Empirical Economics
https://doi.org/10.1007/s00181-023-02395-w

Institutions and economic development: new measurements and evidence

Esther Acquah[1] · Lorenzo Carbonari[2] · Alessio Farcomeni[2] · Giovanni Trovato[2]

Received: 6 July 2022 / Accepted: 21 February 2023

Abstract
We propose a new set of indices to capture the multidimensionality of a country's institutional setting. Our indices are obtained by employing a dimension reduction approach on the institutional variables provided by the Fraser Institute (2018). We estimate the impact that institutions have on the level and the growth rate of per capita GDP, using a large sample of countries over the period 1980–2015. To identify the causal effect of our institutional indices on a country's GDP we employ the Generalized Propensity Score method. Institutions matter especially in low- and middle-income countries, and not all institutions are alike for economic development. We also document non-linearities in the causal effects that different institutions have on growth and the presence of threshold effects.

Keywords Economic development · Institutions · Threshold effects · Mixture model · High-income countries · Low- and middle-income countries

JEL Classification O43 · O47

1 Introduction

In their influential essay, Acemoglu et al. (2005) provide convincing arguments in favor of the idea that institutions *cause* economic prosperity by providing " right" incentives

"We switch now to one of the typical ultimate causes of growth. Institutions do matter—no doubt about it. But: how much? Through what channels? These are much more difficult questions to answer". Crafts and Toniolo (2010).

✉ Lorenzo Carbonari
lorenzo.carbonari@uniroma2.it

1 Fundamentos del Análisis Económico (FAE), University of Alicante, San Vicente del Raspeig, Spain

2 Dipartimento di Economia e Finanza (DEF), Università di Roma "Tor Vergata", Rome, Italy

Published online: 08 March 2023

and constraints to the economic agents. Along the path of economic development, Acemoglu and coauthors claim, institutions emerge as outcomes of social decisions. Particularly, economic institutions encouraging economic growth may arise " *when political institutions allocate power to groups with interests in broad-based property rights enforcement, when they create effective constraints on power-holders, and when there are relatively few rents to be captured by power-holders*". This view traces back to North (1990), who defines institutions as "*the rules of the game in a society or, more formally, [...] the humanly devised constraints that shape human interaction*". Consistently with this definition, the fundamental explanation of comparative growth should be sought in institutional differences. This is the perspective we adopt in this paper.

The attempt to understand cross-country differences in GDP dynamics through this lens is certainly not new.[1] We contribute in two ways. First, we provide new measures to describe a country's institutional environment. Since the institutional setting is a multidimensional phenomenon and the array of connections between institutions and economic development is potentially extremely large, the first contribution of the paper is to propose a brand-new set of indices aimed at summarizing such multidimensionality. In our view, the term "institution" must be intended in a broad sense. Institutions affect the interactions among agents on many grounds. They operate formally, through the design of the *rules of the game*, but also informally, by shaping customs and *social norms*. The possibility for individuals and organizations—like corporations, public entities, financial institutions, etc.—to lead the society as a whole towards productive economic activities crucially depends on the incentives for these activities. Incentives that typically institutions provide. Building on the data provided by the Fraser Institute (2018), we focus on the following five measures: *i) the size of the public sector, ii) the reliability and fairness of the legal system, iii) the degree of liquidity in the financial markets, iv) the degree of openness to international trade* and *v) the strength of regulation*.[2] Our indices are obtained by employing a dimension reduction approach designed for panel data (Farcomeni et al. 2021) and rated on a 0–10 scale. Such a rating reflects the general idea that an institution is better the more it increases market freedom, protects private property rights, provides liquidity to the economy (with a beneficial effect on interest rates and capital accumulation), and promotes trade. These are considered the most important preconditions for a sustained economic development.

We are aware that some of our institutional indices are constructed starting from variables which, at best, can only be taken as proxies for institutions. While the legal system and the regulatory environment are intuitively identifiable as institutions per se, it might not be the same for other indices like, for instance, the size of the public sector. This measure, however, can be intended as a proxy for the welfare state, which is an institution itself or an aggregation of institutions, implicitly assuming that the larger is the public sector, the more developed is the welfare state. An assumption

[1] See the list of studies mentioned below.

[2] As noted in the literature, these sub-dimensions of institutions equally capture policy variables such as the size of the public sector in terms of government expenditure and taxes (see, for instance, De Haan et al. 2006). We will use these indices irrespective of whether they are institutional measures or policies aside from the *main institutional index* obtained with the dimension reduction analysis.

that seems to be supported by the data.[3] Similarly, well-functioning financial market and trade openness are informative about not only the appropriateness of the policies undertaken to pursue these goals but also about the soundness of the institutions which conceive and implement those policies.

As a second contribution, we use these indicators to assess their joint and separate role on GDP. We do this by explicitly taking into account the unobserved heterogeneity among countries. Using an optimal clustering method, we split our sample of 80 countries over the period 1980–2015, into two groups, "high-income" and "low- and middle-income" countries. By doing this we allow for heterogeneous effects of institutions among clusters. Then, applying the restrictions provided by an augmented version of the Solow model, including a role for institutions, we first estimate a Gaussian mixed-effects model to empirically prove the positive *association* between GDP (levels and growth rate) and our institutional indices. Finally, we employ the Generalized Propensity Score method proposed by Hirano and Imbens (2004) to properly address the issues of endogeneity and omitted variable bias and to identify the *causal* effect of institutions on GDP.

Our estimates show that the obtained institutional indices vary across the two groups of countries. We show that improvements in some institutions (i.e., larger values of our institutional indices) may *cause* both higher levels and growth rates of the long-run per capita GDP. Such effects appear stronger for those countries which have been classified as "low- and middle-income", where, comparatively, markets are more dysfunctional and bureaucracies typically less efficient. Specifically, we document the important role played by the legal system in determining the long-run level of GDP in "low- and middle-income" countries. This has an important policy implication. In countries where basic institutions are often lacking, market-friendly policies may not yield desired results or may even be counterproductive. In such a context, reforms should aim at establishing a reliable legal system and protecting property rights.

Differently from the large body of the literature on the topic,[4] which focuses on the linear association between some institutional indices and GDP (levels and growth rate), a final important feature of our analysis is that it looks at and finds non-linear *causal* effects. Institutions affect GDP directly and indirectly, trough their interaction with cluster membership. Improvements in institutions always determine a positive level effect on per capita GDP. Our estimates document an interesting non-linear *causal* effect of (our proxy for) welfare state on GDP: the positive impact of this indicator tends to increase up to some limit (being smaller in the group of "low- and middle-income" countries) and then starts to decline (more sharply in the group of "low- and middle-income" countries). Also, all our institutional indicators display non-

[3] The World Bank documents that, over the period 2000–2019, the total tax revenue (% of GDP) has a correlation of 0.46 with the government expenditure on education (% of GDP), of 0.33 with the domestic general government health expenditure per capita) and of 0.28 with the coverage of social insurance programs (% of population). Moreover, in countries with a large public sector (such as China, France, Finland, Italy, Norway and Singapore), central governments are generally full or majority owners of important state-owned enterprises, which play a crucial role for GDP growth through their technological dynamism and export successes (see, e.g., Chang et al. 2007).

[4] See, e.g., Ali (1997), Dawson (1998), Dawson (2003), Hall and Jones (1999), De Haan and Sturm (2000), Ali and Crain (2001), Acemoglu et al. (2005), De Haan et al. (2006), Cebula (2011), Cebula and Mixon (2012), Iqbal and Daly (2014) and Hussain and Haque (2016).

linear effects (despite not always statistically significant) on GDP growth. As a further check for non-linearity, we carry on a threshold analysis based on the augmented Solow model. This exercise confirms the presence of thresholds effects in the two groups of countries.

Our work relates closely to the empirical literature on the link between institutions and GDP dynamics, which has significantly increased over the last three decades as we have listed above. In general, a positive and direct relationship between institutions and GDP levels/growth rates is found. Estimates, however, substantially vary in terms of magnitude across different samples and/or specifications. Moreover, most of the papers rely only on few variables to capture institutional quality and/or do not provide any causal evidence on the relationship between institutions and GDP dynamics. Since the literature is vast, here we focus our attention to those studies which, like ours, build upon Mankiw et al. (1992) (MRW, hereafter).

Using a large sample of countries over the period 1975–1990, Dawson (1998) find that one standard deviation increase of an initial value of the "economic freedom" index above the mean provides a 3.78 percentage point higher growth rate in the subsequent 15-year sample period, holding the level of freedom fixed over the period. Taking data from 97 countries over the period 1974–89, Knach and Keefer (1995) introduce two institutional variables into an MRW regression, meant to capture the security of property rights and the enforcement of contracts, and find that an increase of one standard deviation in their "rule of law" index leads to an increase in the GDP growth rate by 0.504 of its standard deviation. In a subsequent paper, Keefer and Knack (1997) also show that whenever good institutions are absent convergence tends to be slower.

Analyzing a sample of 127 countries over the period 1950–1994, Hall and Jones (1999) show that differences in capital accumulation, productivity, and therefore output per worker are fundamentally related to differences in "social infrastructure" across countries. The positive impact of the "rule of law" on GDP growth has been found by Barro (1997), for a panel of 100 countries over the period 1960–1990, while Rodrik et al. (2004), using the data set of Acemoglu et al. (2001), find institutions to be crucial in determining the long-run level of a country's income. Their estimates indicate that a one standard deviation increase in institutional quality produces a two log-points rise in per capita incomes. For a panel of 56 countries over the period 1981–2010, Nawaz (2015) find that the impact on GDP growth of various institutional variables is relatively larger in "high-income" countries as compared to the "low- and middle-income" ones.

Using a large sample of countries over the period 1960–2000, Minier (2007) focuses on the indirect effect of (political) institutions on growth, by introducing parameter heterogeneity into a growth regression. In such a frame, there are typically multiple growth regimes and threshold effects, which are ultimately affected by institutional quality. Minier's estimates shed light on the interesting link between institutions and trade. Specifically, the weaker are the institutions of a country (proxied by several policy-related variables), the more it suffers from trade openness.[5]

[5] In Sect. 4.5, we explore the possible existence of non-linearities between institutions and economic growth. The main difference between Minier's work and ours is that we focus on our brand-new institutional indices

While most studies present a linear linkage between institutions and growth, there is also an empirical growth literature that deals with the non-linearities in the canonical cross-country growth regression.[6] For instance, using data on 100 countries over the years 1995–2018, Li and Kumbhakar (2022) propose a quantile regression model in which countries are grouped according to their growth rates, finding a positive effect of economic freedom on per capita GDP growth. In particular, they show that countries that fall into the 20th-50th percentiles of per capita GDP have a positive and significant effect of economic freedom on growth, whereas the effect is not significant below or above these percentiles. Our work belongs to this strand of the literature, examining whether the (causal) relationship between institutions and growth is subject to non-linearities after constructing optimal institutional indices.

The rest of the paper is organized as follows. Section 2 outlines and discusses the methodology proposed to derive the set of institutional indices and the empirical model to assess the role of institutions in explaining GDP dynamics. Section 3 describes the data set. Section 4 presents the estimates, with some comments. Section 5 is a conclusion.

2 Model and methodology

2.1 Institutional indices

Our first goal is to compute time-dependent summaries of indicators of interest. The main purpose of creating these institutional and policy indices is to identify unidimensional latent variables to summarize multidimensional indicators that, to some extent, are measuring similar characteristics from a different perspective. These latent variables can then be used for ranking and identifying different levels (*doses*) of the characteristics of interest (e.g., the reliability and fairness of the legal system). Notice that the resulting summaries are optimal from a specific mathematical perspective. However, they can only give a partial point of view on the information contained in the data.

There are different methods available for dimension reduction. The most widely used (e.g., principal component analysis) is anyway restricted to cross-sectional data and would not be appropriate for multidimensional measurements (in our case: a collection of indices that are deemed to measure different aspects of the same unidimensional latent trait) that are repeatedly measured over time (Hall et al. 2006). Among the different possible approaches proposed by the literature (e.g., Chen and Buja 2009; Maruotti et al. 2017), we opt for a methodology based on the specification of a latent Markov model (Bartolucci et al. 2013, 2014) for the latent trait, as in e.g. Xia et al. (2016) or Vogelsmeier et al. (2019). Specifically, we employ the methodology proposed by Farcomeni et al. (2021), whose main advantage is that it allows us

while using political institutions as the variable that controls the selection of economic institutions which may affect growth.

[6] See, e.g., Barro (1996), Liu and Stengos (1999), Cohen-Cole et al. (2012), Li and Kumbhakar (2022) and, for a survey, Cohen-Cole et al. (2005).

to explicitly consider dependence arising from measurements on the same agent that is repeated over time.

Formally, let X_{itm} denote the m-th indicator for country i at time t. Let also U_{it} denote an unobserved discrete latent variable and w_m be the weight of latent class separation for $m = 1, \ldots, M$. We assume $Z_{it} = \sum_{m=1}^{M} w_m X_{itm}$ follows a latent Markov model according to which Z_{it} is independent of Z_{is} conditionally on U_{it}, which follows a homogeneous first-order Markov chain. Additionally, conditional on $U_{it} = j$ we assume Z_{it} is Gaussian with mean $\xi_j(w)$. The optimal weights $\hat{w}_m$ for $m = 1, \ldots, M$ optimize latent class separation, that is, maximize

$$\sum_{j=1}^{k} \sum_{t} \hat{p}_{tj}(w)(\hat{\xi}_j(w) - \bar{\xi}_t(w))^2, \tag{1}$$

under the constraint $\sum_m w_m^2 = 1$, where $p_{tj}(w) = \Pr(U_{it} = j)$ and $\bar{\xi}_t(w) = \sum_j p_{tj}(w)\hat{\xi}_j(w)$. In words, we set weights so that the latent means (the means of each subgroup as identified by U_{it}) are as far from each other as possible.

The resulting summary is a linear combination of the initial dimensions which optimizes the separation of clusters of agents (e.g., countries that have a more or a less reliable legal system). Weights can be used for the interpretation and assessment of the importance of the original variables. A limitation is a Gaussian assumption for Z_{it}, which might not hold in practice if any X_{ith} is severely skewed, or if H is small.

Our methodology identifies five groups of indicators, which we summarize separately, creating treatment variables z_1 to z_5 (see Tables 11 and 12 in the Appendix for detailed descriptions) and jointly (treatment variable z). Finally, we normalize and scale the resulting indicators on a score of 0 (e.g., no reliability and fairness of the legal system) to 10 (e.g., highest reliability and fairness of the legal system).[7]

2.2 The augmented Solow model

The rest of the paper is aimed at quantifying the *causal* effect of the institutional indices derived above on GDP levels and growth rates. To do this, we extend the canonical MRW's setting to account for a direct impact of institutions on the Total Factor Productivity (TFP) [see, e.g. Nawaz and Khawaja (2019)].[8]

For a country i at time t, we assume that the aggregate output is obtained through the following linearly homogeneous production function:

$$Y_{it} = K_{it}^{\alpha} H_{it}^{\beta} (A_{it} L_{it})^{1-\alpha-\beta} \qquad \text{with} \quad \alpha + \beta < 1 \tag{2}$$

[7] Generally, we can say that higher values of our indices correspond to improvements in the *quality* of the institutions to which the indices refer. In the causal analysis conducted in the Sect. 4.3 we show, however, that, for some institutions, too high values of the index referring to them may lead to a negative effect on GDP dynamics. This potential negative effect suggests to avoid reference to a notion of institutions quality for our indices.

[8] Manca (2010) provides evidence that countries endowed with better institutions have higher TFP growth rates and faster rates of technology adoption.

where Y is the level of real GDP, K is the stock of physical capital, H is the stock of human capital, A is the Harrod-neutral technological progress and L is the labor force. We assume that the labor force and technology grow at the exogenously given rates n and g, respectively. For the sake of simplicity, we also assume that both forms of capital depreciate at the same constant rate δ. Let now $\ln\left(\frac{Y_{it}}{L_{it}}\right)^*$ denote the (natural logarithm of the) level of per capita GDP in the long-run, such that

$$\ln\left(\frac{Y_{it}}{L_{it}}\right)^* = \ln A_{i0} + g_{it} + \left(\frac{\alpha}{1-\alpha-\beta}\right)\ln(s_k)_{it} + \left(\frac{\beta}{1-\alpha-\beta}\right)\ln(s_h)_{it} - \left(\frac{\alpha+\beta}{1-\alpha-\beta}\right)\ln(n+g+\delta)_{it},$$

where s_k and s_h indicate the exogenous fractions of total income invested in physical capital and human capital, respectively. Notice that the term A is a reduced form to capture the large set of factors, other than inputs, that affect the steady-state level of GDP, such as resource endowments, climate, and institutions. Specifically, as in Dawson (1998), the notion that institutions affect productivity can be easily incorporated in the model by assuming A to be a function of institutions (z). Therefore, differently from MRW, in which $\ln(A)_{it} = \alpha + \epsilon_{it}$, with $\epsilon_i \sim N(0,1)$ representing a country-specific shock, in our set-up, we assume: $\ln(A)_{it} = f(z_{it}) + \epsilon_{it}$.[9] Using this, we obtain the following empirical equation:

$$\ln\left(\frac{Y_{it}}{L_{it}}\right)^* = \psi_0 + \psi_1 f(z_{it}) + \psi_2\ln(s_k)_{it} + \psi_3\ln(s_h)_{it} + \psi_4\ln(n+g+\delta)_{it} + \epsilon_{it}, \quad (3)$$

where $\psi_0+\psi_1 f(z_{it})$ is the TFP, ψ_1 captures the effect of institutions on per capita GDP, $\psi_2 \equiv \left(\frac{\alpha}{1-\alpha-\beta}\right)$, $\psi_3 \equiv \left(\frac{\beta}{1-\alpha-\beta}\right)$ and $\psi_4 \equiv -\left(\frac{\alpha+\beta}{1-\alpha-\beta}\right)$. This specification implies that differences in institutions have a homogeneous effect on the level of productivity across countries (ψ_1). The growth of per capita income can be then expressed as a function of the determinants of the steady-state and the initial level of income, i.e

$$\ln\left(\frac{Y_t/L_t}{Y_0/L_0}\right) = \left(1-e^{-\lambda t}\right)\ln\left(\frac{Y_t}{L_t}\right)^* - \left(1-e^{-\lambda t}\right)\ln\left(\frac{Y_0}{L_0}\right) \quad (\lambda > 0), \quad (4)$$

where Y_0/L_0 is the per capita income at some initial time and λ indicates the speed of conditional convergence toward the steady-state. Plugging (3) into (4) we finally get the following empirical equation:

[9] As in Dawson (1998), this specification implies that differences in institutions have a "fixed effect" on the level of productivity across countries.

$$\ln\left(\frac{Y}{L}\right)_{it} - \ln\left(\frac{Y}{L}\right)_{i0} = \zeta_0 + \zeta_1 z_{it} + \zeta_2 \ln(s_k)_{it} + \zeta_3 \ln(s_h)_{it} + \zeta_4 \ln(n+g+\delta)_{it} + \zeta_5 \ln\left(\frac{Y}{L}\right)_{i0} + \epsilon_{it}, \tag{5}$$

where $\zeta_0 \equiv (1-e^{\lambda t})\psi_0$, $\zeta_1 \equiv (1-e^{-\lambda t})\psi_1 f(z_{it})$, $\zeta_2 \equiv (1-e^{-\lambda t})\frac{\alpha}{1-\alpha-\beta}$, $\zeta_3 \equiv (1-e^{-\lambda t})\frac{\beta}{1-\alpha-\beta}$, $\zeta_4 \equiv -(1-e^{-\lambda t})\frac{\alpha+\beta}{1-\alpha-\beta}$ and $\zeta_4 \equiv -(1-e^{-\lambda t})$.

2.3 Estimation method

We first divide countries into groups according to a model-based clustering method. To do so, we restrict to the (log of) GDP in 1980 and compare twenty possible Gaussian mixture models, combining $k = 1, \ldots, 9$ groups with homogeneous or heterogeneous cluster-specific variance. The resulting optimal clustering is then used as a control, being a possible proxy for residual unobserved heterogeneity.

We then estimate Gaussian mixed-effects models in which we include fixed effects for treatment $(z, z_1, \ldots, z_5)$, its square, interactions with cluster indicators, and control variables. For each endpoint x_{it} this leads to the equation

$$x_{it} = \eta_{i0} + \eta_1 z_{it} + \eta_2 z_{it}^2 + \eta_3 c_i + \eta_4 z_{it} c_i + \eta_5 z_{it}^2 c_i + \eta_6 t + \eta_7 \ln(s_k)_{it} + \eta_8 \ln(s_h)_{it} + \eta_9 \ln(n+g+\delta)_{it} + \epsilon_{it}, \tag{6}$$

The model above reduces to (3) where the augmented Solow model is year and cluster (c_i) specific, with $f(z_{it}) = (\eta_1 z_{it} + \eta_2 z_{it}^2 + \eta_3 c_i + \eta_4 z_{it} c_i + \eta_5 z_{it}^2 c_i)/\psi_1$.[10]

Subsequently, we put forward a causal analysis using a Generalized Propensity Score (GPS) method (Hirano and Imbens 2004). This is a generalization of the propensity score method for continuous treatments. Accordingly, we estimate a fixed-effect model to predict each treatment using controls and a country-specific intercept, as

$$E[z_{it}] = \hat{z}_{it} = \eta_{0,i} + t + \eta_1 \ln(y)_{i,t-1} + \eta_2 \ln(s_k)_{it} + \eta_1 \ln(s_h)_{it} + \eta_3 \ln(n+g+\delta)_{it}, \tag{7}$$

where y denotes the log of real per capita GDP, $\ln(Y/L)$. The resulting predicted treatment $\hat{z}_{it}$ and its square is then included in a regression model to predict the outcome x_{it}, which is either the log-GDP or its growth rate, as in

$$E[x_{it}] = \omega_0 + \omega_1 z_{it} + \omega_2 z_{it}^2 + \omega_3 \hat{z}_{it} + \omega_4 \hat{z}_{it}^2 + \omega_5 \hat{z}_{it} \times z_{it} + \omega_6 cluster_i \times z_{it} + \omega_7 cluster_i \times z_{it}^2, \tag{8}$$

together with the treatment, its square, and interactions of treatment and GPS with cluster indicators. The resulting predicted *dose-response* surface can be used to assess

[10] Notice that non-linear (i.e., quadratic) effects are needed in (6) as they are found to be significant in the data. Hence, omitting them would lead to bias in the other parameter estimates.

causal relationships between the treatment and endpoint, as discussed in Hirano and Imbens (2004) and references therein.

We note that a limitation of the GPS method is that it requires a selection-on-observables assumption, unlike Instrumental Variables (IV), Difference-in-Differences (DiD), and similar methods. The latter is not simply applicable in our context anyway as reliable IV are not available for our setting; and complex dose-response relationships are not amenable to assumptions underlying the DiD method. Similar reasoning about these assumptions applies for instance to panel cointegration methods and Generalized Method of Moments (GMM) estimation.

3 Data

To construct our sample, we merge information from three different sources. Our final sample contains country-level data for 80 countries from 1980 to 2015 taken over every fifth year.[11] Our main dependent variable is the real per capita GDP (y) taken from The World Bank (2018). We used this variable to construct our second dependent variable, which is the 5 years average growth rate of the real per capita GDP ($Growth$). This leaves us with seven data points for each country while at the same time controlling for initial income (y_{t-1}) which starts from 1980. Data on the total population used in constructing effective labor ($n + g + \delta$) and the investment share (I/GDP) that are seen to affect GDP dynamics were also taken from The World Bank (2018). The rate of human capital accumulation has been proxied by the Human Capital Index (HC) taken from the PWT (2018).

Finally, the variables used in the construction of our optimal institutional indices were taken from the Fraser Institute (2018) database.[12] The optimal summary index (z) and the optimal sub-indices ($z_i, i = 1, \ldots, 5$) have been obtained by applying the methodology proposed in Sect. 2.1. Specifically, the summary index, z is constructed from the sub-indices *Public sector size* (z_1), *Reliability and fairness of the legal system* (z_2), *Liquidity market openness* (z_3), *Degree of (trade) protectionism* (z_4), and *Regulation* (z_5). As part of our investigation, we will conduct several robustness analyses with the five optimal sub-indices of institutions (z_1 to z_5) as alternative treatments to the overall institutional variable z. A detailed description of the Fraser Institute (2018) variables used to construct our treatment indices and the variables employed in our regressions can be found in Tables 11 and 12 in the Appendix.

Table 1 presents the summary statistics of key variables used in the analysis. Overall, there are 560 observations across 80 countries for 7-year periods taken every fifth year.

[11] The sample is consistent across estimations and consists of a balanced panel, as required by the threshold analysis presented in Sect. 4.5. We exclude from the analysis all the countries for which data are missing. South Korea has been excluded from the final sample because the time patterns for all institutional indices greatly deviate from the relative sample averages. Including South Korea implies less precise estimates and a downsizing of the parameters referred to the institutional indices. This appears incongruous, since South Korea is a well documented example of a growth enhancing interaction between institutions and private sector (see, e.g. Glaeser et al. 2004). For the sake of completeness, Tables 13 and 14, in the Appendix, report the results of the models for GDP level and growth rate presented in the next section, including South Korea. All the remaining estimates are available upon request.

[12] For a detailed description of the raw data, see Gwartney and Lawson (2003).

Table 1 Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
$\ln(y)$	560	8.562	1.586	5.391	11.583
$Growth$	560	0.077	0.121	−0.441	0.519
$\ln(n+g+\delta)$	560	0.135	0.053	0.023	0.383
$\ln(I/GDP)$	560	3.028	0.346	0.092	3.973
$\ln(HC)$	560	0.794	0.311	0.038	1.320
z	560	7.084	2.004	0	10
z_1	560	4.463	2.346	0	10
z_2	560	5.548	2.933	0	10
z_3	560	1.952	2.178	0	10
z_4	560	2.626	2.278	0	10
z_5	560	4.488	2.607	0	10
$cluster$	560	0.288	0.453	0	1

On average, the natural logarithm of real per capita GDP is about 8.56 (equivalent to 5218 (in millions of US Dollars)), and countries' GDP growth rates are approximately 0.08. The average institutional index is approximately 7.1 (score out of 10). The analysis also includes the binary variable '$cluster$', which is 1 for "high-income" countries and zero otherwise.[13] Table 2 reports the correlation matrix among key variables.

4 Results

4.1 Regime Membership

To partially remove effects of initial conditions, we classify countries with respect to their initial per capita GDP in 1980 (y_0). Clearly some countries will move to other clusters and others will persist in their initial cluster. By adjusting we remove confounding due to the initial status of each country. Using the Bayesian Information Criterion (BIC) and as suggested by the Classification Trimmed Likelihood (CTL) curves (Garcia-Escudero et al. 2011; Farcomeni and Greco 2015) presented in Fig. 1, we identify two clusters. The figure shows the objective function at convergence for the different number of clusters and increasing trimming levels α. The curves for $k = 2, 3, 4$ clusters almost overlap, while there is a gap for $k = 1$ versus $k = 2$, indicating that the optimal number of groups is $k = 2$.

We are then left with a predictable grouping reported in Table 3. This leads to the variable '$cluster$', the indicator of being a "high-income" country (Cluster 2). Overall, there are 23 "high-income" countries out of the 80 countries in our sample.[14]

[13] See Section 4.1 for details.

[14] As a robustness check, we run our classification using the average GDP, obtaining basically the same cluster composition (i.e., only Cyprus and Portugal move from a cluster to another). This does not affect the main message of our estimates.

Table 2 Correlation matrix for key variables

	$Growth$	$\ln(y)$	$\ln(y_0)$	$\ln(n+g+\delta)$	$\ln(I/GDP)$	$\ln(HC)$	z	z_1	z_2	z_3	z_4	z_5
$Growth$	1.000											
$\ln(y)$	0.139	1										
$\ln(y_0)$	0.063	0.997	1.000									
$\ln(n+g+\delta)$	−0.253	−0.599	−0.584	1.000								
$\ln(I/GDP)$	0.489	0.285	0.251	−0.083	1.000							
$\ln(HC)$	0.182	0.853	0.843	−0.624	0.228	1.000						
z	0.157	0.288	0.275	−0.188	0.201	0.224	1.000					
z_1	−0.034	0.732	0.737	−0.521	0.165	0.569	0.451	1.000				
z_2	0.050	0.672	0.671	−0.455	0.145	0.542	0.273	0.650	1.000			
z_3	−0.244	−0.238	−0.218	0.168	−0.215	−0.222	−0.880	−0.286	−0.327	1.000		
z_4	−0.157	−0.523	−0.509	0.371	−0.116	−0.511	−0.305	−0.358	−0.468	0.317	1.000	
z_5	−0.014	0.132	0.128	0.008	0.081	0.182	−0.088	0.052	0.253	−0.073	−0.067	1.000

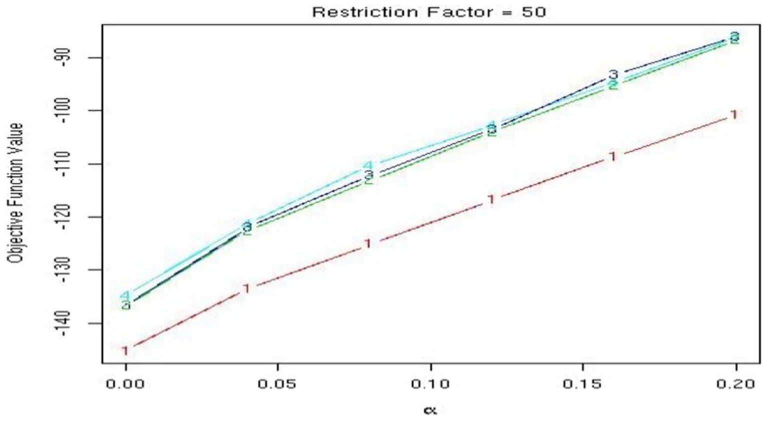

Fig. 1 CTL curves

Table 3 Classification of countries based on initial income (1980)

Cluster 1 (Low- and middle-income)			Cluster 2 (High-income)	
1 Algeria	20 Fiji	39 Nicaragua	58 Australia	77 Sweden
2 Argentina	21 Gabon	40 Niger	59 Austria	78 Switzerland
3 Bangladesh	22 Ghana	41 Nigeria	60 Bahrain	79 United Kingdom
4 Benin	23 Guatemala	42 Pakistan	61 Belgium	80 United States
5 Bolivia	24 Honduras	43 Panama	62 Canada	
6 Botswana	25 India	44 Paraguay	63 Denmark	
7 Brazil	26 Indonesia	45 Peru	64 Finland	
8 Burundi	27 Iran	46 Philippines	65 France	
9 Cameroon	28 Jamaica	47 Portugal	66 Greece	
10 Chile	29 Jordan	48 Senegal	67 Ireland	
11 China	30 Kenya	49 Sierra Leone	68 Israel	
12 Colombia	31 Madagascar	50 South Africa	69 Italy	
13 Congo, Rep.	32 Malawi	51 Sri Lanka	70 Japan	
14 Costa Rica	33 Malaysia	52 Thailand	71 Luxembourg	
15 Cote d'Ivoire	34 Mali	53 Togo	72 Netherlands	
16 Cyprus	35 Mauritius	54 Tunisia	73 New Zealand	
17 Ecuador	36 Mexico	55 Turkey	74 Norway	
18 Egypt	37 Morocco	56 Uruguay	75 Singapore	
19 El Salvador	38 Nepal	57 Zimbabwe	76 Spain	

Countries were clustered according to their initial income in the year 1980

Table 4 Mixed-effect estimates: institutions and GDP level

	Overall	Sub-indices				
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Log of Real per capita GDP						
z	0.001	−0.042	0.058***	−0.035**	−0.018	0.015
	(0.020)	(0.028)	(0.018)	(0.018)	(0.017)	(0.016)
z^2	0.0001	0.008**	−0.004**	0.003*	0.002	−0.001
	(0.002)	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)
$cluster$	2.432***	2.206***	2.700***	2.426***	2.530***	2.477***
	(0.442)	(0.389)	(0.397)	(0.221)	(0.222)	(0.231)
$z \times cluster$	0.046	0.111	−0.094	0.070	−0.056	0.012
	(0.114)	(0.097)	(0.095)	(0.050)	(0.056)	(0.029)
$z^2 \times cluster$	−0.005	−0.012*	0.008	−0.008	0.016	−0.001
	(0.008)	(0.008)	(0.007)	(0.005)	(0.015)	(0.003)
$Year$	0.011***	0.011***	0.012***	0.011***	0.011***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$\ln(n + g + \delta)$	−0.412	−0.332	−0.420	−0.379	−0.325	−0.376
	(0.325)	(0.321)	(0.315)	(0.322)	(0.324)	(0.324)
$\ln(I/GDP)$	0.102***	0.100***	0.093***	0.100***	0.101***	0.104***
	(0.030)	(0.031)	(0.030)	(0.030)	(0.030)	(0.030)
$\ln(HC)$	0.587***	0.603***	0.535***	0.600***	0.574***	0.580***
	(0.156)	(0.154)	(0.153)	(0.154)	(0.156)	(0.157)
$Intercept$	6.945***	6.965***	6.856***	7.001***	6.977***	6.914***
	(0.176)	(0.174)	(0.175)	(0.175)	(0.178)	(0.177)

In model 1, we have estimates with the main institution index (z). The sub-index ($z_i; i = 1, \ldots, 5$) used in the various specification (models 2–6) are as follows: 2—Public sector size (z_1), 3—Reliability and fairness of the legal system (z_2), 4—Liquidity market openness (z_3), 5—Degree of (trade) protectionism (z_4), 6—Regulation (z_5). Standard errors are in parentheses and $*p < 0.10$, $**p < 0.05$, $***p < 0.01$ represent levels of significance

4.2 Estimates

4.2.1 Institutions and GDP level

Table 4 reports the results of the model for GDP level using the *Main institutional index* (Model 1) and the five sub-indices (Models 2–6).

In the analysis conducted on the whole sample, we find that the effect on the long-run level of income of our aggregate institutional index (z) is essentially null in "low- and middle- income" countries (0.001) while it is positive (despite not statistically significant) in "high-income" countries (0.046). Parameter estimates for physical capital (0.102) and human capital (0.587), which are both statistically significant, are in line with the recent empirical literature based on MRW.[15]

[15] See, e.g., Bucci et al. (2022), for a study on non-OECD countries, and Bucci et al. (2019), for a study on OECD countries.

The results presented in the remaining five alternative specifications (models 2–6) employ a set of covariates including one sub-index in each estimation. For "low- and middle-income" countries, the sub-index *Reliability and fairness of the legal system* (model 3) positively (0.058) and significantly (p value < 0.001) affects the level of income in the long-run while we find a negative impact of the *Liquidity market openness* (model 4) sub-index (−0.035, with a p value < 0.005).[16]

4.2.2 Institutions and GDP growth

The analysis conducted on the whole sample shows that improvements in the main institutional index (z) foster economic development in "low- and middle-income" countries.

Table 5 reports the estimates of the growth regression model. The index z is found to have a positive impact (0.030 with a p value < 0.01) on the 5-year average real per capita GDP growth rate (model 1). The effect is not conclusive for "high-income" countries since the parameter for the interaction $z \times cluster$ is not statistically significant. The coefficients for physical capital (0.159) and human capital (0.182) are in line with the literature based on MRW while the coefficient for the lagged value of GDP (−0.061) indicates that there is a slight tendency toward convergence in our sample.

The results for the baseline growth regression when using the five alternative synthetic sub-indices taken in isolation are reported in models 2–6 of the table. There is evidence of *Public sector size* (z_1) being harmful to growth for "low- and middle-income" countries (−0.025, p value < 0.05) while the GDP growth effect of the *Degree of (trade) protectionism* (z_4) is negative in "high-income" countries (−0.070, p value < 0.01).

4.2.3 Estimates with all five sub-indices of institutions

Results in Table 6 present estimates for using all the five sub-indices of institutions ($z_i : i = 1, \ldots, 5$) as regressors together with the other covariates. From model 1 of the table, we find a positive and statistically significant impact on GDP (0.056, p value < 0.01) of the sub-index *Reliability and fairness of the legal system* in "low- and middle-income" countries.

In the growth specification (model 2), the sub-indices that have statistically significant effects are *Public sector size* for "low- and middle-income" countries (−0.027, p value < 0.05) and the *Degree of (trade) protectionism* (z_4) for "high-income" countries (−0.054, p value < 0.05).

4.3 Generalized Propensity Score Analysis

We use the Generalized Propensity Score (GPS) estimator to evaluate the causal effect of each treatment on GDP dynamics. Tables 7 and 8 report the estimates while Figs. 2

[16] This index is meant to capture the relative tightness (low values of the index) or ease of monetary policy (high values of the index). See Table 11 in the Appendix for further details.

Table 5 Mixed-effect estimates: institutions and GDP growth

	Overall	Sub-indices				
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Real per capita GDP growth						
z	0.030***	−0.025**	0.009	−0.002	0.004	0.014*
	(0.009)	(0.012)	(0.008)	(0.008)	(0.008)	(0.007)
z^2	−0.002**	0.003*	−0.001	−0.001	−0.001	−0.001
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
$cluster$	0.159	0.199**	0.234	0.016	0.081***	0.064*
	(0.173)	(0.095)	(0.159)	(0.030)	(0.028)	(0.039)
$z \times cluster$	−0.030	−0.035	−0.069	−0.001	−0.070***	−0.006
	(0.048)	(0.031)	(0.045)	(0.022)	(0.026)	(0.014)
$z^2 \times cluster$	0.002	0.001	0.005*	0.001	0.012*	0.000
	(0.003)	(0.003)	(0.003)	(0.002)	(0.007)	(0.001)
$Year$	−0.0001	0.0001	0.0003	−0.0003	0.0002	0.0001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\ln(y)_{-1}$	−0.061***	−0.061***	−0.063***	−0.058***	−0.056***	−0.061***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)	(0.009)
$\ln(n+g+\delta)$	−0.724***	−0.770***	−0.700***	−0.700***	−0.643***	−0.688***
	(0.125)	(0.126)	(0.126)	(0.123)	(0.120)	(0.12)5
$\ln(I/GDP)$	0.159***	0.176***	0.171***	0.158***	0.166***	0.171***
	(0.013)	(0.014)	(0.013)	(0.013)	(0.013)	(0.013)
$\ln(HC)$	0.182***	0.186***	0.176***	0.183***	0.151***	0.175***
	(0.039)	(0.039)	(0.039)	(0.039)	(0.038)	(0.039)
$Intercept$	−0.057	0.047	0.009	0.056	0.011	−0.022
	(0.072)	(0.072)	(0.070)	(0.069)	(0.070)	(0.071)

See notes under Table 4

Table 6 Mixed-effect model, institutions and GDP -level/-growth

	(1)		(2)	
z_1	−0.034	(0.028)	−0.027**	(0.012)
z_2	0.056***	(0.018)	0.005	(0.008)
z_3	−0.030*	(0.018)	−0.004	(0.008)
z_4	−0.012	(0.017)	0.006	(0.008)
z_5	0.006	(0.016)	0.011	(0.007)
z_1^2	0.007*	(0.004)	0.003*	(0.002)
z_2^2	−0.004*	(0.002)	−0.001	(0.001)
z_3^2	0.003	(0.002)	−0.001	(0.001)
z_4^2	0.002	(0.002)	−0.001	(0.001)
z_5^2	0.000	(0.002)	−0.001	(0.001)
$cluster$	2.080***	(0.547)	0.356*	(0.203)
$z_1 \times cluster$	0.116	(0.099)	−0.019	(0.032)
$z_2 \times cluster$	−0.056	(0.108)	−0.061	(0.047)
$z_3 \times cluster$	0.074	(0.053)	−0.001	(0.024)
$z_4 \times cluster$	−0.074	(0.059)	−0.054**	(0.027)
$z_5 \times cluster$	0.007	(0.030)	−0.004	(0.014)
$z_1^2 \times cluster$	−0.012	(0.008)	0.000	(0.003)
$z_2^2 \times cluster$	0.006	(0.008)	0.005	(0.003)
$z_3^2 \times cluster$	−0.009	(0.006)	0.002	(0.003)
$z_4^2 \times cluster$	0.021	(0.015)	0.008	(0.007)
$z_5^2 \times cluster$	0.0003	(0.003)	−0.00001	(0.001)
$Year$	0.011***	(0.002)	−0.0001	(0.001)
$\ln(y)_{-1}$			−0.053***	(0.010)
$\ln(n+g+\delta)$	−0.476	(0.331)	−0.718***	(0.129)
$\ln(I/GDP)$	0.097***	(0.031)	0.158***	(0.013)
$\ln(HC)$	0.685***	(0.159)	0.167***	(0.040)
$Intercept$	6.838***	(0.183)	0.037	(0.079)

Models (1) and (2) use the log of real per capita GDP and GDP growth rates as dependent variables. See notes under Table 4

and 3 present dose-response curves for "high-income" (solid line) and "low- and middle-income" (dotted line) countries in models 1–6.

From Table 7 and Fig. 2, we see that with the partial exception of *Public sector size* (z_1) (see the second plot of Fig. 2 in which the dotted lines do not always lie above the solid ones), an improvement in institutions causes a more pronounced level effect on GDP in "high-income" countries.

Estimates in Table 8 and dose-response curves in Fig. 3 exhibit some form of non-linearity in the causal effect of institutions on growth.[17] The overall index (z) and

[17] Our aim is to contribute to the empirical literature pointing out that non-linearities matter for understanding economic growth. For a discussion on the relationship between policy evaluation and growth non-linearities see, e.g., Cohen-Cole et al. (2012)

Table 7 GPS estimates: institutions and GDP level

	Overall	Sub-indices				
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Log of Real per capita GDP						
z	0.068	−0.152	−0.057	0.015	−0.281***	0.017
	(0.118)	(0.111)	(0.087)	(0.090)	(0.076)	(0.086)
z^2	0.020	−0.156***	0.008	0.007	0.036***	−0.012
	(0.012)	(0.032)	(0.015)	(0.012)	(0.010)	(0.008)
$\hat{z}$	0.254	0.701***	0.069	−0.128	−0.678***	0.250**
	(0.242)	(0.120)	(0.117)	(0.119)	(0.103)	(0.127)
$\hat{z}^2$	0.006	−0.214***	0.011	0.039	0.070***	−0.037**
	(0.026)	(0.039)	(0.021)	(0.024)	(0.020)	(0.018)
$cluster$	1.857	3.563***	2.625*	2.928***	1.189***	2.557***
	(1.839)	(0.553)	(1.357)	(0.187)	(0.202)	(0.309)
$z \times \hat{z}$	−0.049*	0.359***	0.000	−0.022	−0.026	0.019
	(0.029)	(0.068)	(0.029)	(0.029)	(0.022)	(0.016)
$z \times cluster$	0.225	−0.342*	−0.080	−0.116	0.531**	0.059
	(0.497)	(0.195)	(0.388)	(0.205)	(0.230)	(0.140)
$\hat{z}^2 cluster$	−0.012	0.001	−0.003	0.001	−0.058	0.000
	(0.034)	(0.018)	(0.027)	(0.024)	(0.063)	(0.014)
$Intercept$	6.622***	6.142***	7.259***	7.802***	9.759***	7.273***
	(0.707)	(0.203)	(0.213)	(0.129)	(0.175)	(0.256)

Models 1 to 6 uses the main institutional index and the sub-indices in the various estimations. See notes under Table 4

sub-indices—with the exception of z_4 for "low- and middle-income" countries—display a concave pattern.

The non-linear relationship in the causal effect of *Public sector size* (z_1) on GDP growth rate is reminiscent of Barro (1990). Public provision of infrastructure, rule of law, and protection of property rights is particularly important for growth in the early phases of the economic development. In Panel (2) of Fig. 3, the dotted curve lays above the solid one for $z_1 \geq 5$, suggesting that, to exert a positive effect on growth in "low- and middle-income" countries, the size of the public sector cannot be too low. However, as it gets too large, distortionary effects due to high taxes and public borrowing, as well as diminishing returns to public capital may emerge.[18]

The non-monotonic effect of the strength of regulation (z_5) on GDP growth in the cluster of "high-income" countries seems to capture the stylized fact that a heavier regulatory burden tends to reduce productivity growth in OECD countries.[19]

Trade protectionism (z_4) appears to be an important source of growth in "low- and middle-income" countries. Despite far from been conclusive, this result is consis-

[18] The tendency toward a negative growth effect of a large public sector in rich countries is in line with the empirical literature on the topic (see, e.g., Fölster and Henrekson 1999).

[19] See, e.g., Loayza et al. (2005), Bassanini and Ernst (2006) and Barone and Cingano (2011).

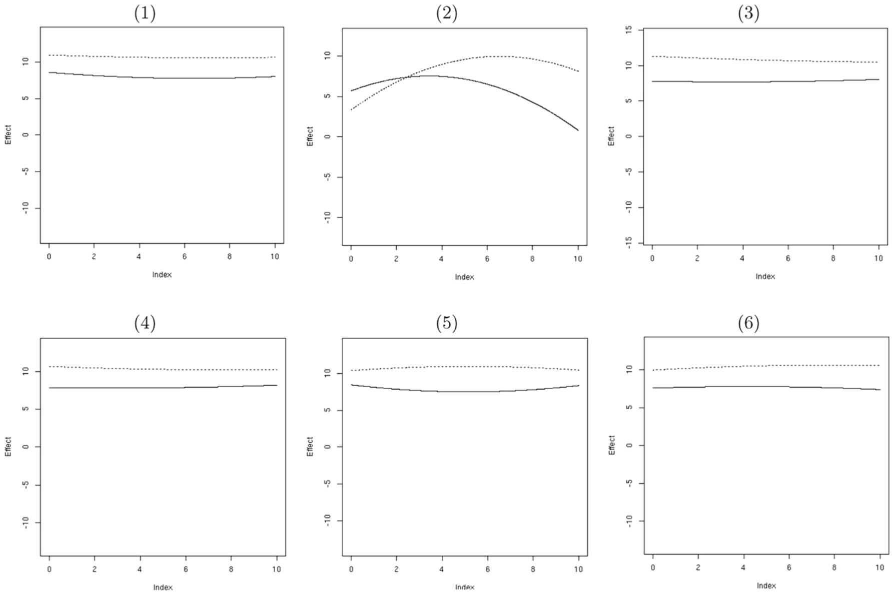

Fig. 2 Dose-response: causal effect of institutions on GDP level. *Note*: The treatments used in the various panels are (1)—Main institutional index (z), (2)—Public sector size (z_1), (3)—Reliability and fairness of the legal system (z_2), (4)—Liquidity market openness (z_3), (5)—Degree of (trade) protectionism (z_4), (6)—Regulation (z_5)

tent with the correlation between protectionist or inward-oriented trade strategies and growth in the so-called "first era of globalization".[20]

4.4 Sub-sample Analysis

With the copious number of studies revealing institutional lapses in developing countries, Tables 15, 16, and 17 as well as Tables 18 and 19 (all of them in the Appendix) report results of the analysis conducted on a restricted sub-sample of "low- and middle-income" countries when using the mixed effect and GPS approaches, respectively.[21] Notice that in this sub-sample analysis, we do not include the interaction $z - cluster$, since it is not identifiable in the sub-sample. The reason is that we stratified by cluster and this variable is a constant in each sub-sample.

From the results presented in Tables 15 and 16, we find no significant effect of institutions on GDP level but a positive linear effect (0.027, p value < 0.01) on its growth rate. In terms of the sub-indices, we observe a non-linear relationship between GDP dynamics and *Public sector size* (z_1) as well as *Degree of (trade) protectionism* (z_6), such that increases in the sub-indices causes higher income and faster growth

[20] See, e.g., Schularick and Solomou (2011).

[21] Estimates from the sample excluding countries such as Chile, Malaysia, Portugal, and Uruguay from the sample are available upon request. These four countries were in the high-income group according to the World Bank income classification as of the year 2015.

Table 8 GPS estimates: institutions and GDP growth

	Overall	Sub-indices				
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Real per capita GDP growth						
z	0.046***	0.008	0.011	0.004	0.019*	0.017
	(0.015)	(0.017)	(0.012)	(0.011)	(0.011)	(0.011)
z^2	−0.005***	−0.014***	−0.003	−0.005***	−0.002	−0.003***
	(0.002)	(0.005)	(0.002)	(0.002)	(0.001)	(0.001)
$\hat{z}$	−0.066**	0.000	−0.023	−0.042***	−0.044***	0.026
	(0.030)	(0.019)	(0.016)	(0.014)	(0.014)	(0.016)
$\hat{z}^2$	0.004	−0.011*	0.000	0.004	0.005*	−0.005**
	(0.003)	(0.006)	(0.003)	(0.003)	(0.003)	(0.002)
$cluster$	0.036	0.076	0.034	−0.011	0.015	0.043
	(0.227)	(0.086)	(0.186)	(0.023)	(0.028)	(0.039)
$z \times \hat{z}$	0.004	0.024**	0.004	0.005	−0.002	0.003
	(0.004)	(0.011)	(0.004)	(0.004)	(0.003)	(0.002)
$z \times cluster$	0.004	−0.028	−0.019	−0.025	−0.085***	−0.018
	(0.061)	(0.030)	(0.053)	(0.025)	(0.032)	(0.018)
$z^2 \times cluster$	−0.001	0.003	0.001	0.006*	0.014	0.002
	(0.004)	(0.003)	(0.004)	(0.003)	(0.009)	(0.002)
$Intercept$	0.111	0.075**	0.098***	0.138***	0.151***	−0.011
	(0.087)	(0.032)	(0.029)	(0.016)	(0.024)	(0.033)

Models 1 to 6 uses the main institutional index and the sub-indices in the various estimations. See notes under Table 4

only if they do not exceed values around 4. There is also a significant non-linear relationship between GDP growth and *Liquidity market openness* (z_4) but the effect is weak (−0.001, p value < 0.10) and decreases at higher values of the index.

Such non-linearities appear even clearer from the dose-response curves shown in Figs. 4 and 5. The beneficial effect on GDP due to improvements in institutions (z) emerges only for higher values of the index ($z > 5$), as shown in Panel (1) of Fig. 4. Almost the opposite instead occurs when we assess the causal impact of z on GDP growth, with a dose-response plot showing a concave pattern, as illustrated in Panel (1) of Fig. 5.

4.5 Threshold Effects

We have documented that improvements in a country's institutional indices produce different effects on GDP (levels and growth rates), depending on whether the country belongs to the "high-income" or the "low- and middle-income" cluster. The analysis presented in Sect. 4.3 provides evidence about the possible non-linear *causal* effects of institutions on GDP dynamics. Those estimates, however, pertain to the reduced form regressions (7) and (8) which go beyond the standard (log-)linear growth model. To

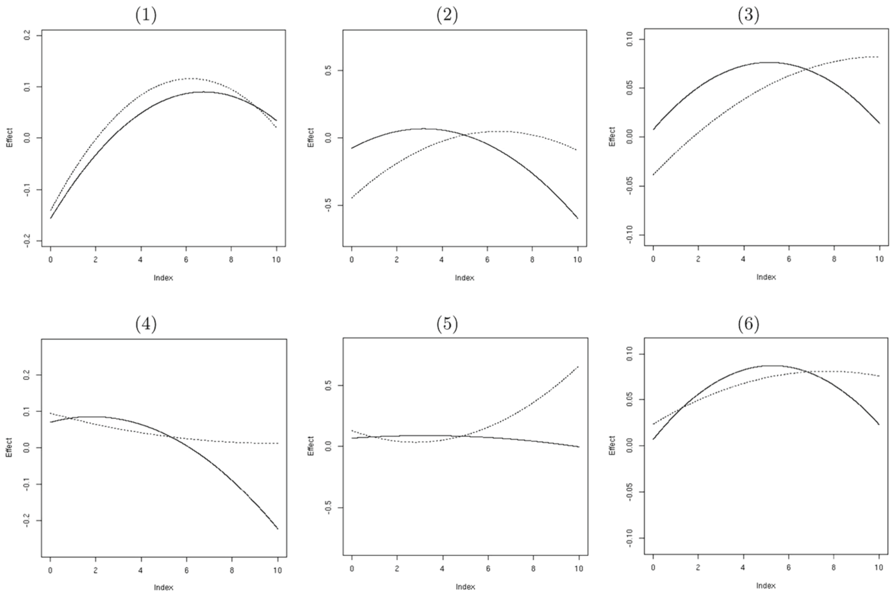

Fig. 3 Dose-response: causal effect of institutions on GDP growth. *Note*: See notes under Fig. 2

reconcile the issue of non-linear effects with the canonical growth model, we carry on a threshold analysis which incorporates all the restrictions provided by the augmented Solow model presented in Sect. 2.2.

To test for the presence of potential threshold effects within the various classifications provided in Table 3, we employ the dynamic panel threshold strategy proposed by Seo and Shin (2016), which allows for non-linear asymmetric dynamics, unobserved heterogeneity, and treats economic institutions as an endogenous variable.[22] For the sake of space, we restrict our attention to the relationship between the main institutional index, (z) and the GDP growth rate.

The model considered is of the form:

$$\triangle y_{it} = \lambda \triangle y_{it-1} + \triangle x'_{it}\beta + (1, x'_{it})\delta 1\{\hat{z}_{it} > \gamma\} - (1, x'_{it-1})\delta 1\{\hat{z}_{it-1} > \gamma\} + \triangle \epsilon_{it}, \tag{9}$$

where y_{it} is the natural logarithm of real per capita GDP, z_{it} is our optimal measure of institutions (transition variable) and x_{it} is a set of covariates including natural logarithms of total population, human and physical capital. Also, γ is the threshold parameter and the error term, ϵ_{it}. We used lagged values of political institutions as one of the instruments that lead to the selection of economic institutions together with the other exogenous covariates in an attempt to address the issue of endogeneity. The use of this instrument is motivated by the *hierarchy of institutions* hypothesis introduced by Acemoglu et al. (2005) where political institutions have been documented to set the stage for their economic institutional counterparts which affect economic outcomes

[22] Acquah (2021) follows a similar exercise (refer for further details on the methodology).

of a country.[23] From equation (9), the hypothesis of interest is the null, $H_0 : \delta = 0$ as against the alternative $H_1 : \delta \neq 0$.

Using the first difference generalized method of moments estimator (FD-GMM), Models 1, 2, and 3 of Table 9 presents the results with the full sample of 80 countries, "high-income", and "low- and middle-income" countries, respectively. To have comparable results, we report the estimated coefficients for countries below (ϕ) and above (τ) the estimated threshold effects in each cluster, respectively.

Following the old "rule of thumb" (see Steiger and Stock 1997; Stock and Yogo 2002) which says for the weak identification surrounding the instrumental variable not to be considered a problem, the F-statistics should be at least 10, we found the F-statistic to be above 10 for "high-income" countries and close to the 10 for "low- and middle-income" countries and the overall sample. In general, the estimated threshold effects ($\hat{\gamma}$) are statistically significantly different from zero and similar to those reported in Acquah (2021) who used the original institutional indices from the Fraser Institute (2018) in a similar estimation approach. Particularly, for economic institutions to influence GDP growth, it must on average develop to a point of 6, 8, and 7 (out of a score of 10) for the full sample of 80, "high-income" and "low- and middle-income" countries, respectively. Since the threshold variable is unit-free, we interpret the estimated long-run effect of institutions towards GDP growth in reference to the estimated threshold parameter ($\hat{\gamma}$) as a way of providing some understanding into the gains or losses of institutions for countries whose institutional developments are below ($\hat{\phi}_{\triangle q}$) and above ($\hat{\tau}_{\triangle q}$) the estimated threshold effect in what follows. From Table 9, we observe a significant difference in the parameter estimates of countries above and below the estimated threshold effect when using our institutional index. Above the estimated threshold effect of 8 (out of 10), changes (if the change persists for 5 years) in our institutional index leads to an increase in the growth rate of "high-income" countries by 0.4 percentage points (Model 2). The corresponding effect is positive for "low- and middle-income" countries but statistically not significant and negative in the overall sample. Interestingly, below the threshold of 7 (out of 10), improvements in the institutional measure are associated with an increase in the GDP growth rate by 0.026 percentage points for the "low- and middle-income" countries (Model 3). The coefficient estimates of the other variables are equally different in magnitude and/or signs for the sample above and below the threshold effect in Models 1–3.

4.6 Instrumental Variables

In this section, we assess how our institutional measures perform in comparison to the most frequently used proxy for institution, namely the *Rule of law index*, within a framework that puts the joint role of institutions and human capital center stage.[24] To do this we estimate a more parsimonious model in which both our institutional measures and human capital are simultaneously treated as endogenous and instrumented using historical variables. Specifically, we use i) the mortality rate of European settlers in former colonies to instrument country's institutional quality, as in Acemoglu et al.

[23] See Acquah (2021) and references therein for a detailed discussion of this point.

[24] We thank an anonymous referee for this suggestion.

Table 9 Institutional threshold effects

	(1)	(2)	(3)
	Dependent variable: Real per capita GDP growth		
$\hat{\gamma}$	6.146***	8.213***	7.003***
	(0.162)	(0.276)	(0.560)
	Estimates below the threshold		
$\phi_{\triangle y_{-1}}$	0.826***	0.427**	0.877***
	(0.014)	(0.193)	(0.021)
$\phi_{\triangle z}$	0.004	0.016	0.026***
	(0.002)	(0.019)	(0.004)
$\phi_{\triangle (n+g+\delta)}$	−0.040	−0.085	0.065
	(0.026)	(0.183)	(0.050)
$\phi_{\triangle (I/GDP)}$	0.016**	−0.152	0.056***
	(0.007)	(0.241)	(0.017)
$\phi_{\triangle HC}$	0.847***	1.764***	0.494***
	(0.084)	(0.593)	(0.098)
	Estimates above the threshold		
$\tau_{\triangle y_{-1}}$	−0.015***	−0.098	−0.071***
	(0.005)	(0.140)	(0.014)
$\tau_{\triangle z}$	−0.015***	0.439***	0.004
	(0.004)	(0.104)	(0.014)
$\tau_{\triangle (n+g+\delta)}$	−0.005*	−0.149	−0.041***
	(0.003)	(0.124)	(0.007)
$\tau_{\triangle (I/GDP)}$	0.203***	0.698**	0.180***
	(0.008)	(0.349)	(0.028)
$\tau_{\triangle HC}$	−0.362***	−0.037	−0.142**
	(0.033)	(0.715)	(0.057)
$\tau_{intercept}$	−0.028	−2.913	0.699***
	(0.081)	(2.235)	(0.163)
F-statistics	9.41 [0.002]	21.02 [0.000]	8.95 [0.003]
N	80	23	57

Estimates follow equation (4) of Acquah (2021) when using the FD-GMM estimator. Results in Models 1, 2, and 3 use the full (80 countries), Clusters 2 (23 high -) and 1 (57 low- and middle-) income countries as reported in Table 3. The F-statistic [and the p-values] to test the strength of the instrumental variable (lagged values of political institutions) is the Cragg-Donald Wald F-Statistic. Standard errors in parentheses and $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$ represent levels of significance

(2001), and ii) the presence of Protestant missionary activity to instrument human capital in the former colonies, as in Acemoglu et al. (2014).[25]

[25] By instrumenting country's institutional quality with the the mortality rate of European settlers in former colonies, Acemoglu et al. (2001) provide a well known argument in favor of a virtuous link between institutions and economic prosperity. The gist of their argument is that where Europeans faced high settler mortality rates, they established *extractive* institutions that are ultimately associated with a low economic

Because the empirical model is identical to that in Acemoglu et al. (2014), we shall be brief. The dependent variable is the (log of the) current level of GDP. Table 10 presents a comparison between the estimates of the main model in Acemoglu et al. (2014), in which the *Rule of law index* is used as a proxy for institutions and the (average) *Years of Schooling* as a proxy for human capital, and two models using our institutional measures, i.e., the *Public sector size* z_1 (Model 1) and the *Reliability and fairness of the legal system* z_2 (Model 2), respectively.[26] The bottom half of the table provides the first stages for the two endogenous variables. The differences in the variables used and the estimation technique justify the differences in the magnitude of the parameters.

As in Acemoglu et al. (2014), the coefficient on human capital is positive and significant (p value < 0.001) while the coefficient on our institutional measure is positive and barely significant (p value < 0.10) in both Models 1 and 2. First stage estimates are in line with those in Acemoglu et al. (2014) and document a negative association between settlers mortality and institutions, which is statistically significant only in Model 2, and between settlers mortality and human capital, which is instead always statistically significant. These results survive to several robustness checks.[27]

Overall, the IV regressions, in which both institutions and human capital are instrumented using historical sources of variation, show a positive effect of the two variables on the current level of GDP. The effect of *Public sector size* (Model 1) and the *Reliability and fairness of the legal system* (Model 2), however, tends to be lower in magnitude and less precisely estimated than the one of the (log of) Human Capital Index. This result is in line with Glaeser et al. (2004) and the literature that suggests that human capital is a more basic source of economic prosperity than political institutions.

5 Concluding remarks

This paper contributes to the debate on the nexus among institutions and economic development in two ways. It provides a new set of indices to capture a country's institutional environment and it empirically investigates whether there is any *causality* running from institutions to economic development.

development. At the opposite, where European colonialists faced low mortality rates, they established *inclusive* institutions that fostered a sustained economic development. Acemoglu et al. (2014) establish a causal relationship among the presence of Protestant missionary activity and long-run differences in human capital in the former colonies. Their argument is that, "*conditional on the continent, the identity of the colonizer, and the quality of institutions, much of the variation in Protestant missionary activity was determined by idiosyncratic factors and need not be correlated with the potential for future economic development. Because Protestant missionaries played an important role in setting up schools, partly motivated by their desire to encourage reading of the Scriptures, this may have had a durable impact on schooling*". For a discussion on the underlying mechanisms through which these historical variables may have affected the current quality of institutions, the reader can refer to the above mentioned paper. For a detailed description of the historical variables see the Appendix of Acemoglu et al. (2014).

[26] The estimates obtained using the *main institutional index* and the sub-indices $z_3 - z_5$ are in line with those presented in Table 10 but less precise. They are omitted to save space and are available upon request. Importantly, the effect of human capital is always positive and statistically significant.

[27] The full 2SLS models estimates are available upon request.

Table 10 2SLS, a comparison with Acemoglu et al. (2014)

Second Stage	Model 1		Model 2		Acemoglu et al. (2014) (1)	
	Dependent variable: log current GDP per capita					
Human capital	2.187***		2.811***		0.223***	
Institutions	0.194*		0.164*		1.126***	
Wu-Hausman test (p-value)	0.486		0.797			
Sargan test (p-value)	0.563		0.106			
First Stage	*Dependent variables: Institutions and Human capital*					
	(z_1)	$\ln(HC)$	(z_2)	$\ln(HC)$	*Rule of law*	*Years of Schooling*
Log capped potential settler mortality	0.155	−0.419***	−0.146***	−0.146***	−0.402***	−1.042***
Log population density in 1500	0.976**	−0.074	−0.023	−0.023	−0.062	−0.131
Primary school enrollment in 1870	−0.007	0.072	0.004	0.035	−0.002	0.069***
Protestant missionaries in the early twentieth century	0.178	0.049**	−0.003	0.021	0.021	0.657*

In Model 1 *Institutions* are captured by the *Public sector size* (z_1); in Model 2 *Institutions* are captured by the *Reliability and fairness of the legal system* (z_2). $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$ represent levels of significance

Building on Fraser Institute (2018), we propose a dimension reduction approach to obtain a new set of indices to summarize the multidimensionality of a country's institutional setting. To identify the causal effect of these brand-new institutional indices on GDP (levels and growth rate) we employ the Generalized Propensity Score estimation approach. Using a large sample of countries over the period 1980–2015, our analysis documents the positive and statistically significant impact that improvements in institutions have on the growth rate of per capita GDP, in the economies that, according to our classification, belong to the cluster of "low- and middle-income". Moreover, we find a sizable effect of human capital on GDP dynamics.

Our causal analysis also shows non-linearities in the effects that different institutions have on income and growth. The empirical model used to test causality takes into account the role of physical and human capital and lets institutions interact with cluster membership. The sub-index that captures the extent of welfare state, which we term *Public sector size* (z_1), displays a concave pattern in both regression models. Improvements of this index produce gains in terms of higher income and faster growth especially in less advanced economies, provided that the value of the sub-index is not too high. Despite not always statistically significant, improvements in all the other considered institutions cause a positive level effect that is larger for "low- and middle-income" countries.

The Mixed-Effect Model also stresses reliability and fairness of the legal system as a crucial driver for economic development. This result is reminiscent of La Porta et al. (2008) and has several policy implications. Specifically, our analysis reveals that the design and the implementation of legal reforms appear to be particularly important in "low- and middle-income" countries. Policy interventions aimed at improving this institution are complex. Such interventions pertain to i) drafting and enacting of laws and regulations, ii) enforcing laws and regulations, and iii) resolving and settling disputes. Like many economists, political scientists, and legal scholars have pointed out, however, legal reforms in a society emerge as an equilibrium outcome, thus reflecting the balance between different interests of different social groups.[28] Moreover, the so-called "legal transplant" has rarely turned out to be successful.[29]

Finally, we document interesting threshold effects which support the existence of non-linearities. Again, higher values in our institutional indices, which typically translate into advances in institutional quality, are particularly important for those countries which are below the estimated threshold and belong to the cluster of "low- and middle-income" countries.

Funding Open access funding provided by Università degli Studi di Roma Tor Vergata within the CRUI-CARE Agreement.

Declarations

Conflict of interest The authors have no conflict of interest to declare.

[28] See, e.g., Besley and Ghatak (2009).

[29] See, e.g., Aldashev (2009).

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

Appendix A Variable description

See Tables 11 and 12.

Table 11 Variables used in the construction of the optimal institutional indices

Public sector size (z_1)	*Liquidity market openness* (z_3)
1A. Government consumption	3A. Money growth
1B. Transfers and subsidies	3B. Standard deviation of inflation
1C. Government investment	3C. Inflation: Most recent year
1D. Top marginal tax rate	3D. Freedom to own foreign currency bank accounts
1E. State ownership of assets	
	Degree of (trade) protectionism (z_4)
Reliability and fairness of the legal system (z_2)	4A. Tariffs
2A. Judicial independence	4B. Regulatory trade barriers
2B. Impartial courts	4C. Black market exchange rates
2C. Protection of property rights	4D. Controls of the movement of capital and people
2D. Military interference in rule of law and politics	
2E. Integrity of the legal system	*Regulation* (z_5)
2F. Legal enforcement of contracts	5A. Credit market regulations
2G. Regulatory restrictions on the sale of real property	5B. Labor market regulations
2H. Reliability of police	5C. Business regulations
Main institutional index (z)	
z_1, z_2, z_3, z_4, and z_5	

Authors' construct compiled from Fraser Institute (2018). See the Appendix Explanatory Notes and Data Sources from Fraser Institute (2018) for the detailed definition of variables

Table 12 Data description and source

Variable	Description	Source
Dependent variable		
y	Real per capita GDP based on constant 2010 international U.S. dollars	The World Bank (2018)
$Growth$	Percentage growth rate of per capita GDP (constant 2010 international U.S. dollars) based on the difference between the natural logarithms of current real per capita GDP and their past values ($(\ln)\frac{y_t}{y_{t-1}}$)	The World Bank (2018)
Main institutional index		
z	Main institutional index. It measures the extent to which the institutions and policies of a country are consistent with the protective function and the freedom of individuals in making their own economic decisions	Our elaboration on Fraser Institute (2018)
Sub-indices		
z_1	Public sector size in terms of expenditures, taxes, and public enterprises	Our elaboration on Fraser Institute (2018)
z_2	Reliability and fairness of the legal system. It measures the reliability of legal structure and the security of property rights	Our elaboration on Fraser Institute (2018)
z_3	Liquidity market openness. It captures the consistency of monetary policies with long-term price stability and the ease with which foreign currencies can be used in both domestic and foreign banks	Our elaboration on Fraser Institute (2018)
z_4	Degree of (trade) protectionism. It measures the freedom of exchange across national boundaries	Our elaboration on Fraser Institute (2018)
z_5	Regulation. It measures the strength of regulation in credit, labor, and goods and service markets	Our elaboration on Fraser Institute (2018)
Controls		
y_{-1}	Initial level of income measured as the lagged values of natural logarithms of per capita GDP (constant 2010 international U.S. dollars)	The World Bank (2018)
I/GDP	Investment rate. Physical capital measured as gross fixed capital formation (% of GDP)	The World Bank (2018)
$n + g + \delta$	Population growth + 0.05 (imposing a 3% technological growth + 2% depreciation). The population growth is the difference between current and past natural logarithms of total population based on the de facto definition of population, which counts all residents regardless of legal status or citizenship	The World Bank (2018)
HC	Human Capital Index measured as the years of schooling	PWT (2018)
$cluster$	Binary variable equals to 1 if a country is classified as "high-income" based on their initial income as at 1985 and zero others	Authors' construct from The World Bank (2018)

Sources: Authors' construct compiled from The World Bank (2018), PWT (2018), Fraser Institute (2018)

Table 13 Mixed-effect estimates: institutions and GDP level

	Overall	Sub-indices				
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Log of Real per capita GDP						
z	0.006	−0.028	0.048*	−0.037**	−0.024	0.020
	(0.015)	(0.028)	(0.029)	(0.018)	(0.020)	(0.016)
z^2	0.0002	0.007*	0.0001	0.003*	0.002	−0.001
	(0.001)	(0.004)	(0.004)	(0.002)	(0.002)	(0.002)
$cluster$	2.305***	2.449***	1.758**	2.371***	2.445***	2.446***
	(0.239)	(0.410)	(0.780)	(0.222)	(0.227)	(0.232)
$z \times cluster$	0.009	0.030	0.130	0.074	0.000	0.006
	(0.036)	(0.104)	(0.194)	(0.051)	(0.038)	(0.030)
$z^2 \times cluster$	0.001	−0.007	−0.009	−0.008	−0.001	−0.001
	(0.003)	(0.008)	(0.013)	(0.005)	(0.005)	(0.003)
$Year$	0.010***	0.011***	0.012***	0.011***	0.011***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$\ln(n + g + \delta)$	−0.551*	−0.395	−0.351	−0.402	−0.352	−0.392
	(0.331)	(0.329)	(0.325)	(0.330)	(0.331)	(0.331)
$\ln(I/GDP)$	0.113***	0.096***	0.093***	0.099***	0.098***	0.102***
	(0.031)	(0.031)	(0.030)	(0.031)	(0.031)	(0.031)
$\ln(HC)$	0.640***	0.685***	0.582***	0.653***	0.607***	0.623***
	(0.158)	(0.158)	(0.155)	(0.157)	(0.159)	(0.159)
$Intercept$	6.929***	6.929***	6.819***	7.002***	7.046***	6.909***
	(0.177)	(0.178)	(0.180)	(0.178)	(0.187)	(0.179)

In model 1, we have estimates with the main institution index (z). The sub-index (z_i; $i = 1, \ldots, 5$) used in the various specification (models 2–6) are as follows: 2—Public sector size (z_1), 3—Reliability and fairness of the legal system (z_2), 4—Liquidity market openness (z_3), 5—Degree of (trade) protectionism (z_4), 6—Regulation (z_5). Standard errors are in parentheses and $*p < 0.10$, $**p < 0.05$, $***p < 0.01$ represent levels of significance

Appendix B Estimates, including South Korea

See Tables 13 and 14.

Table 14 Mixed-effect estimates: institutions and GDP growth

	Overall	Sub-indices				
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Real per capita GDP growth						
z	0.004	−0.020	0.018	−0.003	−0.007	0.013*
	(0.007)	(0.012)	(0.012)	(0.008)	(0.009)	(0.007)
z^2	0.000	0.002	0.000	−0.001	0.000	−0.001
	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
$cluster$	0.083	0.188**	−0.249	0.012	0.051	0.057
	(0.052)	(0.093)	(0.250)	(0.030)	(0.035)	(0.038)
$z \times cluster$	−0.023	−0.039	0.079	0.003	−0.022	−0.005
	(0.017)	(0.030)	(0.068)	(0.022)	(0.017)	(0.014)
$z^2 \times cluster$	0.002	0.002	−0.006	0.001	0.003	0.000
	(0.001)	(0.003)	(0.005)	(0.002)	(0.002)	(0.001)
$Year$	0.000	0.000	0.000	−0.001	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\ln(y)_{-1}$	−0.066***	−0.061***	−0.072***	−0.061***	−0.065***	−0.064***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
$\ln(n+g+\delta)$	−0.721***	−0.779***	−0.637***	−0.706***	−0.686***	−0.697***
	(0.125)	(0.127)	(0.124)	(0.124)	(0.122)	(0.126)
$\ln(I/GDP)$	0.178***	0.178***	0.170***	0.160***	0.175***	0.175***
	(0.014)	(0.014)	(0.013)	(0.013)	(0.013)	(0.013)
$\ln(HC)$	0.190***	0.195***	0.181***	0.199***	0.170***	0.194***
	(0.040)	(0.040)	(0.039)	(0.039)	(0.039)	(0.039)
$Intercept$	0.021	0.040	0.037	0.067	0.080	−0.009
	(0.070)	(0.072)	(0.071)	(0.069)	(0.075)	(0.071)

See notes under Table 4

Table 15 Mixed-effect model, sub-sample analysis, institutions and GDP level

	Overall	Sub-indices				
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Log of Real per capita GDP						
z	0.013	−0.038	0.058***	−0.033	−0.022	0.017
	(0.023)	(0.031)	(0.020)	(0.020)	(0.020)	(0.018)
z^2	−0.001	0.007*	−0.004*	0.003	0.002	−0.001
	(0.002)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)
$Year$	0.008***	0.008***	0.009***	0.008***	0.008***	0.008***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$\ln(n+g+\delta)$	−1.127**	−1.052**	−1.165***	−1.081**	−1.070**	−1.074**
	(0.463)	(0.460)	(0.451)	(0.460)	(0.464)	(0.460)
$\ln(I/GDP)$	0.121***	0.121***	0.115***	0.120***	0.127***	0.124***
	(0.037)	(0.037)	(0.036)	(0.036)	(0.037)	(0.036)
$\ln(HC)$	0.633***	0.682***	0.603***	0.678***	0.683***	0.624***
	(0.222)	(0.221)	(0.218)	(0.221)	(0.224)	(0.221)
$Intercept$	6.984***	7.004***	6.908***	7.044***	7.006***	6.969***
	(0.220)	(0.217)	(0.216)	(0.218)	(0.220)	(0.220)

Models 1 to 6 uses the main institutional index and the sub-indices in the various estimations where: 1—Main institutional index (z), 2—Public sector size (z_1), 3—Reliability and fairness of the legal system (z_2), 4—Liquidity market openness (z_3), 5—Degree of (trade) protectionism (z_4), 6—Regulation (z_5). Standard errors are in parentheses and $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$ represent levels of significance

Appendix C Sub-sample analysis

C.1 Sub-sample estimates

The following results are estimates when using the sub-sample of 57 "low- and middle-income" countries.

See Tables 15, 16, 17, 18, 19 and Figs. 4, 5.

Table 16 Mixed-effect model, sub-sample analysis, institutions and GDP growth

	Overall	Sub-indices				
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Real per capita GDP growth						
z	0.027***	−0.024*	0.009	−0.003	0.006	0.012
	(0.010)	(0.013)	(0.009)	(0.008)	(0.009)	(0.008)
z^2	−0.002	0.003*	−0.001	−0.001	−0.001*	−0.001
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
$Year$	0.0001	0.001	0.001	0.0001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$ln(y)_{-1}$	−0.056***	−0.055***	−0.057***	−0.054***	−0.053***	−0.055***
	(0.009)	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)
$\ln(n+g+\delta)$	−0.841***	−0.811***	−0.826***	−0.834***	−0.803***	−0.808***
	(0.159)	(0.160)	(0.160)	(0.157)	(0.157)	(0.161)
$\ln(I/GDP)$	0.152***	0.171***	0.165***	0.152***	0.163***	0.166***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
$\ln(HC)$	0.176***	0.168***	0.166***	0.177***	0.147***	0.160***
	(0.042)	(0.043)	(0.042)	(0.042)	(0.041)	(0.042)
$Intercept$	−0.050	0.023	−0.003	0.061	0.013	−0.025
	(0.077)	(0.079)	(0.076)	(0.075)	(0.078)	(0.078)

See notes under Table15

Appendix D Alternative methods for construction of institutional indeces

In this appendix we give further motivation for the use of the methodology proposed in Farcomeni et al. (2021) for dimension reduction and automatic construction of institutional indices. Naive alternatives involve either (i) classical Principal Component Analysis (PCA) after treating the data as pooled cross sectional data and (ii) using all Fraser Institute variables directly as separate predictors.

The first route would not be completely scientifically sound as simple pooling would ignore dependence in the data (i.e., the fact that groups of measurements refer to the same nation at different years, and are therefore positively dependent). The consequence would be that the resulting unidimensional summary would not be internally valid. On this point see also Ando and Bai (2017) and references therein. The second route would involve an explosion of the number of parameters (e.g., when all areas are considered together, twenty four predictors would be included in the model instead of just one). This would make interpretation very cumbersome.

In the following we give also empirical evidence of the fact that the naive alternative routes would not be good choices, by comparing the leave-one-out predictions for the Gaussian mixed-effects models. Namely, we omit each measurement in turn, estimate three models (the one that uses our proposed indices, the one that uses PCA-based indices, and the one that uses institutional indicators directly), predict the omitted measurement. The final model summary is the Sum of Squared Errors (SSE) for predictions, that is, the sum of squared differences between the predictions and each

Table 17 Mixed-effect model: institutions and GDP -level/-growth

	(1)		(2)	
z_1	−0.029	(0.032)	−0.027**	(0.013)
z_2	0.056***	(0.021)	0.006	(0.009)
z_3	−0.028	(0.020)	−0.005	(0.008)
z_4	−0.014	(0.020)	0.007	(0.009)
z_5	0.008	(0.018)	0.010	(0.008)
z_1^2	0.006	(0.005)	0.003*	(0.002)
z_2^2	−0.004*	(0.002)	−0.001	(0.001)
z_3^2	0.002	(0.002)	−0.001	(0.001)
z_4^2	0.002	(0.002)	−0.001	(0.001)
z_5^2	−0.0004	(0.002)	−0.001	(0.001)
$Year$	0.008***	(0.003)	0.000	(0.001)
$\ln(y)_{-1}$			−0.049***	(0.010)
$\ln(n+g+\delta)$	−1.156**	(0.463)	−0.809***	(0.161)
$\ln(I/GDP)$	0.116***	(0.037)	0.155***	(0.015)
$\ln(HC)$	0.742***	(0.222)	0.165***	(0.044)
$Intercept$	6.888***	(0.224)	0.027	(0.086)

Models (1) and (2) uses (ln) real per capita GDP and real per capita GDP growth as dependent variable while controlling for all 5 sub-dimensions of institution where, z_1—Public sector size, z_2—Reliability and fairness of the legal system, z_3—Liquidity market openness, z_4—Degree of (trade) protectionism, z_5—Regulation. Standard errors are in parentheses and $*p < 0.10$, $**p < 0.05$, $***p < 0.01$ represent levels of significance

Table 18 GPS estimates, sub-sample analysis: institutions and GDP level

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Log of Real per capita GDP						
	Overall	Sub-indices				
z	0.053	0.030	−0.040	−0.038	−0.188**	0.013
	(0.139)	(0.159)	(0.107)	(0.108)	(0.089)	(0.107)
z^2	0.025*	−0.156***	0.008	0.007	0.034***	−0.006
	(0.015)	(0.039)	(0.018)	(0.014)	(0.012)	(0.010)
$\hat{z}$	0.513	0.386*	0.036	−0.002	−0.935***	0.423**
	(0.318)	(0.211)	(0.154)	(0.146)	(0.136)	(0.200)
$\hat{z}^2$	−0.012	−0.132**	0.019	0.016	0.108***	−0.056**
	(0.034)	(0.064)	(0.027)	(0.030)	(0.025)	(0.027)
$z \times \hat{z}$	−0.056	0.295***	−0.005	−0.011	−0.042	0.010
	(0.034)	(0.090)	(0.034)	(0.034)	(0.026)	(0.021)
$Intercept$	5.921***	6.340***	7.281***	7.724***	10.040***	6.986***
	(0.878)	(0.252)	(0.257)	(0.152)	(0.212)	(0.360)

See notes under Table 15

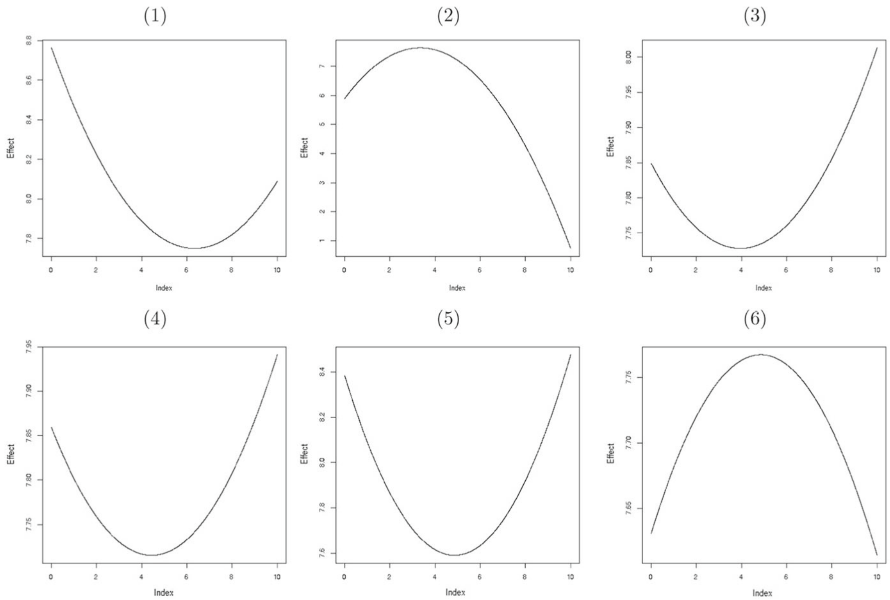

Fig. 4 Dose-response, sub-sample analysis: causal effect of institutions on GDP level. *Note*: The various plots are the dose-response curves when using the generalized propensity score estimator to evaluate the causal effect of each treatment on GDP level for low-/ middle-income from models 1–6. The various treatment are (1)—Main institutional index (z), (2)—Public sector size (z_1), (3)—Reliability and fairness of the legal system (z_2), (4)—Liquidity market openness (z_3), (5)—Degree of (trade) protectionism (z_4), (6)—Regulation (z_5)

Table 19 GPS estimates, sub-sample analysis: institutions and GDP growth

	Overall	Sub-indices				
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Real per capita GDP growth						
z	0.048***	0.005	0.020	0.007	0.021*	0.013
	0.016	0.024	0.014	0.012	0.012	0.013
z^2	−0.005***	−0.017***	−0.003	−0.005***	−0.002	−0.003**
	0.002	0.006	0.002	0.002	0.002	0.001
$\hat{z}$	−0.077**	0.000	−0.042**	−0.047***	−0.051***	0.046*
	0.037	0.032	0.020	0.017	0.019	0.024
$\hat{z}^2$	0.005	−0.014	0.004	0.005	0.006*	−0.008**
	0.004	0.010	0.004	0.003	0.003	0.003
$z \times \hat{z}$	0.004	0.030**	0.002	0.005	−0.002	0.004
	0.004	0.014	0.004	0.004	0.004	0.003
Intercept	0.131	0.079**	0.117***	0.141***	0.158***	−0.034
	0.103	0.038	0.033	0.017	0.029	0.044

See notes under Table 15

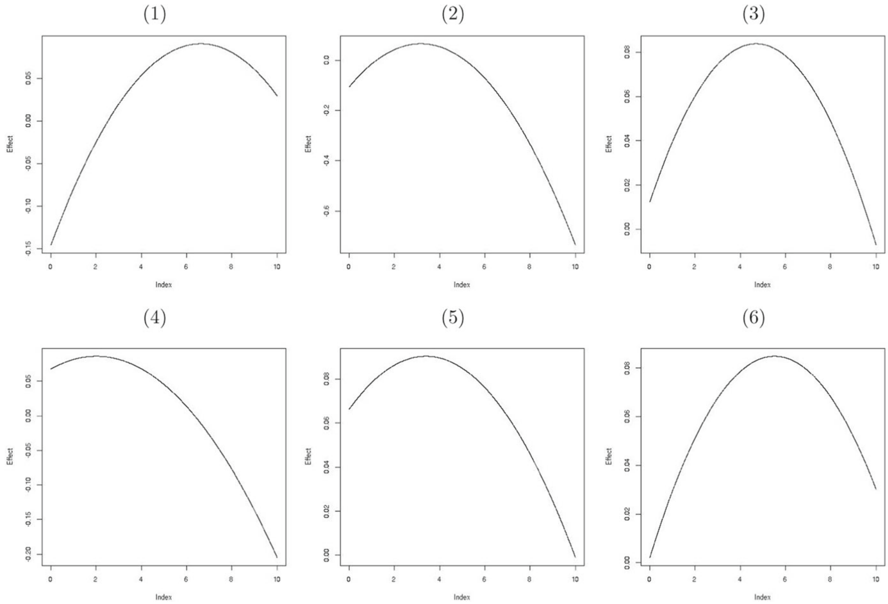

Fig. 5 Dose-response, sub-sample analysis: causal effect of institutions on GDP growth. *Note*: The various plots are the dose-response curves when using a generalized propensity score estimator to evaluate the causal effect of each treatment on GDP growth for low-/ middle-income from models 1–6. See notes under Fig. 4

Table 20 Average Sum of Squared Errors for predictions after Leave-One-Out Cross Validation for our dimension reduction strategy, pooled PCA, no dimension reduction

	GDP growth	GDP level
Proposal	3.637	16.133
PCA	3.713	16.209
Raw indicators	4.189	21.825

omitted measurement. As could be expected, our proposal overall leads to an advantage in terms of predictive performance, as the average SSE for the six models (five areas plus all areas together) involved for each outcome are always smaller with our proposal (Table 20). It shall be mentioned that this applies separately for all models when comparing with raw indicators, while some models actually have a small advantage when comparing our proposal with PCA.

References

Acemoglu D, Gallego FA, Robinson JA (2014) Institutions, human capital, and development. Annu Rev Econ 6(1):875–912

Acemoglu D, Johnson S, Robinson JA (2001) The colonial origins of comparative development: an empirical investigation. Am Econ Rev 91(5):1369–1401

Acemoglu D, Johnson S, Robinson JA (2005) Institutions as a fundamental cause of long-run growth. Handb Econ Growth 1:385–472

Acquah E (2021) Rising from the ashes: A threshold analysis of the growth effect of institutions. Available at SSRN http://ssrn.com/abstract=3782577

Aldashev G (2009) Legal institutions, political economy, and development. Oxf Rev Econ Policy 25(2):257–270

Ali A (1997) Economic freedom, democracy and growth. J Private Enterprise 13(1):1–20

Ali AM, Crain WM (2001) Political regimes, economic freedom, institutions and growth. J Public Finance Public Choice 19(1):3–21

Ando T, Bai J (2017) Clustering huge number of financial time series: a panel data approach with high-dimensional predictors and factor structures. J Am Stat Assoc 112(519):1182–1198

Barone G, Cingano F (2011) Service regulation and growth: evidence from OECD countries. Econ J 121(555):931–957

Barro RJ (1990) Government spending in a simple model of endogeneous growth. J Polit Econ 98(5, Part 2):S103–S125

Barro RJ (1996) Democracy and growth. J Econ Growth 1(1):1–27

Barro RJ (1997) Determinants of economic growth: a cross-country empirical study". MIT Press, Cambridge

Bartolucci F, Farcomeni A, Pennoni F (2013) Latent Markov models for longitudinal data. Chapman & Hall/CRC Press, Boca Raton

Bartolucci F, Farcomeni A, Pennoni F (2014) Latent markov models: a review of a general framework for the analysis of longitudinal data with covariates. TEST 23(3):433–465

Bassanini A, Ernst E (2006) Labour market institutions, product market regulation and innovation: Cross-country evidence. In: Economic perspectives on innovation and invention, page à paraître. Nova Science; Hauppage, NY, USA

Besley TJ, Ghatak M (2009) The de soto effect. LSE STICERD Research Paper No. EOPP008

Bucci A, Carbonari L, Trovato G (2019) Health and income: theory and evidence for OECD countries. In: Bucci A, Prettner K, Prskawetz A (eds) Human capital and economic growth. Springer, Berlin, pp 169–207

Bucci A, Carbonari L, Ranalli M, Trovato G (2022) Health and economic development: evidence from non-OECD countries. Appl Econ. https://doi.org/10.1080/00036846.2021.1939856

Cebula RJ (2011) Economic growth, ten forms of economic freedom, and political stability: an empirical study using panel data, 2003–2007. J Private Enterprise 26(2)

Cebula RJ, Mixon FG (2012) The impact of fiscal and other economic freedoms on economic growth: An empirical analysis. Int Adv Econ Res 18(2):139–149

Chang H-J et al (2007) State-owned enterprise reform. UN DESA Policy Note

Chen L, Buja A (2009) Local multidimensional scaling for nonlinear dimension reduction, graph drawing, and proximity analysis. J Am Stat Assoc 104(485):209–219

Cohen-Cole EB, Durlauf SN, Rondina G et al (2005) Nonlinearities in Growth: from evidence to policy. Social Systems Research Institute, University of Wisconsin, Madison

Cohen-Cole EB, Durlauf SN, Rondina G (2012) Nonlinearities in growth: From evidence to policy. J Macroecon 34(1):42–58

Crafts N, Toniolo G (2010) Aggregate growth, 1950–2005. The Cambridge economic history of modern Europe 2:296–332

Dawson JW (1998) Institutions, investment, and growth: new cross-country and panel data evidence. Econ Inq 36(4):603–619

Dawson JW (2003) Causality in the freedom-growth relationship. Eur J Polit Econ 19(3):479–495

De Haan J, Sturm J-E (2000) On the relationship between economic freedom and economic growth. Eur J Polit Econ 16(2):215–241

De Haan J, Lundström S, Sturm J-E (2006) Market-oriented institutions and policies and economic growth: a critical survey. J Econ Surv 20(2):157–191

Farcomeni A, Greco L (2015) Robust methods for data reduction. Chapman & Hall/CRC Press, Boca Raton

Farcomeni A, Ranalli M, Viviani S (2021) Dimension reduction for longitudinal multivariate data by optimizing class separation of projected latent Markov models. TEST 30(2):462–480

Fölster S, Henrekson M (1999) Growth and the public sector: a critique of the critics. Eur J Polit Econ 15(2):337–358

Fraser Institute (2018) Economic Freedom of the World, Fraser Institute. https://www.fraserinstitute.org/economic-freedom/dataset. Last accessed on 2018-05-11

Garcia-Escudero LA, Gordaliza A, Matran C, Mayo-Iscar A (2011) Exploring the number of groups in robust model-based clustering. Stat Comput 21:585–599

Glaeser EL, La Porta R, Lopez-de Silanes F, Shleifer A (2004) Do institutions cause growth? J Econ Growth 9(3):271–303
Gwartney J, Lawson R (2003) The concept and measurement of economic freedom. Eur J Polit Econ 19(3):405–430
Hall RE, Jones CI (1999) Why do some countries produce so much more output per worker than others? Quart J Econ 114(1):83–116
Hall P, Muller H-G, Wang J-L (2006) Properties of principal component methods for functional and longitudinal data analysis. Ann Stat 34:1483–1517
Hirano K, Imbens GW (2004) The propensity score with continuous treatments. In: Applied Bayesian modeling and causal inference from incomplete data perspectives: an essential journey with Donald Rubin's statistical family, pp 73–84
Hussain ME, Haque M (2016) Impact of economic freedom on the growth rate: a panel data analysis. Economies 4(2):5
Iqbal N, Daly V (2014) Rent seeking opportunities and economic growth in transitional economies. Econ Model 37:16–22
Keefer P, Knack S (1997) Why don't poor countries catch up? A cross-national test of an institutional explanation. Econ Inq 35(3):590–602
Knach S, Keefer P (1995) Institutions and economic performance: cross-country tests using alternative institutional measures. Econ Polit 7(3):207–227
La Porta R, Lopez-de Silanes F, Shleifer A (2008) The economic consequences of legal origins. J Econ Lit 46(2):285–332
Li M, Kumbhakar SC (2022) Do institutions matter for economic growth? Int Rev Econ 1–21
Liu Z, Stengos T (1999) Non-linearities in cross-country growth regressions: a semiparametric approach. J Appl Economet 14(5):527–538
Loayza NV, Oviedo AM, Serven L (2005) Regulation and macroeconomic performance. World Bank, Washington
Manca F (2010) Technology catch-up and the role of institutions. J Macroecon 32(4):1041–1053
Mankiw GN, Romer D, Weil DN (1992) A contribution to the empirics of economic growth. Quart J Econ 107(2):407–437
Maruotti A, Bulla J, Lagona F, Picone M, Martella F (2017) Dynamic mixtures of factor analyzers to characterize multivariate air pollutant exposures. Ann Appl Stat 11:1617–1648
Minier J (2007) Institutions and parameter heterogeneity. J Macroecon 29(3):595–611
Nawaz S (2015) Growth effects of institutions: a disaggregated analysis. Econ Model 45:118–126
Nawaz S, Khawaja MI (2019) Fiscal policy, institutions and growth: new insights. Singap Econ Rev 64(05):1251–1278
North DC (1990) Institutions, institutional change, and economic performance. Cambridge University Press, New York
PWT (2018) Version 9.0, Penn World Table. https://www.rug.nl/ggdc/productivity/pwt/. Last accessed on 14 May 2018
Rodrik D, Subramanian A, Trebbi F (2004) Institutions rule: the primacy of institutions over geography and integration in economic development. J Econ Growth 9(2):131–165
Schularick M, Solomou S (2011) Tariffs and economic growth in the first era of globalization. J Econ Growth 16(1):33–70
Seo MH, Shin Y (2016) Dynamic panels with threshold effect and endogeneity. J Econom 195(2):169–186
Steiger D, Stock J (1997) Instrumental variables regression with weak instruments. Econometrica 65(3):557–586
Stock JH, Yogo M (2002) Testing for weak instruments in linear IV regression
The World Bank (2018) Word Development Indicators, The World Bank. https://databank.worldbank.org/source/world-development-indicators. Last accessed on 19 April 2018
Vogelsmeier LVDE, Vermunt JK, van Roekel E, De Roover K (2019) Latent Markov factor analysis for exploring measurement model changes in time-intensive longitudinal studies. Struct Equ Model 26:557–575
Xia Y, Tang N-S, Gou J-W (2016) Generalized linear latent models for multivariate longitudinal measurements mixed with hidden Markov models. J Multivar Anal 152:259–275