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Institutions and parameter heterogeneity

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Abstract

The role of institutions has taken center stage in the empirical growth literature recently, with many innovative approaches and suggestive results. Most of the previous literature has focused on the direct correlation between institutions and growth or its determinants. In this paper, I investigate the indirect effect that institutions may have on growth through parameter heterogeneity. In particular, the quality of a country's institutions could affect the relationship between growth and its other determinants, such as human and physical capital accumulation, geography, and government policies. After allowing for several types of nonlinearities, the results are generally supportive of Glaeser et al. [Glaeser, E.L., La Porta, R., Lopez-de-Silanes, F., Shleifer, A., 2004. Do institutions cause growth? Journal of Economic Growth, 9 (3), 271–303] in that most of their preferred measures of institutions are not correlated with growth. However, there is some evidence that institutions do matter for policy variables, particularly those associated with trade policy.

JEL classification: O1; O4

Keywords: Institutions; Parameter heterogeneity; Economic growth

1. Introduction

The empirical relationship between "institutions" and economic growth has received a good deal of attention lately. The primary contribution of much of the early literature was new measures of institutions – such as the strength of property rights, the degree of

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political freedoms, or the extent of judicial review of legislation – which were generally entered linearly into a typical growth regression.[1] However, much of this early literature was clouded by issues of causality: although researchers were primarily interested in the effect of institutions on growth, this effect was difficult to identify given that growth generally leads to improved institutions. More recent work has turned to the use of instrumental variables to isolate the effect of institutions on growth. Most famously, Acemoglu, Johnson, and Robinson (AJR) (2001, 2002) use settler mortality and indigenous population density in the year 1500 to instrument for institutional quality: where settlers could thrive, they established strong institutions; elsewhere, they concerned themselves primarily with resource extraction. Relying on instrumental variables, Acemoglu et al. show a strong causal effect of institutions on growth. Rodrik et al. (2004) also use the settler mortality instrument for institutions, and compare it in importance to trade (also instrumented) and geography, finding a much stronger role for institutions than for geography or trade.[2]

Of course, no matter how creative and high-performing instruments are, they are open to criticism. Glaeser et al. (2004, p. 289) criticize the validity of the AJR instruments: "it is far from clear that what the Europeans brought with them when they settled is limited government...what they brought with them is themselves, and therefore their know-how and human capital...."

Glaeser et al. (2004) also criticize most of the commonly used measures of institutions as measuring outcomes rather than institutional constraints (e.g., a country ruled by a dictator who freely chooses good policies should not be ranked as having good institutions). Furthermore, since growth tends to enhance the quality of institutions, Glaeser et al. (2004) argue that many recent measures of institutions, which are only available for the late 1990s, exacerbate concerns about causality when growth is measured over a period starting in 1960.

To address their concerns, I rely primarily on a variable measuring a country's level of executive constraints in 1960 (the beginning of the sample period) as the measure of institutions. One of the key findings of Glaeser et al. (2004) is that this variable is not generally correlated with growth, controlling for other factors that affect growth. Specifically, they argue that human capital is a more significant determinant of growth than institutions, once institutions are measured properly.

In this paper, I take a slightly different approach. It seems that one of the fundamental ways in which "institutions matter" is by affecting the relationship between economic growth and its determinants: e.g., our theories about how human capital affects a country's growth rate depends on institutions within the country being sufficiently strong. In other words, a country's quality of institutions affects how efficiently that country is able to use its factors of production.

In the current empirical literature on institutions and growth, measures of institutional quality are generally included as an additional explanatory variable within a (parameter-

[1] A notable exception to this approach is Eicher and Leukert (2006), in which the authors examine parameter heterogeneity on measures of institutions across OECD and non-OECD subsamples. Using political institutions as instruments for economic institutions, under a "hierarchy of institutions hypothesis," they conclude that institutions matter significantly more in the non-OECD subsample than in the OECD subsample. Their paper differs from this one in that the primary concern here is whether institutions affect the relationship between growth and factors of production; Eicher and Leukert (2006) allowed for a direct effect of institutions on growth.

[2] Persson and Tabellini (2005) employ a variety of econometric approaches to identify the causal effects of electoral rules and presidential vs. parliamentary democracy on economic outcomes. See Acemoglu (2005) for a detailed review.

invariant) linear regression specification. As pointed out previously (e.g., Durlauf et al., 2001), this approach imposes strong homogeneity assumptions: all countries are assumed to have identical aggregate production functions, into which institutions enter linearly as affecting the technical efficiency of production. However, it seems that a more realistic treatment of institutions involves a model in which countries have distinct aggregate production functions, and a country's institutions alter the fundamental production processes of the country (as opposed to simply representing an additive component of the growth process).[3]

Treating institutions as indexing the aggregate production function is not an innocuous assumption, as it suggests that institutions introduce nonlinearities and parameter heterogeneity into the empirical model. Interest in parameter heterogeneity in growth regressions was originally sparked by contributions to growth theory such as Azariadis and Drazen (1990), which suggests the possibility of threshold effects and multiple growth regimes. Following such theory, researchers have typically looked for nonlinearities with respect to the level of "development" in a country, identifying subsamples by indexing on per capita income or literacy rates (e.g., see Durlauf and Johnson, 1995; Desdoigts, 1999; Durlauf et al., 2001).[4] In contrast, in this paper, I investigate the possibility that such thresholds depend on the level of a country's institutions. I use both exogenous and endogenous sample splitting techniques, and allow both for the "deep" parameters of the aggregate production function (i.e., those associated with human and physical capital accumulation, development levels, and geography) and policy parameters to vary with institutional quality. I do not find much evidence of an institutional effect on the "deep" parameters, but do uncover threshold effects in the relationship between policy variables, particularly those associated with trade policy, and growth.

In Section 2, I investigate the relationship between institutions and growth through production functions based on growth fundamentals: development levels, geography, and human and physical capital accumulation. I allow for parameter heterogeneity by introducing interaction terms into the regression specification, and by sample splitting. In Section 3, I focus on the interaction between institutions and policy variables. Section 4 concludes.

2. Institutions and growth fundamentals

Much of the empirical literature on the role of institutions in economic growth has focused on the direct effects on growth of improving institutions such as the protection of property rights and the rule of law.[5] My interest here is on the indirect effect of insti-

[3] This approach is consistent with recent research, such as Caselli and Coleman (2006) and Hansen and Prescott (2002), which explain cross-country income differences and growth patterns as emerging from distinct production processes. Such an approach is also more consistent with the historical view of institutions as affecting the choice of technology and production processes within a country (e.g., see the treatment of institutions in North, 1990).

[4] Other variables introduced as indexing variables – in some cases, in addition to levels of development – include democracy (Minier, 1998), financial development (Minier, 2003), trade openness (Papageorgiou, 2002), and mortality rates (Chakraborty et al., 2006).

[5] In addition, some papers such as Rodrik et al. (2004) investigate the indirect effects of institutions on growth through the (direct) effects of institutions on the "deep" determinants of growth, such as physical and human capital accumulation and productivity growth.

tutions on growth through parameter heterogeneity: in particular, parameter heterogeneity on factors of production such as investment in human and physical capital, geography, and development (as opposed to parameter heterogeneity on the institutions variable itself).

Generally, the empirical growth literature is loosely based on the neoclassical growth model of Solow (1956) and Swan (1956). The textbook version assumes a constant-returns Cobb–Douglas production function:

$$Y_i = A_i K_i^{\alpha} H_i^{\beta} L_i^{1-\alpha-\beta} \tag{1}$$

where Y represents output, and K, H, and L represent stocks of physical capital, human capital, and labor, respectively. The technology parameter, A, represents a set of country-specific factors (e.g., climate) that can affect productivity. The traditional approach in the empirical literature on growth and institutions is to include a measure of institutional quality in a linearly additive term to a conventional growth regression:

$$g\_Y = \beta_z \mathbf{Z} + \beta_I I + \eta \tag{2}$$

where I is a measure of the quality of institutions and $\mathbf{Z}$ is a set of control variables (following theory, $\mathbf{Z}$ typically includes, at a minimum, initial income, physical capital investment and human capital investment). This approach can be justified theoretically by assuming that A is a linear function of institutional quality (see Durlauf and Quah, 1999 for a discussion). However, the literature on institutions suggests a more complex relationship between institutions and growth. For example, North (1990, p. 65), writes that:

> We have only to contrast the organisation of production in a Third World economy with that of an advanced industrial economy to be impressed by the consequences of poorly defined and/or ineffective property rights. Not only will the institutional framework result in high costs of transacting in the former, but also insecure property rights will result in using technologies that employ little capital and do not entail long-term agreements...

Thus, according to North, institutions affect not only the efficiency of production, but also the technology employed. This suggests the possibility of some type of threshold levels of institutional quality that must be met before different technologies can be employed. Specifically, it suggests the possibility that institutions should be viewed as a variable that indexes the aggregate production function:

$$\begin{aligned} Y_i &= A_i K_i^{\alpha_0} H_i^{\beta_0} L_i^{1-\alpha_0-\beta_0} \quad \text{if } I_t < I_0 \\ Y_i &= A_i K_i^{\alpha_1} H_i^{\beta_1} L_i^{1-\alpha_1-\beta_1} \quad \text{if } I_t \geqslant I_0 \end{aligned} \tag{3}$$

where the coefficients α_i and β_i vary with the underlying institutional state I_t. The quantity I_0 thus represents a threshold level of institutional quality that must be achieved to exploit the new level of technology. This is closely related to Bernard and Jones (1996), who assume that countries are indexed by their ability to adopt new technology. (They do not, however, explicitly attribute the source of these differences, which here is institutional quality.) This assumption is reasonable, as the cross-country data on output, factor inputs and factor prices is consistent with countries differing in their aggregate production

functions (not simply in levels of technical efficiency).[6] Differences in social capability (affected by institutions) across countries could determine the countries that are able to adopt and benefit from new technologies. Hansen and Prescott (2002), for example, postulate the existence of multiple aggregate production functions to explain historical growth patterns, and conjecture that institutions have been a key factor in explaining the timing of a transition to a new production function.

For the purpose of growth empirics, the treatment of institutions as indexing the aggregate production function is important, as it implies the presence of multiple growth regimes and thus parameter heterogeneity (for a more detailed discussion, see Durlauf and Quah, 1999). In this paper, I look for nonlinearities in the growth regression induced by differences in institutions across countries.

2.1. Exogenous thresholds

As a base regression, I estimate the following:

$$\begin{aligned} \mathrm{GR}_{1960\text{–}2000} = {} & \beta_0 + \beta_1 \cdot \ln \mathrm{GDP}_{60} + \beta_2 \cdot \ln \mathrm{INV}_{6065} + \beta_3 \cdot \ln \mathrm{SCHOOL}_{60} \\ & + \beta_4 \cdot \mathrm{TEMP} + \beta_5 \cdot \mathrm{EXEC}_{60} + u \end{aligned} \tag{4}$$

where the dependent variable is growth in per capita GDP 1960–2000, and the explanatory variables include initial GDP per capita, investment/GDP ratio averaged over 1960–1965, initial schooling, the percentage of the population that lives in temperate climate zones (measured in 1995), and a measure of the initial level of constraints on the executive branch, taken from Jaggers and Marshall (2000).[7] Glaeser et al. (2004) argue that executive constraints more adequately measure what is meant by "institutions" than do many of the other commonly used variables. They also demonstrate that economic growth tends to improve many institutions, increasing the importance of using initial values of the institutional measures.

The regression estimates appear as regression 1 in Table 1. With the exception of the coefficient estimate on the executive constraints variable, all of the estimates are statistically significant and of the predicted signs.[8] This finding is important, in that it suggests that institutions are not as important for growth as many studies have found, once institutions are measured appropriately (measuring institutional constraints, rather than outcome variables, and measuring the variable at the beginning of the period). However, another possible interpretation is that institutions may not be treated correctly in Regression 1, which allows only for a direct, linear effect on growth.

As an initial look at nonlinearities, I allow the explanatory variables in Eq. (4) to vary depending on the level of initial executive constraints. Regression 2 of Table 1 includes interaction terms between each of the regressors and a dummy variable equal to one if

[6] See, for example, Caselli and Coleman (2006).

[7] The executive constraints variable is described in the original documentation as the "operational (de facto) independence of the chief executive."

[8] This is the regression of Glaeser et al. (2004) with the addition of investment; their data are provided on Rafael La Porta's website in an exceptionally clear format. Their point estimates are very similar; they also fail to find a statistically significant coefficient estimate for executive constraints.

Table 1
Growth regressions 1960–2000

Variable	(1) $\hat{\beta}$ (s.e.)	(2) $\hat{\beta}$ (s.e.)
$\ln GDP_{60}$	−0.020 (0.003)***	−0.016 (0.005)***
$\ln INVEST_{6065}$	0.007 (0.003)***	0.006 (0.005)
$\ln SCHOOL_{60}$	0.008 (0.003)***	0.003 (0.008)
TEMPERATE	0.024 (0.005)***	0.019 (0.007)***
EXEC60	0.001 (0.001)	−0.001 (0.001)
$X_1 \times \ln GDP_{60}$		−0.003 (0.003)
$X_1 \times \ln INVEST_{6065}$		0.002 (0.006)
$X_1 \times \ln SCHOOL_{60}$		0.005 (0.008)
$X_1 \times$ TEMPERATE		0.004 (0.008)
Constant	0.141 (0.023)***	0.139 (0.023)***
Observations	57	57
R^2	0.594	0.609

Notes to table: The dependent variable is the growth rate of GDP per capita 1960–2000. Robust standard errors are shown in parentheses; R^2 is adjusted R^2. ***Indicates statistical significance at the 99% level or better; **at 95%; and *at 90%. The variable X_1 is an indicator variable equal to one if the country's level of executive constraints is equal to or less than the median. See Appendix A for variable definitions and sources.

the observation has executive constraints at or below the median value (on a 7-point scale, the median in this sample is 5; higher numbers indicate a more constrained executive).[9] Since the hypothesis is that a country's institutions need to be of a sufficient quality in order for, say, increases in human or physical capital to generate increased growth, the coefficient estimates on the interaction terms are expected to be negative. In fact, none of the interaction terms is statistically different from zero, and only the estimates on climate and initial GDP remain statistically significant. From Table 1, there is not much evidence that institutions affect growth indirectly, in the sense of affecting the parameters of the aggregate production function. In Section 3, I discuss whether institutions may have such an interactive effect on policy variables.

2.2. Endogenous sample splitting

However, splitting on the median value of initial executive constraints is an ad hoc approach to investigating potential parameter heterogeneity. To address this possibility more completely, I use a semiparametric sample splitting procedure known as a regression tree, which allows for the endogenous determination of subsamples into an unknown number of sample splits, based on multiple control variables.[10] An alternative would be the threshold regression of Hansen (2000); the primary advantage of the regression tree is that it allows for any number of variables to be considered as "split variables" that separate the full sample into subsamples.

The regression of interest is:

[9] Results in Table 1 are not changed by splitting the sample at other feasible points.

[10] See Breiman et al. (1984) and Härdle (1990) for more complete discussions of regression tree analysis. Other applications in a growth context include Cooper (1998), Durlauf and Johnson (1995), and Minier (1998, 2003).

$$\mathrm{GR}_{1960\text{–}2000} = \beta_0 + \beta_1 \cdot \ln \mathrm{GDP}_{60} + \beta_2 \cdot \ln \mathrm{INV}_{6065} + \beta_3 \cdot \mathrm{SCHOOL} + \beta_4 \cdot \mathrm{TEMP} + u \tag{5}$$

This is Eq. (4), excluding executive constraints as an explanatory variable; the hypothesis here is that the level of executive constraints affects the relationship between growth and the exogenous variables, rather than affecting growth directly: i.e., executive constraints affect the parameters of the aggregate production function, rather than entering as a separate input. The set **S** of potential split variables (that is, the variables used for sorting the sample into subsamples) includes: initial GDP per capita, initial schooling, investment, the percentage of the population that lives in temperate zones, and three measures of institutions from Glaeser et al. (2004): the average of the ranking of executive constraints 1960–2000; a measure of whether legislators were elected by a plurality system; and a measure of whether elections followed proportional representation.[11] All variables are defined more completely in Appendix A.

Since it is unclear which of these measures best captures "institutions" in the sense of determining parameter heterogeneity, including all of them allows their relevance to be endogenously determined. Including the other variables (initial GDP as a measure of overall economic development, initial schooling as a measure of human capital, and the percentage of the population living in temperate climates as a measure of geography) allows for institutions to be tested against these variables as potential split variables.[12]

The procedure is as follows. For each proposed split variable $s \in \mathbf{S}$, the observations are indexed by s, and all possible binary data splits based on s are examined. For each split, the regression (5) is estimated on each subsample, and the sum of squared residuals over both subsamples is computed. This procedure is repeated for each possible split variable s; the data split that minimizes the total sum of squared residuals is considered the first split of the data. This process is repeated on each of the subsamples until the data cannot be split further. (Note that, for each split, all potential split variables are considered.)

At this stage, the tree is likely to be overparameterized, since there has been no cost to introducing further splits. The tree is "pruned" to determine the best specification, in the sense of minimizing total sum of squared residuals. First, starting with the fully divided specification, terminal splits that decrease total error variance by the smallest amount are sequentially eliminated.[13] This results in a series of trees, from the OLS full-sample regression (with no splits) to the full tree identified by the original procedure (in which no subsample can be split further).

A cross-validation procedure is used to select the final specification. For each of the trees identified in the procedure above, the total sum of squared residuals across all subs-

[11] Two additional measures of institutions considered by Glaeser et al. (2004) – measuring the extent of judicial independence and constitutional review of legislation – are excluded as split variables since they reduce the sample size by 16 observations, to 54. The regression tree on the smaller sample allowing for splits based on judicial independence and constitutional review does not identify any splits based on these two variables. In addition, I exclude the subjective/outcome measures included in Glaeser et al. (2004): government effectiveness, degree of autocracy, and risk of expropriation. Executive constraints are averaged over the sample to preserve the larger sample size.

[12] Previous regression tree analyses such as Durlauf and Johnson (1995), Minier (1998) confirm the importance of GDP per capita as a potential split variable. Note that each variable is considered for every possible split, so each measure of institutions is tested against GDP.

[13] Terminal splits are those splits in which the resulting subsamples are not split further.

Table 2
Growth regression: sample split by regression tree

	(1)	(2)	(3)
Executive constraints:		Low	High
lnGDP60	−0.012 (0.002)	−0.010 (0.005)	−0.016 (0.003)
lnINV	0.007 (0.002)	0.004 (0.004)	0.002 (0.003)
lnschool60	0.006 (0.002)	0.005 (0.003)	0.005 (0.002)
Temperate	0.018 (0.004)	0.016 (0.009)	0.023 (0.004)
Constant	0.085 (0.016)	0.067 (0.033)	0.128 (0.020)
Observations	70	20	50
R^2	0.505	0.454	0.527

Notes to table: The dependent variable is log growth of GDP per capita, 1960–2000. Conventionally estimated standard errors appear in parentheses; they are heteroskedasticity-consistent in Regression 1. The three subsamples are identified by the regression tree procedure described in the text; the split on executive constraints occurs at a level of 3.24 (scale of 1–7, with 7 representing the highest level of constraints). Data source: Glaeser et al. (2004). Countries in each subsample are listed in Appendix B.

amples is computed using the "leave-one-out" method.[14] The tree with the smallest cross-validated sum of squared residuals is selected as the final specification; it yields the piecewise linear approximation that converges in mean squared error to the best nonlinear predictor.[15] Note that the full-sample OLS specification is tested against the identified splits; if the relationship is linear, the regression tree procedure does not force a nonlinear specification on the data.

Here, the pruning process selects a tree with two subsamples. The only split in the (endogenously selected) most preferred specification is based on the ranking of executive constraints. Recall that this split was also considered against splits based on any level of GDP, schooling, population in temperate zones, and the other measures of institutional quality;[16] also, this split was preferred by the pruning procedure to other specifications, including OLS on the full sample.

Regression 1 of Table 2 presents the regression on the full 70-country sample; regressions 2 and 3 represent the subsamples selected by the regression tree procedure. Regression 2 includes the countries with lower levels of executive constraints, while regression 3 includes the countries with higher levels.[17]

Interestingly, given that the regression tree procedure preferred this split to the full sample regression, the coefficient estimates across the subsamples are not markedly different between the countries with the "better" institutions (regression 3), and those with lower executive constraints (regression 2).[18]

[14] That is, for each subsample, the residual for each observation i is based on the predicted value of observation i from the regression estimated on all subsample observations other than i.

[15] See Breiman et al. (1984).

[16] However, splits are identified sequentially, and only binary splits are considered.

[17] The split on executive constraints occurs at a level of 3.24, on a scale from 1 to 7 where higher numbers indicate more constraints. Kenya is the country with executive constraints ranked as 3.24.

[18] Asymptotic theory that would allow for a statistical test of the difference between the regressions does not exist; however, it is highly unlikely that such a test would uncover differences in this case, given the magnitudes of the estimates and standard errors. In addition, although the split presented results in the lowest cross-validated sum of squared residuals of any possible split (including no split), OLS on the full sample is preferred under the more restrictive 1-SE criterion for selecting the final tree.

What can we conclude from Table 2 about whether institutions matter for growth? On the one hand, the level of executive constraints was selected as a split variable – over variables such as initial GDP and education, which have previously been found to endogenously determine growth regimes – suggesting that it may have some indirect effects on the aggregate production function. However, there is no consistent difference between the parameter estimates of the low-executive-constraint countries (regression 2) and those with higher levels of executive constraints. Thus, it is difficult to conclude that there is much evidence that institutions affect growth indirectly by altering the relationship between growth and schooling, investment, initial GDP, or the percentage of the population in a temperate climate. In the following section, I turn to the possibility that institutions matter through their effects on policies, rather than on "deeper" determinants of growth.

3. Institutions and policy variables

In the previous section, I found little evidence that institutions affect the underlying aggregate production function through the parameters on capital accumulation, initial income, education, or climate. However, another possibility is that institutions may affect the growth process indirectly by affecting the marginal effect of policy variables on growth. In this section, I investigate that possibility.

There are two reasons to expect such a nonlinearity. First, there is the conventional wisdom that high-quality institutions are a necessary precursor to effective policy. This is largely related to the credibility of a country's government in transparently pursuing and achieving its policy goals, and is part of the motivation behind the push for international aid to be contingent on "good governance" in the countries receiving aid. In addition to rewarding countries for undertaking institutional reform, many believe that policies function more effectively once countries have attained a threshold level of institutional quality: "[c]ountless development efforts have failed because countries lack institutions with the ability to sustain their economic policies." (Graham, 2002, p. 1).

Second, there are theoretical reasons to expect that the effect of policy on growth is conditional on institutional characteristics of a country. For example, a prediction of Aghion et al. (2005) is that any policy that increases product market competition has a positive effect on firms in sectors close to the technology frontier, and a neutral (or negative) effect on firms in sectors further from the technology frontier. Thus, in models such as Aghion et al. (2005), the effect of policy depends on a country's distance from the technological frontier. Since institutions are considered a key determinant of a country's technological position (see Parente and Prescott, 2000), an implication is that the quality of institutions could alter the marginal effect of policy on growth.

3.1. Empirical results: Interaction terms

To address the idea that institutions need to be sufficiently strong before policy can be effective, I include an interaction term between a dummy variable indicating that the country has the median level or less of executive constraints and each policy variable. I also include an interaction term between each policy variable and GDP (a dummy

variable equal to one if initial GDP per capita is below the sample median), to guard against the institution interaction term reflecting only a country's development level.

The regression to be estimated is similar to those estimated in earlier sections, but includes a policy variable, interaction between the policy variable and GDP, and an interaction between the policy variable and the executive constraints variable. That is, the regression estimated is of the form:

$$\begin{aligned} \mathrm{GR}_{1960\text{–}2000} = {} & \beta_0 + \beta_1 \cdot \ln \mathrm{GDP}_{60} + \beta_2 \cdot \ln \mathrm{INV}_{6065} + \beta_3 \cdot \ln \mathrm{SCHOOL}_{60} \\ & + \beta_4 \cdot \mathrm{TEMP} + \beta_4 \cdot \mathrm{POL} + \beta_5 \cdot \mathrm{POL} \times X_{\mathrm{GDP}} + \beta_6 \cdot \mathrm{POL} \times X_{\mathrm{EXEC}} + u \end{aligned} \tag{6}$$

where variables are defined as before; X_{GDP} and X_{EXEC} are dummy variables indicating that the country's values of GDP and EXEC, respectively, are below the median.

I consider 29 policy-related variables in turn (sample size is 59, limiting degrees of freedom for including multiple variables at once; robustness is discussed further in the following subsection). Table 3 lists the variables considered, and includes *p*-values for the estimate of β_6 when the estimates are statistically significant at 90% or better. The policy data are from Levine and Renelt (1992), and cover either the period 1960–1989 or the period 1974–1989.[19] Note that only statistically significant results are presented.

As seen in Table 3, there are a number of variables for which the correlation with growth is statistically significantly lower for countries with levels of executive constraints below the median. Many of these variables relate to fiscal and trade policy, although the most statistically significant results generally concern trade policy.[20]

The magnitude of these interaction terms is not insignificant: for example, the (statistically insignificant) coefficient estimate on exports entered linearly is 0.003 (standard error of the estimate is 0.010), suggesting that countries with strong institutions see very little change in growth following an increase of one standard deviation (0.11) in exports/GDP (an increase of 0.03% points); countries with weaker institutions see a *decrease* ten times larger in magnitude (0.4% points). Given that the sample mean of growth is 2%, this is a sizeable decrease. This difference is very similar for a one standard deviation increase (0.24) in total trade.

3.2. Robustness

Of course, a natural concern with the results of the preceding section is that they reflect a spurious correlation, due to the choice of other explanatory variables, rather than an

[19] All data are described more completely in Appendix A.

[20] To further address the relationship between human capital and institutions, I repeated the analysis in Table 3 replacing the interaction term between the policy variable interacted with GDP per capita with an interaction term between the policy variable and a variable indicating that the country's level of human capital is below the median. In most cases, the results were very similar to those presented in Table 3; three variables that are marginally statistically significant (growth rate of domestic credit, standard deviation of BMP, and overall international financial openness) are no longer significant when the human capital interaction term is included.

Table 3
Policy variable interaction terms

Variable	β (s.e.)	p-Value
Fiscal policy variables		
Government consumption share of GDP	−0.049 (0.024)	0.049
Central government corporate income tax revenue/GDP	−0.120 (0.073)	0.106
Central government defense expenditure/GDP	−0.263 (0.114)	0.027
Central government deficit/GDP		
Gov't educational expenditure/GDP	−0.212 (0.095)	0.031
Gov't consumption net of educ. and defense/GDP	−0.070 (0.036)	0.060
Central government individual income tax/GDP		
Social security tax revenue/GDP		
Central government tax revenue/GDP	−0.025 (0.014)	0.090
Total government expenditure/GDP	−0.023 (0.012)	0.057
Total central government expenditure/GDP		
Monetary policy variables		
Growth rate of domestic credit	−0.015 (0.009)	0.089
Standard deviation of domestic credit growth	−0.007 (0.004)	0.083
Average inflation of GDP deflator		
Standard deviation of inflation		
Trade policy variables		
Export share of GDP	−0.042 (0.012)	0.001
Black-market exchange-rate premium		
Standard deviation of BMP	−0.004 (0.002)	0.093
Import share of GDP	−0.036 (0.013)	0.008
Measure of overall trade openness		
Measure of overall int'l finance openness	−0.021 (0.012)	0.081
Gravity-based measure of openness		
Import taxes/GDP	−0.056 (0.029)	0.064
Real exchange rate distortion	−0.007 (0.003)	0.023
Total trade (exports + imports)/GDP	−0.020 (0.006)	0.003
Other variables		
Population growth rate	−0.003 (0.002)	0.088
Average annual number of revolutions and coups		
Central government gross capital formation		
Index of civil liberties	−0.002 (0.001)	0.081

Notes to table: Only statistically significant coefficient estimates are presented. The coefficient estimate, robust standard errors and p-values are for the policy variable interacted with a dummy variable indicating that the level of executive constraints is less than or equal to the median. The dependent variable is growth 1960–2000; other explanatory variables are initial GDP per capita, initial schooling, investment, the percentage of the population in temperate zones, the policy variable entered linearly, and the policy variable interacted with GDP per capita. Data sources: Glaeser et al. (2004) and Levine and Renelt (1992).

underlying significant correlation. To address this, I use the robustness procedure of Sala-i-Martin (1997) as a measure of the robustness of the results.[21]

[21] More recently, Sala-i-Martin et al. (2004) propose a robustness test based on Bayesian model averaging; it is not employed here because of the need for a balanced panel, which would significantly reduce the sample size.

Following Sala-i-Martin (1997), for each variable of interest, 4060 regressions are estimated.[22] As given by Eq. (6), each regression includes initial GDP, initial schooling, investment, and population in temperate zones, as well as the variable of interest in three forms: linearly, interacted with the dummy variable indicating that GDP is below the median, and interacted with the dummy variable indicating that the executive constraints variable is below the median. To determine robustness, each possible combination of three additional control variables is added to this regression, selected from the set of all variables tested (i.e., all variables listed in Table 3). The likelihood-weighted mean of the point estimate $\hat{\beta}_m$ and its standard deviation $\hat{\sigma}_m$ are computed, as follows:

$$\bar{\beta}_m = \sum_{j=1}^{K} \omega_{mj}\hat{\beta}_{mj}; \quad \bar{\sigma}_m^2 = \sum_{j=1}^{K} \omega_{mj}\hat{\sigma}_{mj}^2 \tag{7}$$

where the weights ω_{zj} are proportional to the likelihoods L_j:

$$\omega_{mj} = \frac{L_{mj}}{\sum_{i=1}^{K} L_{mi}} \tag{8}$$

One can then estimate the CDF from the mean and variance of the estimates; a variable's robustness is determined by the proportion of the distribution lying to the left or right of zero.

Table 4 presents results from this procedure, for the variables with interaction terms that pass the robustness test at the 10% level or better. In the final column are *p*-values from the robustness test under the assumption that the estimates are normally and non-normally distributed, respectively. The table gives the coefficient estimates for the base regression (i.e., Eq. (6), not including any of the other policy variables), both for the policy variable entered linearly, and for the policy variable and the interaction term with initial executive constraints. For three of the variables – real exchange rate distortion, government consumption, and government consumption net of education and defense – the coefficient estimate on the variable entered linearly, with no interaction terms, is statistically significant (and more highly so than the coefficient on the interaction term when it is included).

Recall that the robustness procedure tests the significance of the coefficient estimate on the interaction term. In all cases in Table 4, when interaction terms are included, the coefficient estimate on the policy variable entered linearly is not statistically different from zero, but the estimate on the interaction term is. This implies that the relationship between the policy variables and growth in the entire sample (more precisely, in the subsample with executive constraints above the median) is not distinguishable from zero, but this correlation *is* statistically significant and negative in the subsample of countries with executive constraints less than the median.

The results are strongest for exports/GDP, imports/GDP, and total trade/GDP. As before, this suggests that there are interactive effects between the degree of trade openness and the quality of institutions. Specifically, although the correlation between "openness" (measured by the quantity of trade) and growth is close to zero in countries with strong institutions, this correlation is negative among countries with weaker institutions.

[22] All combinations of three variables from a set of 30, or 30!/(3!27!) = 4060.

Table 4
Robust results – interaction term

	No interaction terms		Interaction terms		
Variable	β (s.e.)	p-Value	β (s.e.)	p-Value	p^*
EXPORTS	−0.002 (0.013)	0.855	0.003 (0.010)	0.799	
EXPORTS × X_1			−0.042 (0.012)	0.001	0.018, 0.040
IMPORTS	−0.011 (0.007)	0.125	0.002 (0.009)	0.796	
IMPORTS × X_1			−0.036 (0.013)	0.008	0.039, 0.047
TRADE	−0.005 (0.005)	0.364	0.001 (0.005)	0.833	
TRADE × X_1			−0.020 (0.006)	0.003	0.023, 0.044
RERD	−0.013 (0.003)	0.000	−0.005 (0.005)	0.317	
RERD × X_1			−0.007 (0.003)	0.023	0.094, 0.055
GOV	−0.059 (0.028)	0.044	−0.022 (0.024)	0.361	
GOV × X_1			−0.049 (0.024)	0.049	0.072, 0.025
DEE	−0.018 (0.018)	0.321	−0.026 (0.016)	0.115	
DEE × X_1			−0.263 (0.114)	0.027	0.087, 0.024
GOVX	−0.102 (0.037)	0.008	−0.028 (0.037)	0.462	
GOVX × X_1			−0.070 (0.036)	0.060	0.101, 0.025
EDE	−0.094 (0.067)	0.170	−0.005 (0.066)	0.945	
EDE × X_1			−0.212 (0.095)	0.031	0.110, 0.090

Notes to table: The dependent variable in all regressions is growth 1960–2000. X_1 is a dummy variable equal to one if the country's level of initial executive constraints is 5 or less (on a 7-point scale). Other explanatory variables are initial GDP per capita, initial schooling, investment, and percentage of the population in temperate climates. The regression with the interaction term also includes an interaction term with a dummy variable indicating that the country's level of GDP per capita is below the median. The column labeled p^* gives the p-values on the executive constraints interaction term estimate from the Sala-i-Martin robustness procedure described in the text, under the assumption that the estimates are normally and non-normally distributed, respectively. Variable definitions: TRADE: (exports + imports)/GDP; RERD: real exchange rate distortion; GOV: government consumption/GDP; DEE: defense expenditure/GDP; GOVX: government consumption excluding education and defense/GDP; EDE: government educational expenditure/GDP. Variables are defined more completely in Appendix A.

This is not inconsistent with the predictions of Aghion et al., 2005, in which increasing competition (here, through trade policy) benefits companies that are closer to the technology frontier (which may depend on the quality of a country's institutions, as argued by Parente and Prescott, 2000 and others), but hurts those further from it.[23]

4. Concluding remarks

The relationship between institutions and growth is undeniably complex. Progress in understanding the empirical relationship has definitely been made recently, through innovative instruments, econometric methodology allowing for better accounting of causality, and more appropriate measures of institutions. However, it is likely that institutions affect

[23] On average, the countries with strong institutions have significantly higher levels of trade volume than do those with weaker institutions. The mean value of total trade (imports plus exports, scaled by GDP) is 0.63 (standard error of 0.27) in the countries with higher levels of the institutions variable, and 0.51 (0.25) in the countries with weaker institutions.

growth in many ways: perhaps directly, but also by affecting variables that in turn affect growth, and by affecting the aggregate production function determining how other variables affect growth.

In this paper, I have been concerned primarily with the last relationship, and have found evidence that institutions do affect the relationship between trade openness and growth. In particular, countries with weak institutions appear to suffer from trade openness in ways that countries with better institutions do not. This finding is consistent with a role for institutions similar to that in models like Aghion et al. (2005). Perhaps equally important, I find little evidence that institutions affect the relationship between growth and its fundamental determinants.

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Table A.1A
Growth and institution variables

Variable	Definition	Source	Mean (s.e.)
GROWTH	Growth of GDP per capita, 1960–2000	S-H	0.02 (0.02)
lnGDP60	Log GDP per capita, 1960	S-H	7.83 (0.90)
lnSCHOOL	Log of years of schooling of population over age 25	B-L	0.93 (1.01)
lnINVEST	Log of average investment/GDP, 1960–1965	S-H	2.63 (0.77)
POPTEMP	Percentage of the population living in temperate climate zones, 1995	CID-G	0.33 (0.43)
EXECCON	Extent of institutionalized constraints on decision-making powers of chief executive: 1 = unlimited executive authority through 7 = executive parity or subordination	J-M	4.23 (2.38)
EXPROP	Risk of expropriation (confiscation or nationalization): 0 = highest risk through 10 = lowest risk, averaged 1982–1997	ICRG	7.33 (1.70)
AUTOCRACY	degree of autocracy: 0 = democracy through 2 = autocracy, averaged 1960–1990	ACLP	0.77 (0.57)
GOVEFF	Government effectiveness: −2.5: least effective through 2.5: most effective, averaged 1998–2000	KKM	0.24 (1.00)
PLURAL	Percentage of years 1975–2000 in which legislators elected under winner-take-all rule	BCGKW	0.67 (0.46)
PROP	Percentage of years 1975–2000 in which candidates elected under proportional representation	BCGKW	0.57 (0.49)

Notes to table: Data from Glaeser et al. (2004), with the exception of investment (taken directly from Penn World Tables). Original sources: S-H: Aten, B., Heston, A., Summers, R., 2002. Penn World Tables v. 6.1, Center for International Comparisons, University of Pennsylvania. B-L: Barro, R.J., Lee, J.-W., 2000. International Data on Educational Attainment, working paper No. 42, Center for International Development. CID-G: Center for International Development, Geography Data Sets. J-M: Jaggers, K., Marshall, M.G., 2000. Polity IV Project, Center for International Development and Conflict Management, University of Maryland. ICRG: International Country Risk Guide. 1996. Political Risk Services, East Syracuse NY. ACLP: Alvarez, M., Cheibub, J.A., Limongi, F., Przeworski, A., 2000. Democracy and Development. Cambridge University Press, Cambridge. KKM: Kaufmann, D., Kraay, A., Mastruzzi, M., 2003. Governance Matters III, Working Paper Draft for comments, World Bank. BCGKW: Beck, T., Clarke, G. Groff, A. Keefer, P. Walsh, P., 2001. New Tools in Comparative Political Economy, World Bank Economic Review 15(1); 165–176.

Appendix A. Variable definitions

The following table defines variables used in the tables; all data are from Glaeser et al. (2004) (Table A.1A) or Levine and Renelt (1992) (Table A.1B). "Source" in the table identifies the original source of the data, given in more detail in the table notes.

Table A.1B
Policy variables

Variable	Definition	Source	Mean (s.e.)
GOV	Government consumption/GDP	WB	0.15 (0.05)
CTX*	Central government corporate income tax revenue/GDP	IMF	0.03 (0.04)
DEE*	Central government defense expenditure/GDP	IMF	0.03 (0.03)
DEF*	Central government surplus/deficit to GDP	IMF	−0.05 (0.04)
EDE*	Government educational expenditure/GDP	IMF	0.04 (0.02)
GOVX*	Government consumption less defense and education/GDP	IMF	0.09 (0.04)
ITX*	Central government individual income tax revenue/GDP	IMF	0.03 (0.04)
SST*	Social security tax revenue/GDP	IMF	0.04 (0.04)
TAX*	Central government tax revenue/GDP	IMF	0.21 (0.09)
TEX*	Total government expenditure/GDP	IMF	0.31 (0.13)
XTX*	Central total government expenditure/GDP	IMF	0.03 (0.03)
GDC	Growth rate of domestic credit	IMF	0.24 (0.22)
STDD	Standard deviation of domestic credit growth	IMF	0.35 (0.75)
PI	Average inflation of GDP deflator	WB	0.24 (0.61)
STDI	Standard deviation of PI (inflation)	WB	0.56 (2.45)
X	Exports/GDP	WB	0.28 (0.19)
BMP	Black-market exchange-rate premium	Picks	0.31 (0.56)
BMS	Standard deviation of BMP	Picks	0.43 (0.91)
IMP	Imports/GDP	WB	0.32 (0.18)
LEAM1*	Measure of overall trade openess	Leamer	0.03 (0.15)
LEAM2*	Measure of overall financial openess	Leamer	0.29 (0.14)
MP	Gravity-based measure of openess based on import penetration	L-R	−0.00 (0.16)
MTX*	Import taxes/import value	IMF	0.09 (0.06)
RERD*	Real exchange-rate distortion	Dollar	1.21 (0.40)
TRD	Total trade (exports + imports)/GDP	WB	0.59 (0.32)
INV	Investment/GDP	WB	0.21 (0.06)
GPO	Population growth rate	WB	2.11 (0.97)
REVC	Number of revolutions and coups per year	Barro	0.21 (0.26)
CGC*	Central government gross capital formation	IMF	0.03 (0.03)
CIVL	Index of civil liberties	Barro	3.75 (1.85)
RGDP	Real GDP per capita ($1000s)	S-H	1.91 (1.71)

Notes to table: An asterisk next to the variable name indicates that the variable is available over 1974–1989, rather than 1960–1989. Sources: IMF: International Monetary Fund, Government Finance Statistics and it International Finance Statistics. WB: World Bank, World Social Indicators and it National Accounts. Picks: Picks Currency Yearbook, World Bank updates. Leamer: Leamer, E.E., 1988. Measures of Openness. In: Baldwin R. (Ed.), Trade Policy Issues and Empirical Analysis, National Bureau of Economic Research Conference Report Series, University of Chicago Press, Chicago, pp. 147–200. Dollar: Dollar, D., 1992, Outward-Oriented Developing Economics Really do Grow More Rapidly: Evidence from 95 LDCs, 1976–1985. Economic Development and Cultural Change 40, 523–544. S-H: Summers, R., Heston A., Penn World Tables, 1988. A New Set of International Comparisons of Real Product and Price Level Estimates for 130 Countries, 1950–1985. Review of Income and Wealth (34), 1–25. Barro: Barro, R.J., 1991. Economic growth in a cross-section of countries. Quarterly Journal of Economics 106, 407–444.

Table B.1
Country classification

Low executive constraints			High executive constraints		
Argentina	Honduras	Peru	Australia	Ireland	Sweden
Bolivia	Indonesia	Philippines	Austria	Israel	Switzerland
Brazil	Jordan	Portugal	Belgium	Italy	United Kingdom
Cameroon	Mali	Senegal	Canada	Japan	United States
Chile	Mexico	Spain	Colombia	Republic of Korea	
Dominican Rep.	Nepal	Thailand	Costa Rica	Malaysia	
Ecuador	Nicaragua	Togo	Denmark	Netherlands	
El Salvador	Niger	Uruguay	Finland	New Zealand	
France	Pakistan	Venezuela	Greece	Norway	
Ghana	Panama		Iceland	South Africa	
Guatemala	Paraguay		India	Sri Lanka	

Notes to table: Only countries with no missing data for the regressions in Table 1 are included. "Low executive constraints" includes all countries for which the value of the executive constraints variable in 1960 is 1–5; "high executive constraints" includes those for which the value is 6–7.

Appendix B. Country classification

Table B.1 lists the countries in each node from the regression tree procedure of Section 2.

References

Acemoglu, D., 2005. Constitutions, politics, and economics: A review essay on Persson and Tabellini's the economic effects of constitutions. Journal of Economic Literature 43 (4), 1025–1048.

Acemoglu, D., Johnson, S., Robinson, J.A., 2001. The colonial origins of comparative development: An empirical investigation. American Economic Review 91, 1369–1401.

Acemoglu, D., Johnson, S., Robinson, J.A., 2002. Reversal of fortune: Geography and institutions in the making of the modern world income distribution. Quarterly Journal of Economics 117, 1231–1294.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P., 2005. Competition and innovation: An inverted-U relationship. Quarterly Journal of Economics 120 (2), 701–728.

Azariadis, C., Drazen, A., 1990. Threshold externalities in economic development. Quarterly Journal of Economics 105 (2), 465–490.

Bernard, A.B., Jones, C.I., 1996. Technology and convergence. Economic Journal 106 (437), 1037–1044.

Breiman, L., Friedman, J.L., Olshen, R.A., Stone, C.J., 1984. Classification and Regression Trees. Pacific Grove, Wadsworth, CA.

Caselli, F., Coleman, W.J., 2006. The world technology frontier. American Economic Review 96 (3), 499–522.

Chakraborty, S., Pérez-Sebastián, F., Papageorgiou, C., 2006. How diseases matter: Some empirical evidence, manuscript.

Cooper, S.J., 1998. Multiple regimes in U.S. output fluctuations. Journal of Business and Economic Statistics 16 (1), 92–100.

Desdoigts, A., 1999. Patterns of economic development and the formation of clubs. Journal of Economic Growth 4 (3), 305–330.

Durlauf, S., Johnson, P., 1995. Multiple regimes and cross country growth behavior. Journal of Applied Econometrics 10 (4), 365–384.

Durlauf, S.N., Quah, D.T., 1999. The New Empirics of Economic Growth. Elsevier Science, North-Holland, pp. 235–308.

Durlauf, S.N., Kourtellos, A., Minkin, A., 2001. The local Solow growth model. European Economic Review 45, 928–940.

Eicher, T., Leukert, A., 2006. Institutions and Economic Performance: Endogeneity and parameter heterogeneity. Working Paper, University of Washington.

Glaeser, E.L., La Porta, R., Lopez-de-Silanes, F., Shleifer, A., 2004. Do institutions cause growth? Journal of Economic Growth 9 (3), 271–303.
Graham, C., 2002. Strengthening Institutional Capacity in Poor Countries. Brookings Institution Policy Brief no. 98.
Hansen, B.E., 2000. Sample splitting and threshold estimation. Econometrica 68 (3), 575–603.
Hansen, G.D., Prescott, E.C., 2002. Malthus to solow. American Economic Review 92 (4), 1205–1217.
Härdle, W., 1990. Applied Nonparametric Regression. Cambridge University Press, Cambridge.
Jaggers, K. Marshall, M.G., 2000. Polity IV Project. Center for International Development and Conflict Management. University of Maryland.
Levine, R., Renelt, D., 1992. A sensitivity analysis of cross-country growth regressions. American Economic Review 82 (4), 942–963.
Minier, J., 1998. Democracy and growth: Alternative approaches. Journal of Economic Growth 3 (3), 241–266.
Minier, J., 2003. Are small stock markets different? Journal of Monetary Economics 50 (7), 1593–1602.
North, D., 1990. Institutions, Institutional Change, and Economic Performance. Cambridge University Press.
Papageorgiou, C., 2002. Trade as a threshold variable for multiple regimes. Economics Letters 77, 85–91.
Parente, S.L., Prescott, E.C., 2000. Barriers to Riches. MIT Press.
Persson, T., Tabellini, G., 2005. The Economic Effects of Constitutions. MIT Press.
Rodrik, D., Subramanian, A., Trebbi, F., 2004. Institutions rule: The primacy of institutions over geography and integration in economic development. Journal of Economic Growth 9 (2), 131–165.
Sala-i-Martin, X., 1997. I just ran two million regressions. American Economic Review Papers and Proceedings 87 (2), 178–183.
Sala-i-Martin, X., Doppelhofer, G., Miller, R.I., 2004. Determinants of long-term growth: A Bayesian averaging of classical estimates (BACE) approach. American Economic Review 94 (3), 813–835.
Solow, R.M., 1956. A contribution to the empirics of economic growth. Quarterly Journal of Economics 70, 65–94.
Swan, T., 1956. Economic growth and capital accumulation. Economic Record 32, 344–361.