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What underlies weak states? The role of terrain ruggedness ☆

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ABSTRACT

This article documents terrain ruggedness as an underlying cause of lack of state capacity. The paper contends that rugged topography poses significant costs to cooperation among the constituent groups within the state. This problem then translates into inability to commit to policies and under-provision of public goods, leading to such outcomes as poor protection of rule of law, limited tax revenue, civil violence, and ultimately, a weak state apparatus. Using several indicators capturing different dimensions of state capacity, the paper econometrically tests its argument in a sample of 187 independent countries and finds robust and clear evidence in favor of its reasoning. Further, the paper documents that delayed urbanization constitutes an important transmission mechanism for the significant role of terrain ruggedness in reduced state capacity.

1. Introduction

There is a resurgent and growing debate in the literature on the role of the state machinery in promoting economic development (see Besley and Persson 2011a; Dincecco and Katz, forthcoming). However, in contrast to earlier debates that focus on the appropriate level of government intervention, current discussions center on the questions of what constitutes an effective state apparatus and why inefficient states emerge and persist (Acemoglu et al. 2011). This paper concentrates on the underlying foundations for effective states, and asks: what are the impediments to the development and sustainability of state capacity? The paper argues that exogenous obstacles that increase transaction costs among different human settlements within a geographical area are important hurdles to state formation and progression. In particular, rough topography, as an exogenous barrier that reduces the cooperation among human groups, is a fundamental factor in the early development of effective states and is, in turn, an important predictor of state capacity today.

One strand of research in political economy addressing state formation recognizes that a state is formed by a group of citizens that share common interests and aim to satisfy particular needs, such as defense and basic public goods.[1] Specifically, agents form coalitions to overcome a common enemy or a problem when the benefits of creating such a group are larger than the benefits of acting

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[1] "The Leviathan" by Hobbes (1961) is one of the first systematic treatises of the state, which heavily influenced subsequent research on a state's core dimensions, such as its genesis, evolution, capacity, and failure.

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alone. In this sense, state formation is an outcome of collective action (Blanton and Fargher 2008; Ostrom 1998; Levi 1989; Olson 1971). However, constituencies that suffer from cooperation and coordination failures are unable to form states that provide successful outcomes for citizens (North et al. 2009). These polities typically feature a monopoly of power by certain factions and a lack of credible commitments. They also exhibit the classic public goods problem, such as free-riding on tax contributions of other localities (see Dincecco and Katz, forthcoming).[2]

Cooperation among the state's constituents is needed not only for forming the state, but also to increase its capacity over time. The recent economics literature defines state capacity as the ability to tax effectively and to provide growth-enhancing public goods. These functions and competencies of the state promote economic development and welfare distribution (Besley 2011; Acemoglu 2005). The political science literature places more emphasis on the state controlling its own territory, and providing and enforcing the rule of law (Evans 1995; Migdal 1988). Importantly, both fields hold the common view that all the state's economic and political functions are tightly connected, and society's inability to invest in them will result in weak state machinery, which generates feeble tax revenue, reduced provision of public goods, diminished rule of law, and political instability.

If state capacity is vital for increasing welfare, then what determines its initiation, evolution and persistence? Instead of focusing on the achievement of a capable state apparatus in its completeness, we re-focus the attention on the underlying factors behind a society's capacity to reach collective decisions in the first place. Our core argument is that impediments to collective action among the constituents of the state will determine where a state falls in the state capacity "spectrum", and can help predict the efficacy of the state machinery today.

Accordingly, this paper empirically investigates the role of terrain ruggedness, a factor that features as a major exogenous obstacle for building capable states. Our core hypothesis is that because the ruggedness of the terrain increases the costs of cooperation—by raising transaction costs—and reduces the benefits of collective behavior, the more prevalent this characteristic is within a country, the weaker the state apparatus is likely to be. Our argument is predicated on the premise that terrain ruggedness presents considerable challenges for the provision of public goods, not only by constituting a physical obstacle to infrastructure development, but also by restricting congregation, communication, and interaction among the constituencies. Anecdotal evidence suggests that groups living in proximity but separated by highly rugged surfaces rarely exchange or cooperate due to the unsurmountable transportation costs they face (see Osborne 2013).

Nevertheless, there can be several corollaries to our core hypothesis. For example, more rugged countries might end up hosting dense populations so that people in these locations can congregate and cooperate more easily. In this case terrain ruggedness might have a positive effect on state capacity. Alternatively, although cooperation is easier on flat plains, it is also a lot easier to extract rents and dominate citizens in ways that are not always conducive to the emergence of private property rights. Wittfogel's (1957) "hydraulic hypothesis" is one of the earliest articulations of this argument.[3] Consequently, while no ruggedness may increase the chances of forming a polity, that polity may become too strong and detrimental for long-run state stability (e.g., Iraq, Syria, and Egypt).[4] The effects of terrain may also work through intermediaries. For example, topography may shape the demographic landscape, and this might in turn affect the state's capabilities. Michalopoulos (2012) shows that variations in elevation and soil quality increase ethnic diversity (measured by linguistic differences), a factor that might adversely affect collective action and efficacy of the state.[5] All these considerations suggest a careful empirical analysis to tease out the role of rugged topography in state capacity.

We must stress that our emphasis on collective action as foundation of a state does not rule out other theories underlying state formation. The literature has widely discussed the role of war (e.g., Tilly 1992), elite domination (e.g., Acemoglu and Robinson 2008), and colonization (e.g., Olsson 2009) in the making of modern states (see Section 2). Nor does it rule out other plausible explanations that might link terrain ruggedness and state capacity, such as generalized trust, norms, and shared networks. The latter are clearly alternative explanations in regard to the role of rugged topography in state capacity; however, they are also important ingredients for collective action.

Our terrain ruggedness measure, originally constructed by Riley et al. (1999) and later improved by Nunn and Puga (2012), precisely quantifies topographic irregularities in a country's land area. Based on data for 30 arc sec (926 m) elevation differences across the entire surface of the Earth in a global dataset developed through international collaboration led by the United States Geological Survey Center (GTOPO30), it accurately measures topographic characteristics of a certain geographical area by using satellite images. Elevation observations that are regularly spaced at 30 arc sec in GTOPO30 facilitate an precise measure of terrain characteristics (Nunn and Puga 2012). This degree of precision for the terrain structure captures the proximate conditions that affect collective behavior among different human groups and the costs of cooperation arising from geographic constraints. For instance, settlements that lie on different sides of hills or in different altitudes within a short span are likely to face non-negligible costs of communication and cooperation. Only fine grid measurements of the Earth's surface can allow quantification of the collusion costs of topographic disturbances. Simple distance variables, like "as-the-crow-flies" measures, or indicators reflecting larger scale irregularities, such as the percentage of mountains in a country's surface area, are too crude to capture this type of settlement dispersion and the associated costs of inter-group cooperation.[6]

[2] Ostrom (1998) argues that these social dilemmas are the underlying rationale for the state to arise and to exist.

[3] Wittfogel (1957) argued that in Oriental polities where the agriculture relied on irrigation, a centralized command was required to manage the water resources, leading ultimately to autocratic regimes. In polities where the agriculture relied instead on rainfall, there was comparatively lower need for centralization, hence lower tendency for despotism. See Bentzen et al. (2014) for an empirical test of this hypothesis, and also Olsson and Paik (2014) for an argument along similar lines.

[4] We would like to thank an anonymous referee for this point.

[5] Nunn and Puga (2012) show that rugged countries in Africa suffered fewer adverse consequences of slave trade in the long run, given that it was difficult to "recruit" slaves on such topography.

[6] Topographic heterogeneity may underlie the spatial choice of early settlements, but this does not change the thrust of our main argument.

Fig. 1 portrays the different levels of terrain ruggedness across countries of the world. Most of Africa, Northern Europe, the east of South America, Canada and Australia are generally smooth, while Southern Europe, most of Central and Southeastern Asia, China, and the east of the Americas are highly rugged. This sizeable variation in the topographic characteristics around the globe, along with varying levels of state performance exhibited by countries, permits assessment of our hypothesized relationship.

After documenting the effect of terrain ruggedness on state capacity, we explore one specific mechanism through which this direct effect may matter: early urbanization. The central reasoning here is that urbanized societies are more likely to have solved their collective action problems earlier, and might have better infrastructure, connectivity, and organizational capital today. This reasoning implies that terrain ruggedness may have delayed urbanization, and consequently, led to reduced state capacity.

Our findings show that terrain ruggedness strongly predicts state capacity today, both directly and through the early urbanization channel. Our results are robust to accounting for alternative mechanisms that might explain state formation (e.g., artificial states), intermediaries, such as ethnic fractionalization, and to controlling for possible spatial dimensions of terrain ruggedness among neighboring countries.

The rest of the paper is organized as follows. Section 2 provides an overview of theories regarding state, its formation, and the role of terrain ruggedness in collective behavior. Section 3 describes the data and methodology, Section 4 discusses the empirical results, while Section 5 presents some robustness analysis. Finally, Section 6 concludes.

2. The state and its formation

In his seminal book, Olson (1971) theorizes that the state is formed by a group of citizens sharing common interests and aiming to satisfy their particular needs. Hence, this strand of research explains the origin of the state by cooperation leading to collective action. Levi (1989) posits that agents form groups or coalitions to overcome a common enemy when the benefits of creating such a group are larger than the benefits of acting alone.[7] Maintenance of the state also requires that the benefits of, and incentives for, cooperation are preserved over time. Accordingly, an organizational structure that deters the formation of internal factions (e.g., through a "Weberian monopoly of violence") and distributes the benefits of collective action is integral to the sustenance of the state. The size of the coalition can also affect state capacity because incentives to cooperate are reduced due to the free-rider problem as the coalition size increases (Olson 1971). Collective action theory thus highlights common interests and incentives for cooperation as key to state formation and persistence.

There are also other theories that explain state formation. For example, Tilly (1992) argues, particularly in the European context, that modern states emerged as a consequence of military competition. Fighting wars requires vast resources and bureaucratization was seen as a more efficient way of resource extraction. Under the elite domination theory, a state emerges when a small and cohesive group conquers a large disorganized group (Acemoglu and Robinson 2008). Colonization explains the origin of current states by independence wars, cessation of territories, or international pressure on colonial powers. These theories do not consider collective action as a determinant of state formation; however, they do not rule out that cooperation could play a role in improving a state's progression. In the latter case, collective action, though not explaining why a state is formed, might explain the development of state capacity.

2.1. What is state capacity?

State capacity is perhaps best defined by its antithesis. The political science literature refers to "fragile states" or "weak states" as those that are unable to provide basic public goods, effectively exert control over their territory, commit to a policy, or enforce the rule of law (Evans 1995). In economics, the concept is more commonly related to the capacity to raise taxes and provide public goods. Acemoglu (2005) defines weak states as those that cannot tax and regulate the economy or deal efficiently with non-state actors. It is commonly held that weak states lack the capability to increase citizens'long-term welfare.

It must be noted that "state capacity" is different from "political regime". A state with a democratic regime might be weak, while a more dictatorial regime may have a stronger state apparatus. Also, the extent to which variations within in political systems can explain different levels of state capacity is not clear. Both consolidated democracies and non-democratic states may face problems related to legitimization of the state. Moreover, weak states are different from failed states. The latter refer to countries where neither security nor justice is delivered by the state, such as Somalia or Sudan.[8] Further, the lack of state capacity is not unique to poor or developing countries. For instance, the recent explosion of social violence in Bahrain, which has one of the highest incomes per capita in the Gulf, is an example where high income and social unrest can co-exist.

2.2. Terrain ruggedness as impediment to collective behavior

In the collective action research strand, an important predictor of cooperation within a group is transaction costs. North (1991) emphasizes that higher transaction costs can offset the gains from cooperation, even in settings where all individuals want to cooperate. North describes situations where societies facing higher transaction costs are more likely to remain idle or even decline, while those facing lower transaction costs will progress over time. Olson (1971, pp. 46–47) argues that, "Any group that must organize to

[7] Using archeological data, Blanton and Fargher (2008) find evidence that even pre-modern states provided public goods in exchange for income from taxpayers, such as in Egypt, the Aztecs, China, and Ancient Greece.

[8] However, a weak state could become a failed state (Collier 2009).

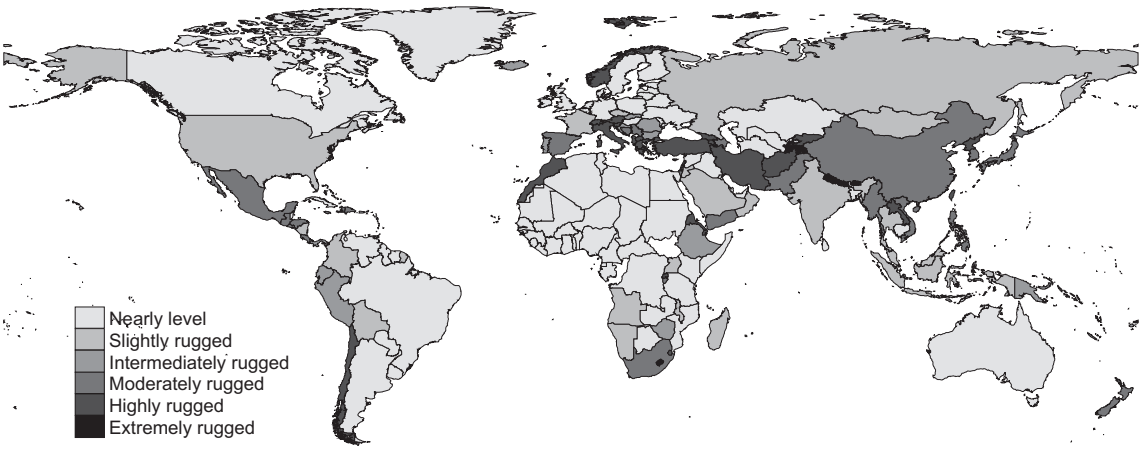

Fig. 1. Terrain Ruggedness Index.

obtain a collective good, will find that it has a certain minimum organization cost that must be met…The organizational costs include the costs of communication among group members, the costs of any bargaining among them, and the costs of creating, staffing, and maintaining any formal group organization." Then the question is: what determines transaction costs?

Physio-geography is clearly a non-trivial source of transaction costs. Some early societies confronted substantial constraints and prohibitive costs due to geographical factors. Stasavage (2010, p. 628) cites several sources on how tough geography led to absenteeism in assembly meetings due to prohibitive travel costs in early European polities. From a geographic constraint perspective, Nunn and Puga (2012) explain that terrain ruggedness makes transportation and construction costly, reduces agricultural profits, and is negatively related to income per capita. Along these lines, several World Bank reports for Latin America argue that rugged terrain imposes serious transaction costs on the region given difficulties in the delivery of infrastructure and basic services (World Bank 2009).[9]

There can be several other plausible linkages from geographical constraints to state capacity. For example, topography could determine certain institutions. Dell (2010) documents the persistent negative effects of initial institutions, designed on the basis of terrain ruggedness, on current levels of consumption in Peru. The *mita*, a forced labor system in silver mines, was imposed by the Spanish colonizers only in places surrounded by mountains, so that the native population could not escape. Dell (2010) demonstrates that current consumption is 25% lower in areas where *mita* was in place.

There could also be a "positive" channel from rugged topography to institutions: higher accountability of the government. Rugged terrain might result in small polities, where civic participation, associational life, and engagement in societal activities are common. In such a setting, citizens could aggregate their interests and form pressure groups. The government in these settings typically faces higher levels of accountability, and can function more efficiently. Putnam's (1993) classic example of the differences between institutional performances of Northern versus Southern Italian regions could epitomize this notion.

Terrain ruggedness might, nevertheless, adversely affect the overall stock of social capital. Polities facing rugged topography over a sufficiently large space may have comparatively lower ability to develop generalized trust, norms of reciprocity, and shared networks.[10] It is widely argued that generalized trust is one of the many social norms that could serve as a credible commitment for agents to cooperate (Acemoglu and Jackson, 2015; Ostrom and Ahn 2009).[11] Constituencies spread over such a space may succumb to frequent disagreements, lack of trust, and therefore, may host weak states.

Another strand of literature highlights the role of terrain ruggedness in civil conflicts. It is well known that mountainous topography increases the likelihood or duration of civil wars by providing rebels with an advantage and negatively affecting a state's military operations (Buhaug et al. 2009; Fearon and Laitin 2003). Examples related to Colombia, Algeria, Peru, Cuba, and Afghanistan are well documented (Acemoglu et al. 2010; Arreguín-Toft 2001).[12] However, ruggedness might also impose transaction costs on the distribution of resources or other benefits of collective action, which might be the underlying cause of the tensions. Coupled with limited congregation and communication, constituencies constrained by rugged terrain may thus feature a lack of a social contract or frequent violations of it, which is followed by armed tensions, and consequently, weak states (North et al. 2009).

[9] Ulubasoglu and Cardak (2007) find that landlocked countries, which are generally mountainous, exhibit higher inequality between rural and urban educational attainment due to difficulties associated with public service delivery to rural areas.

[10] However, social trust might not necessarily reflect the aggregate level of trust within a society, particularly if there are many groups. For instance, one group might exhibit high levels of trust within their members, but not with the other members, rendering generalized trust low. Similarly, a group might feature high bonding social capital, but low bridging capital. Bridging social capital is typically what is needed to sustain a state.

[11] Fear of punishment is another social norm that can ensure group cooperation (Greif 2006).

[12] Similarly, Herbst (2000) argues that colonizers conquered territories to the extent that benefits from geographical expansion did not offset the costs.

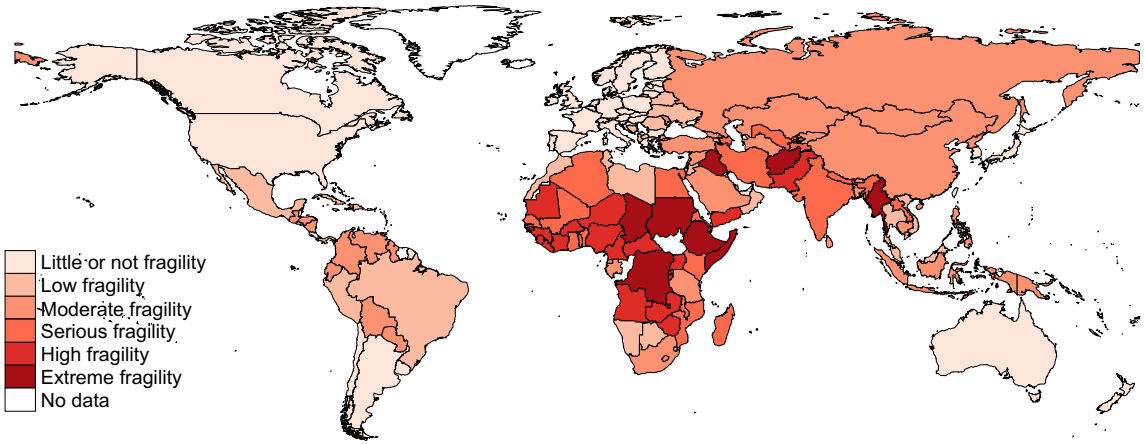

Fig. 2. State Fragility Index, 2009 (Marshall and Cole, 2011).

3. Data and methodology

Several sources have attempted to translate the concept of state capacity, state fragility, or weak states into single indicators. In this vein, the popular State Fragility Index by Marshall and Cole (2011) provides important summary information about the ranking of nearly 160 countries in the spectrum of the states. This variable scores each independent country with a population of 500,000 and above on their effectiveness and legitimacy in security, political, economic and social dimensions. The score ranges between 0 (no fragility) and 25 (extreme fragility). According to Marshall and Cole, the measure closely signals the state's capability to make and implement public policy, deliver basic public goods, and manage civil conflict. We adopt this metric (in particular, its 2009 value) as our first state capacity measure. Fig. 2 shows a global map of the distribution of State Fragility Index scores across the world. It is evident that Africa and Asia host several weak states.

However, the State Fragility Index has drawbacks. Importantly, it merges causes and consequences of state capacity into one single measure. Moreover, it may not capture the multidimensionality of the state capacity concept put forward by Besley and Persson (2011a). The main problem is that although state capacity refers to the ability of the state to perform different tasks, this ability cannot be observed directly, but rather through its outcomes (e.g., rule of law, civil conflict, and public goods delivery, and so on). Motivated by this critique, we attempt to measure separate dimensions of state capacity.

The first separate dimension is legal capacity, which is the capability to enact and enforce laws aiming to protect citizens' rights on an equal basis. Commonly known as the rule of law, this concept suggests that all citizens are constrained by the rules of society, including the rulers, lawmakers, and judges (Besley and Persson 2011a). Upholding the rule of law is not a trivial matter as it implies a strong commitment to an ongoing flow of resources from the state treasury to the judiciary and the police in order to enforce the legal framework throughout the country and without exclusions. From the state capacity point of view, the rule of law is a public good subject to huge transaction costs, and whose provision could be reduced due to rough topography (Olsson and Hansson 2011). We use the popular indicator by Kaufmann et al. (2010) to measure the rule of law, which ranges between 2.5 (high) and −2.5 (low) averaged for the period 1996–2010, as our second measure of state capacity.

Another dimension of state capacity is fiscal capability, which is defined as the extent to which the state can extract revenue from its constituents and enforce tax legislation and compliance (Besley et al. 2013; Dincecco and Katz, forthcoming; Levi 1989; Tilly 1992). Fiscal capacity is deeply rooted in collective action because financing public goods raises social dilemmas; a commonly known case is the free-riding problem. It is theoretically well established that all would be better off if everyone contributes to the public good (Ostrom 1998). Importantly, field experiments show that agents cooperate when the transaction costs to communication are low (Isaac et al. 1994). Thus, transaction costs appear to be an important determinant of the extent to which collective action takes place and public good is funded. Where geographical challenges, such as rugged terrain, introduce substantial transaction costs to collective behavior, contributions to the public good are likely to be reduced. We use tax revenue per capita in 1999 to measure fiscal capacity. The choice of this metric is motivated by the work of Dincecco and Katz (forthcoming) and Besley and Persson (2011a).[13] In particular, we use the data on central government tax revenue per capita in 1999 from the IMF Governance Finance Statistics.[14]

A final dimension of state capacity we explore is the ability to manage tensions among the state's constituents. As indicated in Section 2, rugged topography may not only constitute a platform for conflict in its own right, but also lead to distributional problems, frequent violations of the social contract, and the onset of civil conflicts. We use the number of years that a country had experienced

[13] Dincecco and Katz (forthcoming) associate the increased tax revenue per capita in Europe between 1650 and 1913, which occurred mainly due to adoption of uniform tax systems at the nation level, with strong state capacity.

[14] We also used tax revenue per capita in 2003, another comparable year, and the share of income taxes in total taxes averaged for the period 1990–2010, as alternative fiscal capacity measures. Direct taxes are closely linked to collective action of the majority (see Aidt and Jensen 2009a). These measures yielded similar results.

civil war between 1975 and 2006, taken from the Uppsala Conflict Data Program and International Peace Research Institute UCDP/PRIO Armed Conflict Dataset, as our fourth measure of state capacity.

To test the relationship between terrain ruggedness and state capacity, we estimate the following equation:

$$Y_i = \alpha_0 + \alpha_1 \mathrm{TRI}_i + \mathbf{Z}_i \boldsymbol{\beta} + \varepsilon_i \tag{1}$$

where Y_i is one of the four state capacity measures discussed above for country i, TRI is the Terrain Ruggedness Index, **Z** is a vector of controls, and ε_i is the error term.

The main hypothesis is that $\alpha_1 > 0$ for the State Fragility Index and proportion of years in civil wars, and $\alpha_1 < 0$ for the rule of law index and tax revenue per capita (the latter is used in natural logarithms). Eq. (1) is estimated using OLS.

As mentioned in the Introduction, our TRI is taken from Nunn and Puga (2012). It uses grid-cells spaced at 30 arc sec (926 m) to compute the variability of the terrain. This measure is highly precise as it captures small changes in the terrain (i.e., cliffs and hills).[15] TRI is computed as the square root of the sum of the squared differences in elevation between a particular grid cell and the eight adjacent points on the compass (North, Northeast, East, Southeast, South, Southwest, West, and Northwest).[16] Thus, it captures the features of terrain that matter for providing public goods[17] better than larger changes in the topography, such as the difference between a plateau and a mountain. To provide a feel for the measure, the Netherlands and Mauritania are measured to be nearly flat, with scores of 0.037 and 0.115 respectively, while Nepal and Lesotho are extremely rugged, with scores of 5.043 and 6.202 respectively.

The main control variable included in **Z** is the ethnic fractionalization index developed by Alesina et al. (2003). Ethnic fragmentation is an important indicator of the cohesiveness of society and a prominent parameter in theoretical models of state capacity (i.e., Besley and Persson 2009, 2011a). Ethnic fractionalization in a political jurisdiction adversely affects public good provision and taxation. This is because individuals derive higher utility from cooperation with members of the same ethnic group than with individuals from other ethnicities (Alesina et al. 1999). We present our main results conditional on ethnic fractionalization, but revisit the rationale for doing so in Section 4.5.[18]

We also include income per capita in vector **Z**. Nunn and Puga (2012) find that terrain ruggedness has a negative impact on income so it might be that a country has a weak state apparatus because it is poor and not because of terrain ruggedness itself. To avoid the risk of reverse causation between income and the state capacity, we use the log of real income per capita in 1950 in our estimation.[19]

Other control variables in **Z** are log area, and common macro comparative development variables, including colonial origins, independence year[20] and legal origins, to control for particular institutions arising historically that might affect a state's strength.

The main sample consists of 187 independent countries (i.e., United Nations members) around the world. Table 1 presents the descriptive statistics of the key variables. Definitions and sources of the data are provided in Table A1 in the Appendix A.

4. Empirical results

4.1. The State Fragility Index

Table 2 reports the estimation results of Eq. (1), with the State Fragility Index being the dependent variable.[21] Column 1 shows that, conditional on ethnic fractionalization, TRI has a highly significant effect on state fragility. The positive coefficient suggests that an increase in TRI by one unit augments the State Fragility Index by 0.46 points on the scale of 0–25, indicating a state weakening effect. Ethnic fractionalization itself also has a strongly significant detrimental effect on state fragility. Column 2 adds the log of real income per capita to the model. All three explanatory variables are statistically significant, though there is a reduction in the estimate of the coefficient on TRI. This means that some of the effect of TRI on state fragility works through income. This column constitutes our baseline specification.

To investigate the sensitivity of our hypothesized effect, we subject our baseline results in Column 2 to several perturbations. First, we eliminate countries in Africa, Asia, Europe, or Latin America from the global sample one at a time. Columns 3–6 show that the statistical significance of TRI disappears when countries in Asia or Europe are removed from the sample. This is not surprising, given that many countries located in Asia are weak and rugged, while TRI exhibits strong variations across European countries. Thus, removing these countries from the sample leaves less room for TRI to explain the differences in the State Fragility Index. Second, we use subsamples of non-OECD countries, former colonies, and small states in Columns 7, 8, and 9, respectively. Although TRI has the expected detrimental effect on state capacity, the estimated coefficient is statistically insignificant in these subsamples. Third, Columns 10–12 add,

[15] To provide a perspective, the G-Econ project uses large-scale DEMs based on grid-cells that are spaced at 1° (approximately 3600 arc sec or 111.2 km).

[16] To obtain the TRI of the country's land area, Nunn and Puga average across all grid cells in the country not covered by water. The units for the TRI correspond to the units used to measure elevation differences. In Nunn and Puga's calculation, ruggedness is measured in hundreds of meters of elevation difference for grid points 30 arc sec (926 m on a meridian) apart. See Nunn and Puga (2012, p. 21–22).

[17] See Collier et al. (2013), who find that terrain ruggedness greatly increases the cost of road construction.

[18] We also considered linguistic fragmentation instead of ethnic fractionalization in Eq. (1). However, this variable is estimated to be largely insignificant. This finding is consistent with the literature studying ethnic fractionalization, which suggests that ethnicity matters more as a barrier to cooperation and that language differences can be overcome, at least for basic communication.

[19] Controlling for income per capita in 1950 provides the benefit of capturing several control variables at once, such as latitude, climate or other initial conditions. We thank an anonymous referee for raising this point.

[20] The year of independence is also included to control for different waves of decolonization. See Acemoglu et al. (2008) and Olsson (2009).

[21] The state fragility data presented in Fig. 1 suggest concentration of weak states in some regions, such as Africa and Asia. Statistically speaking, this problem could result in spatial correlation of the residuals, so we cluster the standard errors of all regressions by regions when the State Fragility Index is the dependent variable.

Table 1
Descriptive statistics for key variables.

Variables	Obs.	Mean	Std. Dev.	Median	Min	Max
State Fragility Index 2009	157	8.821	6.406	9	0	25
Rule of law 1996–2010	187	−0.063	0.987	−0.212	−2.348	1.939
Log tax rev. per capita USD 1999	110	6.095	1.850	6.104	2.220	9.665
Years in civil war (1975–2006)	161	4.251	8.353	0	0	31
Terrain Ruggedness Index	187	1.372	1.345	0.939	0.002	6.74
Ethnic fractionalization	187	0.440	0.256	0.437	0	0.930

using the global sample, additional sets of controls one at a time, including the log area, colonial origins and legal origins. These exercises demonstrate that a significant effect of TRI is found only in the specification with log area. Finally, Column 13 presents a specification that includes all the controls. The coefficient of TRI is significant in this case. The coefficient estimate of 0.496 suggests that, all else being equal, if Nepal (with a TRI equal to 5.043) was less rugged, so as to have the mean level of TRI in the sample (i.e., 1.372), it would have had a score of state fragility similar to that of India.

4.2. The rule of law

Table 3 presents the results using the rule of law index as the dependent variable. Column 1 reports that, conditional on ethnic fractionalization, TRI is statistically insignificant. Column 2 adds the log of real income per capita; the statistical significance of TRI remains unchanged. Using different subsamples in Columns 3–9 also shows an insignificant TRI effect on rule of law. Columns 10, 11, and 12 add log area, colonial origins, and legal origins to the baseline regression, respectively, with the result that TRI is still insignificant. In the specification that includes all the controls in Column 13, TRI attains a negative coefficient that is significant at the 10% level. Its estimate suggests that, all else being equal, if Nepal with TRI equal to 5.043 had been less rugged, so as to have the mean TRI level in the sample, its rule of law index would have been improved to achieve the score reported for Morocco.[22]

4.3. Tax revenue per capita

Table 4 displays the results using the log of tax revenue per capita in 1999 as the outcome variable proxying the fiscal capacity of the state. Column 1 shows that, conditional on ethnic fractionalization, the coefficient of TRI is negative and significant at the 5% level. The estimate implies that an increase in TRI by one unit reduces tax revenue per capita by 24.2%. In Column 2, log income per capita is added to the specification. Doing so reduces the *t*-statistic of TRI to −1.352.

The next few columns subject the baseline specification in Column 2 to some robustness checks. TRI is negative and statistically significant at 5% when Africa is removed from the global sample; see Column 3. However, TRI is insignificant when Asia, Europe and Latin America are removed in Columns 4, 5, and 6, respectively. Columns 7, 8, and 9 utilize only non-OECD countries, only former colonies, and exclude small countries, respectively. The coefficients on TRI remain negative with *t*-statistics around 1.5, except for the specification that includes former colonies only, in which case the effect disappears altogether. Columns 10, 11, and 12 add log area, colonial origins, and legal origins respectively, to the baseline regression, one at a time. TRI is estimated to be negative and generally significant. Finally, Column 13 includes all the controls simultaneously. The negative relationship between TRI and tax revenue remains robust in the presence of all the controls, indicating 20.7% lower tax revenue per person for each unit of increased TRI score. This estimate suggests that all else being constant, if Nepal had a TRI equal to the mean of the sample, it would have collected 76% higher tax revenue per capita in 1999, which is as much as the Kyrgyz Republic collected in that year.

4.4. Presence of civil war

Results using the number of years of civil war a country has experienced since 1975 as the indicator of state capacity are displayed in Table 5. Column 1 shows that, conditional on ethnic fractionalization, TRI has a positive effect on the number of years of civil war. The results indicate that an increase of TRI by one unit increases the length of a civil war, on average, by one year. Column 2 adds log income per capita and all variables remain significant, with the signs being as expected. Ethnic fractionalization has strongly significant positive sign in both columns.

In Columns 3–6, we exclude Africa, Asia, Europe or Latin America from the global sample one at a time, respectively. The coefficient of TRI remains statistically significant except when Africa and Asia are removed. This result makes sense given the concentration of civil conflicts in these continents. Columns 7–9 demonstrate that the TRI–civil war relationship is significant within non-OECD countries and when small countries are excluded from the sample. Columns 10–13 indicate that all the results remain robustly significant when controls are included either in separate sets or together. The coefficient estimate for TRI in Column 13 suggest that, all else being equal, if Nepal, which experienced 11 years of civil war in the sample period, had been less rugged such that it was at the mean TRI level, it would have experienced only seven years of civil war.

[22] Although Table 3 does not indicate a robust significant effect of TRI in Columns 1–12, a non-linear specification of TRI (unreported) finds a significant effect in most of the regressions (with the linear term being negative and quadratic term positive). However, that non-linear effect becomes a linear effect in the fully specified model of Column 13, given that the quadratic term becomes insignificant. Those results are available upon request.

Table 2
Dependent variable: State Fragility Index 2009.

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Terrain Ruggedness Index	0.468***	0.207*	0.374**	−0.0137	−0.0434	0.240**	0.222	−0.0753	0.0698	0.311**	0.265	0.201	0.496**
	(4.700)	(2.142)	(3.419)	(−0.0496)	(−0.500)	(3.065)	(1.868)	(−0.420)	(0.424)	(3.245)	(1.960)	(1.938)	(2.965)
Ethnic fractionalization	14.55***	11.16***	8.929***	10.76***	9.716***	11.51***	9.750***	8.402***	11.29***	10.79***	10.39***	9.761***	7.973***
	(4.325)	(9.844)	(4.761)	(6.495)	(12.99)	(11.74)	(7.331)	(8.099)	(10.04)	(9.817)	(7.939)	(11.71)	(5.940)
Log per cap. inc. 1950		−3.887***	−3.341***	−4.364***	−3.752***	−3.841***	−3.543***	−3.911***	−4.144***	−3.844***	−3.635***	−3.929***	−3.367***
		(−9.139)	(−20.94)	(−11.45)	(−7.118)	(−9.739)	(−8.338)	(−8.059)	(−9.057)	(−6.733)	(−7.471)	(−14.79)	(−6.715)
Log area										0.384*			0.617**
										(2.528)			(3.050)
Controls											CO	LO	CO, LO
Constant	1.515	31.98***	27.82***	35.78***	32.43***	31.60***	30.68***	34.35***	34.19***	27.89***	25.16	30.79***	−5.227
	(0.644)	(10.22)	(19.98)	(11.18)	(8.304)	(11.76)	(11.86)	(9.867)	(9.319)	(6.647)	(1.037)	(17.70)	(−0.196)
Observations	157	157	107	114	123	134	125	102	136	157	157	157	157
R-squared	0.323	0.587	0.438	0.665	0.518	0.605	0.440	0.539	0.621	0.598	0.602	0.611	0.645
Sample	All	All	All excluding Africa	All excluding Asia	All excluding Europe	All excluding Latin America & Caribbean	Only non-OECD countries	Only former colonies	All excluding small countries	All	All	All	All

Robust *t*-statistics clustered by regions in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Data on former colonies are obtained from Olsson (2009). Independence years are obtained from Acemoglu et al. (2008). Small countries are those whose population is less than 1.5 million. Data on legal origins are obtained from La Porta et al. (2008). East Timor's legal origin is coded as French. The legal origin for Palau is not specified. CO stands for colonial origins and independence year. LO stands for legal origins.

Table 3
Dependent variable: rule of law 1996–2010.

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Terrain Ruggedness Index	−0.00438	0.0171	0.0429	0.0567	−0.0556	0.0273	0.0127	−0.0153	0.0727	−0.0154	−0.0255	0.0369	−0.0692*
	(−0.0743)	(0.361)	(0.740)	(1.155)	(−1.124)	(0.554)	(0.260)	(−0.318)	(1.119)	(−0.383)	(−0.668)	(0.793)	(−1.936)
Ethnic fractionalization	−1.684***	−1.223***	−1.390***	−1.171***	−1.051***	−1.218***	−0.677***	−0.763***	−1.061***	−1.058***	−1.114***	−1.213***	−0.840***
	(−6.528)	(−5.643)	(−4.796)	(−4.819)	(−4.489)	(−5.316)	(−3.010)	(−3.021)	(−4.044)	(−4.710)	(−5.358)	(−5.379)	(−3.863)
Log per cap. inc. 1950		0.609***	0.707***	0.603***	0.451***	0.676***	0.315***	0.469***	0.681***	0.605***	0.518***	0.617***	0.499***
		(7.947)	(7.302)	(7.085)	(5.582)	(8.639)	(4.538)	(5.584)	(7.575)	(7.012)	(7.358)	(8.549)	(6.796)
Log area										−0.099***			−0.110***
										(−4.822)			(−5.188)
Controls											CO	LO	CO, LO
Constant	0.684***	−4.049***	−4.799***	−4.097***	−3.017***	−4.419***	−2.426***	−3.356***	−4.734***	−3.067***	5.071*	−4.198***	7.559***
	(3.911)	(−6.608)	(−6.143)	(−5.854)	(−4.970)	(−6.934)	(−4.594)	(−5.335)	(−6.572)	(−4.284)	(1.829)	(−7.186)	(3.024)
Observations	187	187	135	156	145	154	153	122	141	187	187	186	186
R−squared	0.191	0.429	0.360	0.473	0.335	0.495	0.252	0.397	0.472	0.484	0.548	0.460	0.609
Sample	All	All	All excluding Africa	All excluding Asia	All excluding Europe	All excluding Latin America & Caribbean	Only non-OECD countries	Only former colonies	All excluding small countries	All	All	All	All

Robust *t*-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Data on former colonies are obtained from Olsson (2009). Independence years are obtained from Acemoglu et al. (2008). Small countries are those whose population is less than 1.5 million. Data on legal origins are obtained from La Porta et al. (2008). East Timor's legal origin is coded as French. The legal origin for Palau is not specified. CO stands for colonial origins and independence year. LO stands for legal origins.

Table 4
Dependent variable: log tax revenue per capita 1999.

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Terrain Ruggedness Index	−0.242**	−0.113	−0.204**	0.102	−0.0927	−0.120	−0.117	0.00257	−0.144	−0.165**	−0.142*	−0.122	−0.207**
	(−2.290)	(−1.352)	(−2.118)	(1.420)	(−0.902)	(−1.546)	(−1.263)	(0.0189)	(−1.465)	(−2.091)	(−1.683)	(−1.445)	(−2.587)
Ethnic fractionalization	−4.438***	−3.185***	−3.071***	−2.871***	−2.684***	−3.318***	−2.745***	−2.129***	−2.864***	−2.806***	−3.153***	−3.337***	−2.540***
	(−7.626)	(−6.506)	(−4.786)	(−4.919)	(−4.941)	(−6.283)	(−5.044)	(−3.356)	(−5.525)	(−5.416)	(−6.130)	(−6.606)	(−4.799)
Log per cap. inc. 1950		1.326***	1.263***	1.368***	1.169***	1.407***	0.942***	1.173***	1.390***	1.333***	1.283***	1.325***	1.240***
		(7.816)	(6.204)	(6.952)	(5.913)	(7.605)	(4.569)	(5.406)	(7.470)	(7.480)	(6.544)	(7.466)	(6.507)
Log area										−0.165***			−0.199***
										(−3.315)			(−3.684)
Controls											CO	LO	CO, LO
Constant	8.264***	−2.272	−1.697	−3.022*	−1.507	−2.664*	0.0499	−1.947	−2.899*	−0.760	5.370	−2.338	11.56*
	(24.93)	(−1.607)	(−0.989)	(−1.802)	(−0.955)	(−1.739)	(0.0310)	(−1.073)	(−1.888)	(−0.496)	(0.771)	(−1.569)	(1.810)
Observations	110	110	88	90	77	90	79	64	93	110	110	110	110
R-squared	0.341	0.631	0.563	0.643	0.560	0.691	0.448	0.591	0.677	0.664	0.675	0.637	0.717
Sample	All	All	All excluding Africa	All excluding Asia	All excluding Europe	All excluding Latin America & Caribbean	Only non-OECD countries	Only former colonies	All excluding small countries	All	All	All	All

Robust *t*-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Data on former colonies are obtained from Olsson (2009). Independence years are obtained from Acemoglu et al. (2008). Small countries are those whose population is less than 1.5 million. Data on legal origins are obtained from La Porta et al. (2008). East Timor's legal origin is coded as French. The legal origin for Palau is not specified. CO stands for colonial origins and independence year. LO stands for legal origins.

Table 5
Dependent variable: years in civil war 1975–2006.

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Terrain Ruggedness Index	0.998**	0.955*	0.602	1.116*	1.192*	0.909*	1.072*	0.580	1.588***	1.152**	0.822*	0.958**	1.131**
	(1.979)	(1.956)	(1.184)	(1.687)	(1.953)	(1.777)	(1.868)	(0.858)	(2.796)	(2.381)	(1.669)	(2.027)	(2.275)
Ethnic fractionalization	7.115***	5.749**	7.481**	6.840**	5.141	5.324**	4.808	1.129	6.435**	4.436*	7.177**	5.503**	3.940
	(2.972)	(2.353)	(2.478)	(2.586)	(1.654)	(2.016)	(1.460)	(0.313)	(2.179)	(1.860)	(2.509)	(2.208)	(1.421)
Log per cap. inc. 1950		−1.385**	−3.381***	−0.504	−1.024	−1.474**	−0.759	−1.274*	−1.829**	−1.352**	−1.910***	−1.407**	−1.651**
		(−2.180)	(−3.332)	(−0.912)	(−1.445)	(−2.367)	(−0.924)	(−1.759)	(−2.295)	(−2.128)	(−2.662)	(−2.219)	(−2.244)
Log area										1.010***			1.101***
										(3.507)			(3.388)
Controls											CO	LO	CO, LO
Constant	−0.299	11.09**	27.28***	2.930	8.960	11.94**	7.385	13.45**	14.07**	1.201	28.25	10.71*	−13.99
	(−0.227)	(2.019)	(3.197)	(0.585)	(1.515)	(2.163)	(1.137)	(2.129)	(2.021)	(0.209)	(0.936)	(1.835)	(−0.450)
Observations	161	161	111	131	127	134	129	106	132	161	161	161	161
R−squared	0.054	0.092	0.200	0.077	0.064	0.093	0.061	0.062	0.116	0.144	0.121	0.101	0.184
Sample	All	All	All excluding Africa	All excluding Asia	All excluding Europe	All excluding Latin America & Caribbean	Only non-OECD countries	Only former colonies	All excluding small countries	All	All	All	All

Robust *t*-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Data on former colonies are obtained from Olsson (2009). Independence years are obtained from Acemoglu et al. (2008). Small countries are those whose population is less than 1.5 million. Data on legal origins are obtained from La Porta et al. (2008). East Timor's legal origin is coded as French. The legal origin for Palau is not specified. CO stands for colonial origins and independence year. LO stands for legal origins.

4.5. Terrain ruggedness and ethnic fractionalization

So far we have presented estimates of the direct effect of TRI (i.e., the effect that is net of ethnic fractionalization). We argue that ethnic fractionalization should be included in the empirical model of state capacity because there is good reason to believe that ethnic fragmentation might be disconcerting for the operations of the state. However, even more importantly, ethnic fractionalization might itself be correlated with the topographic structure of a country. In a recent study, Michalopoulos (2012) showed that variations in elevation and regional soil quality are important determinants of contemporary ethnic diversity.[23] In this case ethnic fractionalization may become a confounding factor for TRI. This section investigates the role of ethnic fractionalization in the TRI–state capacity relationship further. Our objective is to clarify the direct (i.e., net of ethnic fractionalization) versus the total (i.e., inclusive of the ethnic fractionalization–channel) effect of terrain ruggedness on state capacity.

Table 6 presents the estimates of TRI without ethnic fractionalization in Eq. (1). All the controls in **Z** (i.e., log initial real income per capita, log area, colonial origins, independence year, and legal origins) are included in the model. Column 1 shows that TRI is estimated to be insignificant in explaining the State Fragility Index. Without extra information, this finding might imply that if it was not for the effect that runs through the collective action problem (and other possible channels), TRI would actually foster state-building as a result of the effect it has on ethnic fractionalization. However, the results in Columns 2–4 show that the coefficients of TRI are only marginally different compared to when ethnic fractionalization was included in the model. This finding leads us to conclude, along the lines of Besley and Persson (2011a), that the State Fragility Index might suffer from measurement issues, and that more specific dimensions of state capacity, such as legal capacity, fiscal capacity, and conflict management, are directly and negatively affected by terrain ruggedness.

4.6. Early urbanization as a transmission mechanism

We have shown the effect of terrain ruggedness on state capacity to be negative and significant, meaning that geographic constraints arising from rough topography weaken a state's capabilities. However, given the reduced form framework, our analysis above cannot say much about the mechanisms through which this direct negative effect emerges. This section focuses on early urbanization (i.e., in 1900) as a possible mechanism.

The effect of the initial pattern of urbanization on state formation in Europe has been subject to numerous scholarly works (e.g., Stasavage, 2010). The novelty in our approach is to generalize this argument to a large group of countries and test it empirically as an explicit mechanism between TRI and several state capacity measures. There are two possible dimensions of early urbanization that may facilitate stronger states today. First, building up cities (i.e., urbanization) per se requires that citizens choose to stay in a specific urban area and not to exit. Urbanized societies are more likely to have solved their tax collection problem, and have better infrastructure and connectivity. This is because minimal organizational costs, for which the cost of the first unit of collective good will be exceedingly high in relation to the cost of the subsequent units, are more likely to be borne in an urban setting (Olson, 1971). Indeed, Aidt and Jensen (2009b) find that urbanization reduces the transaction cost for collecting taxes, making it more likely that states adopt income taxes as an important source of revenue. It is also well documented that urban centers typically do not exhibit self-sufficient production patterns, and therefore need to exchange and cooperate with other polities in order to endure. Economic gains from trade, specialization, and agglomeration determine the viability of urban centers. In addition, in various parts of the world, urban settlements were granted some degree of autonomy to self-manage their laws, rules, and even taxes. Thus, cities (i.e., those with a "sizeable" population) are considered a cooperation success (Glaeser, 2011). Urbanization is also likely to yield stronger political organization through labor unions, churches, universities, and professional associations. In general, organizational capital, which is needed to build and sustain a state, is likely to emerge in an urbanized society.

The second effect is related to the "earliness" of this phenomenon. That is, for early urbanized societies, the timeframe considered for the above phenomena becomes larger, such that there is a longer period over which organizational capital can emerge, and in stronger terms. Therefore, based on this discussion we hypothesize that all else being equal, terrain ruggedness delays the urbanization process and societies in which this happened are less likely to have strong states today.

In light of this, we first test whether TRI can explain early urbanization, and whether early urbanization can, in turn, predict the measures capturing state capacity.[24] Results with all four dependent variables are displayed in Table 7. Columns 1 and 2 demonstrate that TRI is negatively related to urbanization in 1900, even after several controls are included. That is, the more rugged the country, the less urbanized it was in 1900.[25] The next question is whether the extent of early urbanization affects a country's ability to act collectively today.

Column 3 shows that, controlling for income and ethnic fractionalization, countries with early urbanized societies have stronger states. Results in Column 4, to be compared to those in Column 13 in Table 2, suggest that the direct effect of TRI on the State Fragility

[23] Michalopoulos (2012) defines ethnic diversity based on linguistic fragmentation.

[24] The data for urban populations in 1900 were obtained for 107 countries from Chandler (1987). Urban area refers to settlements with populations above 40,000. The urbanization rate is the total urban population divided by the total population of the country. Data for countries' total population were obtained from McEvedy and Jones (1978). If a country has no settlement with population above 40,000, then the urbanization rate of that country was assumed to be 0. All related regressions include a dummy variable to control for the assumption that countries with no settlements greater than 40,000 in 1900 had a 0 urbanization rate.

[25] Since early urbanization is likely to be related to initial institutions, this finding can also shed some light on the importance of physio-geography for the initial institutions that matter for current outcomes (Dell, 2010, Stasavage 2010).

Table 6
Terrain ruggedness and ethnic fractionalization.

Independent variables	(1)	(2)	(3)	(4)
	State Fragility Index	Rule of law	Log tax revenue per capita	Years in civil war
Terrain Ruggedness Index	0.334	−0.0719**	−0.198*	1.048**
	(0.760)	(−1.976)	(−1.903)	(2.132)
Log per cap. inc. 1950	−3.511***	0.522***	1.373***	−1.717**
	(−5.380)	(6.403)	(6.414)	(−2.293)
Controls	Yes	Yes	Yes	Yes
Constant	−24.77	8.843***	34.76***	−23.35
	(−0.945)	(3.415)	(6.434)	(−0.777)
Observations	157	186	110	161
R-squared	0.575	0.572	0.641	0.174

Robust *t*-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.
Control variables include log area, colonial origins, independence year and legal origins.

Index works to a very important extent through the early urbanization channel, as the coefficients of TRI are insignificant in this column while they are significant in Table 2.

Column 5 shows that early urbanization is positively related to the score of rule of law. Column 6, to be compared to Column 13 in Table 3, indicates that the effect of TRI on the rule of law works through the early urbanization mechanism, given that the TRI is statistically insignificant in this column while it is significant at the 10% level in Table 3.

Column 7 shows a positive relationship between early urbanization and log tax revenue per capita. The direct positive effect of early urbanization is consistent with Aidt and Jensen (2009b), who find that urbanization reduces the cost of tax collection. However, we estimate the coefficient on early urbanization with a *t*-statistic of only around 1. Our unreported regressions show that in the absence of log per capita income, early urbanization is significantly estimated, but including log per capita income in the model inflates its standard error. This finding suggests that early urbanized societies have higher income levels, which in turn leads to higher taxes per capita. The estimates in Column 8, to be compared to those in Column 13 in Table 4, show that as expected, early urbanization does not work as a channel between TRI and tax collection once the level of income is controlled in the model. Thus, a summary of our finding is that less rugged countries urbanized earlier, and this channel is effective on tax collection only through the higher incomes that followed.

Last, controlling for several variables, early urbanization has the predicted negative relationship with the length of civil war in Column 9. When TRI is included in Column 10, both TRI and early urbanization remain significant. Compared to Column 13 in Table 5, TRI's coefficient is reduced by 9%. This finding overall suggests that rugged countries that urbanized early faced slightly fewer years of civil wars than those that urbanized later.

Table 7
Mechanism: early urbanization.

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Urbanization in 1900	Urbanization in 1900	State Fragility Index	State Fragility Index	Rule of law	Rule of law	Log tax revenue per capita	Log tax revenue per capita	Years in civil war	Years in civil war
Urbanization in 1900			−6.931*	−5.673	2.301***	2.173***	1.185	0.634	−15.92**	−12.56*
			(−2.052)	(−1.406)	(3.902)	(3.589)	(0.996)	(0.503)	(−2.331)	(−1.790)
Terrain Ruggedness Index	−0.00808*	−0.0154***		0.383		−0.0514		−0.205**		1.039**
	(−1.752)	(−2.980)		(1.777)		(−1.464)		(−2.398)		(2.122)
Ethnic fractionalization		−0.0807***	7.027***	7.320***	−0.714***	−0.717***	−2.436***	−2.510***	2.920	3.743
		(−2.798)	(8.215)	(7.706)	(−3.371)	(−3.374)	(−4.596)	(−4.835)	(1.056)	(1.363)
Log per cap. inc. 1950			−3.069***	−3.011***	0.403***	0.392***	1.243***	1.210***	−1.503*	−1.362*
			(−14.01)	(−12.05)	(5.956)	(5.700)	(5.268)	(4.990)	(−1.886)	(−1.731)
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.0766***	1.107***	8.488	1.571	6.495***	7.479***	26.98***	28.24***	−5.003	−18.64
	(6.904)	(4.514)	(0.382)	(0.0584)	(2.993)	(3.168)	(4.678)	(5.121)	(−0.163)	(−0.585)
Observations	187	186	157	157	186	186	110	110	161	161
R-squared	0.012	0.241	0.656	0.660	0.627	0.631	0.700	0.718	0.198	0.217

Robust *t*-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Control variables include log area, independence year, colonial origins and legal origins. Columns (1) to (2) estimate urbanization using OLS. Columns (3) and (4) estimate State Fragility Index using OLS and clustered standard errors by regions. Columns (5) to (10) present estimates using clustered standard errors. Regressions in Columns (3) to (10) include a dummy variable to control for the assumption that countries with no settlements greater than 40,000 in 1900 had 0 urbanization rate.

5. Robustness checks

5.1. Statistical independence and spatial spillovers in state capacity

If bordering countries share similar terrain characteristics, then each country may not constitute a statistically independent observation. For instance, the whole of Africa may very well be considered as a few independent data points based on physio-geography (e.g., many countries share the Sahara desert). This suggests that spatial spillovers may exist in state capacity among neighboring countries.[26]

To test for a global spatial autocorrelation of state fragility, Moran's I test for terrain ruggedness was performed using a contiguity matrix — entries are 1 for countries sharing a common land border, and 0 otherwise.[27] The Moran's I statistic for the sample is equal to 0.274, with a z-score of 5.019 and a p-value of 0.00, suggesting global spatial autocorrelation. We address this problem by incorporating such spatial dimension in the estimation.[28] Thus, Eq. (1) becomes:

$$Y_i = \alpha_0 + \alpha_1 \mathrm{TRI}_i + \alpha_2 \mathrm{W}Q_j + \mathbf{Z}_i\boldsymbol{\beta} + \varepsilon_i \tag{2}$$

where W is a spatial weight matrix. To obtain W, we use a contiguity matrix weighted by neighbor's surface area. Q_j are i's neighbors TRI. A significant estimate for α_2 would indicate possible spatial spillovers across bordering countries.

The estimates of Eq. (2) using neighbors' ruggedness are shown in Table 8. In general, no evidence is found on neighbors' ruggedness affecting the different state capacity variables directly; see Columns 1, 2, 5, 6, 7, and 8. With the inclusion of neighbors' ruggedness, TRI maintains its explanatory power for the State Fragility Index, fiscal capacity, and years in conflict; see Columns 2, 6, and 8. This implies that results in Tables 2, 4, and 5 above are robust to accounting for spatial autocorrelation.

On the other hand, the estimate of TRI for rule of law in Columns 3 and 4 becomes insignificant when the neighbors'TRI is included in the model. In fact, neighbors'TRI itself is estimated to be significant in Columns 3 and 4. This could indicate some spillover effect of neighbors' ruggedness, reducing the score of a country's rule of law, but we cannot say how this works specifically. In the literature of relative geography, Bosker and Garretsen (2009) find that income per capita in one country is affected by its own score of rule of law and also by the score of its neighbors. They find that trade is a channel through which this effect takes place, though one might ask what if trade with neighboring countries is also a function of terrain ruggedness? This question deserves deeper analysis.

Finally, it is noteworthy that results in Columns 7 and 8 show that neighbors'TRI has a positive effect on years of civil conflict in a country, although the effect is insignificant at conventional levels. The positive effect is in line with cases in which insurgencies use neighboring countries as sanctuaries for attacks, as the Kurdistan Worker's Party (PKK) did from Northern Iraq into Turkey for many years, but such an effect appears to be weak globally.

5.2. Other possible mechanisms

This paper uses the collective action argument to explain the role of topography in the formation and progression of a state. However, as indicated, there are several other plausible linkages that may run from terrain ruggedness and state capacity. Putnam's (1993) seminal work emphasizes the role that social capital, which comprises trust, social norms, and shared networks, plays in inducing a society to cooperate more. Bjørnskov (2006) tests this concept and finds that trust is the key component of social capital and drives better governance. Thus, in unreported regressions (available upon request), we introduce a measure of trust in our Eq. (1) to analyze whether generalized trust could be a potential channel through which TRI impacts on state capacity. To capture social trust, we follow the growing literature on social capital and use the percentage of population answering “yes” to the question “Generally speaking, would you say that most people can be trusted or that you need to be very careful in dealing with people?” in the World Values Survey. In order to maximize the sample size, we average all the information available in the six waves of this survey since 1981.

Mostly, social trust is not statistically significant in regressions for the State Fragility Index, tax revenue per capita, and years in civil war, nor is there any change in the coefficients on TRI. Yet, there is some evidence that trust is correlated with the rule of law[29] and that this correlation reduces the significance of TRI in Eq. (1). Thus, an increase in trust might reduce the negative consequences of TRI for legal capacity. While we could not completely rule out social trust as a factor enhancing the other dimensions of state capacity, it is our conjecture that trust may affect a state's foundations and progression through its association with other interactive factors, such as history, wars, climate, and ultimately, institutions. For instance, in a recent study, Nunn and Wantchekon (2011) show that the transatlantic and Indian Ocean slave trade that Africa was subjected to more than 400 years ago strongly explains the mistrust within African society today. Moreover, Ahlerup et al. (2009) find that the level of social trust has a differentiated impact on the economic

[26] See also Ades and Chua (1997) and Murdoch and Sandler (2004) for the negative consequences of social unrest and civil wars that spread spatially across countries.
[27] Data are obtained from Mayer and Zignago (2005).
[28] This subsection does not try to answer if there are spillover effects of state capacity among countries, but whether or not there are spillover effects of terrain ruggedness.
[29] See Yu et al. (2015) for a recent and interesting relationship on trust and rule of law.

Table 8
Terrain ruggedness and spatial correlation; dependent variable: different dimensions of state capacity.

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	State Fragility Index	State Fragility Index	Rule of law	Rule of law	Log tax revenue per capita	Log tax revenue per capita	Years in civil war	Years in civil war
Neighbors' Terrain Rugged	−0.798	−0.322	−0.201**	−0.192**	0.0359	0.204	1.610	0.875
	(−0.842)	(−0.407)	(−2.381)	(−2.218)	(0.211)	(1.033)	(1.319)	(0.704)
Terrain Ruggedness Index	0.375	0.563**	0.0197	−0.0365	−0.118	−0.239***	0.614	0.953*
	(1.679)	(2.574)	(0.362)	(−0.888)	(−1.381)	(−2.935)	(1.111)	(1.666)
Ethnic fractionalization	10.85***	7.943***	−1.325***	−0.840***	−3.187***	−2.596***	6.121**	3.915
	(11.67)	(6.167)	(−6.057)	(−3.688)	(−6.517)	(−4.979)	(2.513)	(1.399)
Log per cap. inc. 1950	−3.907***	−3.389***	0.601***	0.489***	1.329***	1.267***	−1.383**	−1.607**
	(−9.793)	(−6.369)	(7.752)	(6.937)	(7.737)	(6.205)	(−2.226)	(−2.218)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Constant	32.80***	−4.352	−3.762***	8.063***	−2.316	10.63	9.880*	−16.72
	(10.08)	(−0.150)	(−6.078)	(3.055)	(−1.584)	(1.577)	(1.870)	(−0.536)
Observations	157	157	185	184	110	110	161	161
R-squared	0.592	0.646	0.455	0.615	0.631	0.720	0.104	0.187

Robust *t*-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Control variables include log area, independence year, colonial origins and legal origins. Columns (1) and (2) estimate State Fragility Index using OLS and clustered standard errors by regions. Columns (3) to (8) present estimates using clustered standard errors.

development of a country depending on the degree of formal political institutions. One would probably need to model some interactions to capture such linkages in empirical work.

Another possible mechanism is related to artificial states. Although we have controlled for colonial legacy as an important factor behind this phenomenon, artificial political boundaries that do not coincide with "natural" ethnic divisions may obscure our collective action story; see Alesina et al. (2011) for a systematic and innovative treatment of these states. We incorporate their fractal measure of artificial states into our main equation, but this does not change the thrust of our results (results are available upon request).

Regime type might also blur the "mapping" from collective action to state capacity. For instance, lack of collective action from citizens might lead to an autocrat taking over the reign of the country, who might, in turn, establish a strong state. That could be the case of countries where the characteristics of rainfall and the lack of collective action might have facilitated the imposition of strong dictatorships (Bentzen et al. 2014). We test whether TRI explains constraints on the executive at independence, with the latter being a measure of the regime type, but find no significant link to initiate this mechanism (results are available upon request).[30]

One might be concerned that it is not ruggedness, but highlands versus lowlands that is captured by TRI. Addressing this concern requires controlling for average altitude in the regressions. The pairwise correlation between TRI and log mean elevation (obtained from Michalopoulos, 2012) in our sample is, as anticipated, relatively high, standing at 0.54. Regressions (available upon request) indicate that all else being equal, controlling for log mean elevation does not change the thrust of our conclusions.

Finally, rugged terrain might lead to densely populated settlements in plain areas but fewer settlements in rugged areas. If this is the case, one should take into account the distribution of the population in the country more seriously. We run our regressions using population-weightedTRI, which factors in the population share of each 30 by 30 arc sec cell in the computation of TRI(Nunn and Puga, 2012). The results with this index are statistically significant on all four measures for state capacity (results available upon request).

6. Conclusions

Traditionally, the state has been conceived as an organization that is able to implement any type of policy. However, constraints related to the state's capacity to do so have generally been disregarded. Accordingly, a recent research agenda has begun investigating the main determinants of state capacity (Acemoglu, 2005; Besley and Persson 2009, 2010, 2011a, 2011b; Dincecco and Katz, forthcoming). Considering that the success of the state depends on cooperation, ability to commit, and provision of public goods, this paper indicates an exogenous feature that can affect collective behavior among the constituencies of the state: physiogeography. We hypothesized that rugged terrain might make it more difficult to form and sustain a successful polity where constituents can cooperate and exchange effectively given lower transaction costs. A corollary to our argument is that smooth plains might be more conducive to polities in which rents can be extracted or citizens can be dominated more easily so as to prevent the emergence of private property rights, such that the state becomes detrimental for long-run stability (e.g., Iraq, Egypt, and Syria).

[30] It would be desirable to investigate TRI's explanatory power on historical state capacity. Historical series on state capacity measures are, unfortunately, not available for many countries. Although it would not replace this shortcoming, repeating the analysis above for only contemporary *developed* countries, yields, as anticipated, much less significant evidence, reflecting a weaker link between state capacity and "initial conditions" in that set of countries.

Our analysis provides robust and clear evidence that terrain ruggedness, representing physio-geography, plays a direct negative role in the capabilities of the state. Exploiting sizeable variations in the topography of countries around the world, we document that this factor strongly predicts today's state capacity. Our estimates imply, for example, that all else being equal, if Nepal, one of the most rugged countries in the world, had been less rugged so as to be at the mean ruggedness level in our sample, it would have had better rule of law (similar to that of Morocco) between 1996 and 2010, 79% higher tax revenue per capita (a level analogous to that of the Kyrgyz Republic) in 1999, and seven years of civil war instead of 11 between 1975 and 2006.

We also demonstrate that early urbanization, being an intermediate outcome of collective action, constitutes a significant mechanism for the observed relationship between terrain ruggedness and state capacity. More specifically, countries that urbanized in the relatively distant past so as to develop the necessary infrastructure and organizational capital to co-habit in large settlements can maintain a stronger state apparatus that can provide improved public goods provision. While there may be other possible mechanisms involved, such as social trust, their effects are likely to be more nuanced in that they may interact with other variables, such as the power of the elites, history, and other initial conditions. These mechanisms, together with other underlying factors, can be a fruitful research avenue for empirical work on state capacity.

Appendix A

Table A1
Data sources and descriptions.

Variable	Description	Source
Terrain Ruggedness Index	Index capturing terrain ruggedness based on a digital elevation model (GTOPO30) whose data is spaced at 30 arc sec (926 m)	Nunn and Puga (2012)
Ethnic fractionalization	Probability that two randomly selected persons from a country belonging to different groups meet.	Alesina et al. (2003)
State Fragility Index	Index rating countries according to their level of fragility in four dimensions: security, governance, economic development, and social development	Marshall and Cole (2011)
Rule of law	The extent to which agents have confidence in, and abide by, the rules of society	Kaufmann et al. (2010)
Tax per capita (USD)	Tax revenue per capita in local currency/exchange rate with respect to the US dollar in 1999	IMF (2012)
Years in civil war	Number of years that a country has experienced civil war between 1975 and 2006	Uppsala University, CDP/PRIO Armed Conflict Dataset v.4-2007
Log income per capita 1950	Log of income per capita in real USD in 1950 from the Maddison database taken from Nunn and Puga (2012)	Nun and Puga (2012)
Constraints on the executive	The extent of institutionalized constraints imposed on decision-makers and chief executives	Marshall and Cole (2011)
Log area	Log of surface area in squared kilometers	Center for International Development at Harvard University
Independence year	Year when independence was gained	Olsson (2009)
Colonial origins	Dummy variables indicating if the colonial power was the United Kingdom, France, or Spain	Acemoglu and Robinson (2008)
Legal origins	Dummy variables indicating if the legal origins were of British or French origin.	La Porta et al. (2008)
Urbanization 1900	Total population in urban areas in 1900 from Chandler (1987) divided by total population of the country from McEvedy and Jones (1978)	Chandler (1987) and McEvedy and Jones (1978)
Contiguity matrix	Square matrix containing a dummy variable for countries sharing a common border	Mayer and Zignago (2005)
Elevation	Mean elevation in meters above sea level	Center for International Development at Harvard University
Artificial states	Variable *Partitioned* measuring how artificial a country is	Alesina et al. (2011)
Small countries	Dummy = 1 if country has a population below 1.5 million	World Bank
Non-OECD countries	Dummy = 1 if country does not belong to the OECD	OECD
Asia	Dummy = 1 if country is located in Asia (excluding the Middle East)	World Bank
Africa	Dummy = 1 if country is located in Africa	World Bank
Europe	Dummy = 1 if country is located in Europe	World Bank
Latin America	Dummy = 1 if country is located in Latin America or in the Caribbean	World Bank

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