock-Yogo Critical Values for CD Stat. | (16.38) | (16.38) | (16.38) | (16.38) | (16.38) | (16.38) |
| Anderson LR statistic | 46.62 | 47.46 | 22.10 | 30.17 | 29.84 | 35.21 |
| Hansen J statistic | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Endogeneity Test (p-values) | 0.1828 | 0.3603 | 0.1356 | 0.0689 | 0.1785 | 0.0000 |
| Root MSE | 0.58 | 0.57 | 0.56 | 0.56 | 0.55 | 0.62 |
| R-Squared | 0.75 | 0.77 | 0.77 | 0.78 | 0.78 | 0.72 |
| Observations | 107 | 107 | 109 | 140 | 140 | 134 |
| Instruments | | | Latitude | | | Climate Zone |

The figures in parentheses are robust *t*-statistics; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

7) A Reversal of Fortune?

As mentioned earlier, Acemoglu *et al.* (2002) [AJR] have suggested that countries that were subject to European colonisation after 1500 have experienced a “reversal of fortune”, with the poorer ones tending to have higher per capita incomes today than those that were rich in 1500. They argue that the quality of institutions established in the colonies reflected not just the disease environment, as reflected in settlers’ mortality (as they had previously argued in Acemoglu *et al.*, 2001), but also the tendency to establish “extractive institutions” in areas of high population density such as Meso-America. This argument suggests that any effect of the agricultural transition date on per capita income in these

countries that existed in 1500 has since been erased by what happened in colonial times. Consequently the relationship between the agricultural transition date and current per capita incomes should be much weaker for ex-colonies, or at least for those that were colonised many centuries ago.

To test this hypothesis we consider whether the AT coefficient varies across the sample. In results that are not shown, we found that there was no significant difference between ex-colonies and the rest. There is, however, a significant difference between early ex-colonies (those colonised before 1850) and the rest of the sample, as shown in Table 9. The regressions in Table 9 are Models 1 and 2 of Table 7, with the addition of a dummy that is equal to one for a country that was colonised before 1850, and zero otherwise, and this dummy multiplied by AT. The F-statistic shows that, in both cases (using either property rights or the rule of law as the measure of institutional quality), the null hypothesis that these two additional variables have zero coefficients can be rejected at the 5% level. Moreover in both cases, the estimated coefficient of AT for early colonies is only about 0.1, much smaller than in the rest of the sample (although not actually negative as the “reversal of fortune” hypothesis suggests).

Table 9: Testing for Differences in Early Colonies

| Dependent Variable: 2000 GDP per capita | | |
|---|-----------------------|-----------------------|
| ESTIMATION METHOD: 2SLS | Model 1 | Model 2 |
| Institutional Quality (Property Rights) | 0.483*** (7.22) | |
| Institutional Quality (Rule of Law) | | 1.112*** (8.13) |
| Log Agricultural Transition Date (AT) | 0.488*** (2.69) | 0.384*** (3.18) |
| EC Dummy * AT | -0.372 (-1.40) | -0.276 (-1.48) |
| Shelf Area | 0.0293 (1.18) | -0.00191 (-0.07) |
| Fatal Malaria Risk | -0.0391*** (-3.80) | -0.0247*** (-2.80) |
| Pre-1850 Colonisation Dummy (EC) | 3.396 (1.58) | 2.592* (1.71) |
| Constant | 1.777 (1.11) | 5.257*** (5.00) |
| Endogeneity Test | 0.2109 | 0.0906 |
| Cragg-Donald F-Statistic | 36.27 | 26.73 |
| Stock-Yogo Critical Values for CD Statistic | (16.38) | (16.38) |
| Anderson LR-Statistic | 33.162 | 25.660 |
| Hansen J-Statistic | 0.0000 | 0.000 |
| F-test (EC & EC*AT coeffs=0) (<i>p</i> -value) | 0.0373 | 0.0143 |
| Root MSE | 0.57 | 0.56 |
| R-Squared | 0.76 | 0.78 |
| Observations | 109 | 143 |

Robust *t*-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

If the agricultural transition date can be taken as an index of development in pre-colonial times, then the “reversal of fortune” hypothesis suggests that institutional quality should be negatively correlated with it, at least for the early colonies. Table 10 shows regressions for institutional quality in the entire sample, allowing the AT coefficient to vary first between all ex-colonies and the rest (Models 3 and 4), and then between early colonies and the rest (Models 5 and 6). In neither case is there evidence of a significant difference in the AT coefficient across the sample. There tends to be a negative relationship between AT and institutional quality, but not a statistically significant one, and what stands out is the strong relationship between institutional quality and latitude.

These results are only partially supportive of AJR’s argument. Assuming that AT can be taken as an index of pre-colonial development, there is no evidence of the predicted strong

negative correlation with institutional quality, even for early colonies, and, although for per capita GDP the AT effect is much smaller in early colonies, it does not have the negative sign that the “reversal of fortune” thesis would suggest.

Table 10: Determinants of Institutional Quality

| OLS ESTIMATES | | | | | | |
|-------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | Model 1 | Model 3 | Model 3 | Model 4 | Model 5 | Model 6 |
| Dependent Variables: | Property R. | Rule of Law | Property R. | Rule of Law | Property R. | Rule of Law |
| Log Agr. Transition Date (AT) | -0.316 (-1.07) | -0.186 (-1.38) | -0.624* (-1.82) | -0.235 (-1.45) | 0.0767 (0.18) | -0.223 (-1.31) |
| AC Dummy * AT | | | 0.128 (1.58) | 0.0437 (1.43) | | |
| EC Dummy * AT | | | | | -0.959* (-1.68) | 0.115 (0.44) |
| Shelf Area | 0.141 (1.55) | 0.147* (1.74) | 0.127 (1.28) | 0.147* (1.69) | 0.0747 (0.73) | 0.154* (1.78) |
| Latitude | 0.0725*** (6.84) | 0.0304*** (5.78) | 0.0708*** (4.66) | 0.0329*** (4.18) | 0.0640*** (5.36) | 0.0317*** (5.24) |
| Fatal Malaria Risk | -0.0107 (-0.69) | -0.0111 (-1.55) | -0.00690 (-0.44) | -0.00944 (-1.37) | -0.0159 (-0.78) | -0.00973 (-1.20) |
| Ex-Colony Dummy (AC) | | | -1.297* (-1.70) | -0.258 (-0.70) | | |
| Early Colony Dummy (EC) | | | | | 7.507 (1.58) | -0.862 (-0.40) |
| Constant | 6.501*** (2.72) | 0.634 (0.59) | 9.202*** (2.97) | 0.900 (0.59) | 3.556 (0.99) | 0.887 (0.66) |
| F-test (p-values) | | | 0.2333 | 0.7956 | | |
| F-test (p-values) | | | | | 0.0987 | 0.8074 |
| Observations | 111 | 153 | 111 | 153 | 111 | 153 |
| Root MSE | 1.45 | 0.85 | 1.44 | 0.85 | 1.43 | 0.85 |
| R-squared | 0.45 | 0.31 | 0.45 | 0.32 | 0.47 | 0.31 |

Robust *t*-statistics in parentheses: * $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; the null for the F-tests is that the two additional variables (relative to Model 1 or 2) have zero coefficients.

8) Conclusions

We have tested the Diamond-Olsson-Hibbs hypothesis that prehistoric biogeography determined the date of the transition to sedentary agriculture and thereby still influences per capita incomes today, using the rich data set on the timing of the transition provided by Putterman and Trainor (2006). We confirm both elements of the hypothesis: the correlation between prehistoric biogeography and the transition to agriculture, and between

the timing of the transition to agriculture and current per capita incomes. Our results are robust to alternative measures of institutional quality and of geographical factors, and to the inclusion of regional and other dummies. There is a significantly weaker correlation between the timing of the agricultural transition and per capita income in early colonies, which is consistent with the Acemoglu *et al.* (2002) argument that the colonisation process led to faster development in the poorer regions, although we do not find evidence of an actual “reversal of fortune”. An early transition to agriculture is not associated with better institutions, which are strongly correlated with latitude but little else.

Data Appendix

| <i>Variable</i> | <i>Source</i> |
|---|---|
| Cumulative Years Since the Transition to Agriculture | Putterman and Trainor (2006) www.econ.brown.edu/fac/Louis_Putterman |
| Prehistoric Bio-geographical Conditions | Olsson and Hibbs (2005) www.douglas-hibbs.com |
| Rule of Law | Kaufman et al. (2005) www.info.worldbank.org/governance/wgi/index.asp |
| Property Rights | Gwartney and Lawson (2006) www.freetheworld.com |
| Latitude, Population Share Speaking European Languages, Fatal Malaria Risk. | Sachs (2003) http://www.earth.columbia.edu/articles/view/1040 |
| Continental Shelf Area | Pruett and Cimino (2000) www.unep.org/GEO/geo3/ |
| Ethnic Fractionalization | Fearon and Laitin (2003) www.stanford.edu/~jfearon/ |
| Oil Producers | International Energy Agency www.esds.mcc.ac.uk/wds_ia/ |
| Years of Colonisation | World Statesmen.org www.worldstatesmen.org |
| GDP per Capita (2000) (PPP adjusted) | World Bank. (World Development Indicators) www.esds.mcc.ac.uk/wds_wb/ |
| Trade at Current Prices | Heston and Summers (2006) (Penn World Table 6.2) www.pwt.econ.upenn.edu |
| Frankel and Romer Trade Shares | Frankel and Romer (1999). Appendix to the Paper. |
| Average Temperature, Frost Days and Wet Days | Mitchel et al. (2003). www.cru.uea.ac.uk/cru/data/hrg |

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