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State Capacity and Economic Development: A Network Approach†

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We study the direct and spillover effects of local state capacity in Colombia. We model the determination of state capacity as a network game between municipalities and the national government. We estimate this model exploiting the municipality network and the roots of local state capacity related to the presence of the colonial state and royal roads. Our estimates indicate that local state capacity decisions are strategic complements. Spillover effects are sizable, accounting for about 50 percent of the quantitative impact of an expansion in local state capacity, but network effects driven by equilibrium responses of other municipalities are much larger. (*JEL* D85, H41, H77, O17, O18)

Though we often take for granted the existence of central and local states with the capacity to enforce law and order, regulate economic activity, and provide public goods, many states in less-developed parts of the world lack this capacity. In Migdal's (1988, p. 33) words: "In parts of the Third World, the inability of state leaders to achieve predominance in large areas of their countries has been striking …"

The idea that such state capacity is vital for economic development, though latent in the writings of Hobbes and Weber, began to attract more attention as a consequence of analyses of the "East Asian Miracle." A series of books by Johnson (1982); Amsden (1989); Wade (1990); and Evans (1995) argued that a key to the economic success of East Asian economies was that they all had states with a great deal of capacity. Others, such as Herbst (2000) and Centeno (2002), linked the economic failure of African or Latin American nations to their limited state capacity. This hypothesis also receives support from the cross-country empirical evidence presented in Gennaioli and Rainer (2007) and the within-country evidence

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in Michalopoulos and Papaioannou (2013) and Bandyopadhyay and Green (2012), which find a positive association between measures of (historical) political centralization and present-day outcomes.[1]

In this paper, we contribute to this literature in several dimensions. We study the effect of state capacity of Colombian municipalities on public goods provision and prosperity. We conceptualize "state capacity" as the presence of state functionaries and agencies. This represents one aspect of what Mann (1986, 1993) calls the "infrastructural power" of the state (see also Soifer 2008). Colombia provides an ideal laboratory for such an investigation for several reasons. There is a wide diversity of local state presence, public goods provision, and prosperity across the country, and many important aspects of local state capacity in Colombia—including notary offices, health centers, health posts, schools, libraries, fire stations, jails, deed registry offices, tax collection offices, and part of the bureaucracy—are decided at the local level. Finally, and critically for our empirical strategy, Colombia's history of colonization provides us with sources of potential exogenous variation in local state capacity, which we exploit in order to deal with endogeneity and reverse causality concerns and to isolate the impact of state capacity (rather than other social and institutional factors). In particular, we focus on the historical presence of colonial state officials, colonial state agencies, and the colonial "royal roads" network. The road network, for example, was partially based on precolonial indigenous roads and was overhauled when the modern system of roads was built in Colombia starting in the 1930s. This network has disappeared and thus provides an attractive source of variation in the historical presence of the state and the cost of building and expanding local state capacity (especially when we control for distance to current roads). We exploit this royal road network, as well as information on the location of various colonial state offices and officials, in order to isolate historical sources of variation in the cost of building state capacity today.

Our main contribution is that, differently from all of the literature in this area, we model the impact of state capacity in one municipality on public goods provision and economic outcomes in neighboring areas. We expect (and empirically find) such neighborhood spillovers to be important both because borders across municipalities are porous, and because building a functioning bureaucracy in the midst of an area where state capacity is entirely missing is likely to be much more difficult.

Cross-municipality effects also imply that building state capacity is a strategic choice for each municipality. If municipalities free-ride on their neighbors' investments, state capacity choices will be strategic substitutes. Conversely, if municipalities find it harder or less beneficial to build state capacity when it is missing in their neighborhood, they will be strategic complements. Other important reasons for strategic complementarities include: (i) when there is a functioning state in the neighborhood, voters may be more likely to demand it of their own politicians; (ii) some problems, such as defeating criminal organizations or dealing with contagious

[1] Relatedly, Rauch and Evans (2000); Acemoglu (2005); Besley and Persson (2009, 2011); and Dincecco and Katz (forthcoming) document positive correlations between tax to GDP ratio or measures of meritocracy in the state bureaucracy and economic development, and Osafo-Kwaako and Robinson (2013) show a positive correlation between political centralization and development using ethnographic data on political centralization from the Standard Cross-Cultural Sample.

diseases, may be beyond the capability of the local state at the municipality level; (iii) the judicial system may not function just in a single municipality.

We incorporate these strategic aspects by modeling the building of state capacity as a network game in which each municipality takes the national state's as well as their neighbors' actions into account and chooses its own state capacity. We then estimate the parameters of this model, exploiting both the network structure and the exogenous sources of variation discussed above. The key parameters concern: (i) the impact of own state capacity on own prosperity (and public goods); (ii) spillovers on neighbors; and (iii) the parameters of the best response equation concerning how state capacity decisions depend on neighbors' state capacities. In the process, we clarify why both empirical approaches that ignore the endogeneity concerns and those that do not model the network structure of interactions will lead to potentially misleading estimates.

Estimates of the "best response" equations linking a municipality's state capacity to its neighbors' state capacity indicate that these decisions are strategic complements. To estimate the effect of own and neighbors' state capacity on measures of public goods provision and prosperity, we use one of three empirical approaches: (i) linear instrumental variables (IV) applied to each dimension of prosperity; (ii) generalized method of moments (GMM); or (iii) simulated method of moments (SMM) using all dimensions of prosperity simultaneously. In each case, we clarify how the reduced-form parameters map into the structural ones. Our results show large and fairly precise effects of both own and neighbors' state capacity on the measures of prosperity and public goods provision.

Our benchmark estimates imply, for example, that moving all municipalities below median state capacity to the median will have a "partial equilibrium" direct effect (holding the level of state capacity of all municipalities above the median constant) of reducing the median poverty rate by 3 percentage points, increasing the median coverage rate of public utilities (electricity, aqueduct, and sewage) by 4 percentage points, and increasing the median secondary school enrollment rate by 3 percentage points. About 57 percent of these impacts is due to a direct effect, while 43 percent is due to network spillovers. The "full equilibrium" effect is very different, however. Once we take into account the equilibrium responses to the initial changes in local state capacity in the network, the median coverage rate of public utilities increases by 10 percentage points, the median fraction of the population in poverty falls by 11 percentage points, and median secondary school enrollment rates increase by over 26 percentage points. These large impacts, which are entirely due to network effects, highlight not only the central role that state capacity plays in economic development but also the importance of taking the full equilibrium effects into account.

In addition to bolstering the case for our empirical strategy using falsification exercises, overidentification tests, and a number of specification checks, we also demonstrate that our main estimates are quite robust. They are very similar (i) when we only exploit historical sources of variation from neighbors of neighbors (instead of relying on variation of the neighbors); (ii) if we do not control for the current road network (our baseline results do control for this network); (iii) when we focus on subsets of our instruments; (iv) when we assign different weights on the spillovers from different neighbors or even when we allow spillovers to go beyond adjacent municipalities; (v) when we include a battery of additional controls; (vi) when we exclude high crime areas or capital cities; (vii) when we use more flexible functional forms; and (viii) when we vary the form of spillovers.

We also extend our structural model to incorporate the decisions of the national state concerning local state capacity. In Colombia, while municipalities hire and pay for a range of local state employees (a large part of it with transfers from the national state), the number of police and judges in the municipality are decided by the national state. Incorporating this additional layer of interaction in the structural model has little effect on our estimates of the impact of local state capacity, but allows us to shed light on the role of national state presence.

We are unaware of any other study that either estimates the effect of local (municipality-level) state capacity on local outcomes, or models and estimates the network externalities and strategic interactions in this context. The only partial exceptions we are aware of are Dell's (2015) study of how changes in law enforcement shift the activities of drug gangs across the transport network linking Mexican municipalities to the United States; a recent paper by Durante and Guiterrez (2013) on the role of inter-jurisdictional cooperation in crime-fighting across Mexican municipalities; Case, Rosen, and Hines' (1993) work on the relationship between the public expenditures of neighboring US states; and Di Tella and Schargrodsky's (2004) work showing (negative) spillovers in policing from one part of Buenos Aires to neighboring areas.

In addition, our paper relates to several literatures. First, we build on and extend the literature on the effect of state capacity on economic development, which has already been discussed. In addition to the empirical and historical studies mentioned above, there has recently been a small literature on the modeling of the emergence of state capacity or persistence of states which lack capacity ("weak"). Acemoglu (2005) constructs a model in which a self-interested ruler taxes and invests in public goods and citizens make investment decisions. Weak states are detrimental to economic development because they discourage the ruler from investing in public goods, as they limit his or her future ability to raise taxes. Besley and Persson (2009, 2011) also emphasize the importance of state capacity and suggest that state-building will be deterred when each group is afraid that the state they build will be used against them in the future.[2] Our model takes a different direction, and in the process, highlights a new effect: state-building will be deterred unless a national body plays a defining role in this process, because local authorities will underinvest in state capacity as they ignore the spillovers they create on their neighbors. Since our estimates suggest that these spillovers are sizable, this effect could be quite important in practice.

In utilizing a network game to model state-building investments and for our empirical work, our paper also relates to the literature on network games. Theoretically, our model is a variant of Calvó-Armengol, Patacchini, and Zenou (2009); Bramoulle, Kranton, and D'Amours (2014); and Allouch (2015). Other papers dealing with related issues include Topa (2001); Katz, Kling, and Liebman (2001); Sacerdote

[2] Acemoglu, Ticchi, and Vindigni (2011) and Acemoglu, Robinson, and Santos (2013) provide various models of persistence of weak states with low state capacity, while another branch of literature, including Thies (2005); Gennaioli and Voth (forthcoming); and Cárdenas, Eslava, and Ramírez (2011) for Colombia, investigates the historical determinants of state capacity.

(2001); Nakajima (2007); Bayer, Ross, and Topa (2008); and Bramoulle, Djebbari, and Fortin (2009); though, to the best of our knowledge, no other study uses a similar empirical strategy or combines structural modeling and historical instrumental variables to estimate the parameters of this type of model.

There is a small literature on within-country variation in state capacity as well. O'Donnell (1993) emphasized that the uneven distribution of state capacity in Latin America led to variation in the quality of democracy at the subnational level. Related ideas have emerged in the literature on civil wars, with scholars suggesting that conflict starts and persists in parts of countries with low state capacity (e.g., Goodwin 2001; Fearon and Laitin 2003; and Kalyvas 2006; as well as Sánchez 2007, for the Colombian case).[3] Research on within-country income differences has pointed to institutional differences as a potential cause of this variation (e.g., Acemoglu and Dell 2010; Acemoglu, García-Jimeno, and Robinson 2012; Bruhn and Gallego 2012), but has not focused on variation in state capacity.

The rest of the paper proceeds as follows. Section I provides a discussion of the Colombian context, particularly focusing on the weakness of the local and the national state. Section II presents a simple model of investments in state capacity within a network. Section III presents our data. Section IV discusses our empirical strategy and presents our main estimates and some robustness checks focusing on the simplified model without the national state. Section V describes our empirical strategy and results for the general model. Section VI shows how our estimates can be used for determining the gains from optimally reallocating state capacity investments across municipalities. Section VII concludes. Appendix A presents proofs and derivations, while online Appendix B contains additional results.

I. Context

State capacity in Colombian history has been notable in its relative absence on average and its great variability. In 1870, with a total population of around 2.7 million, the total number of both state and national level public employees in Colombia was 4,500, or just 0.0015 bureaucrats per inhabitant (Palacios and Safford 2002). In contrast, public employees per capita in the United States in 1870 were 0.011, an order of magnitude greater (1870 US census).

The Colombian state also lacked another key aspect of state capacity, the capability to raise fiscal revenues, which remained absent well into the twentieth century (Deas 1982; and Rincón and Junguito 2007). As late as 1970, tax revenue was only around 5 percent of GDP (Rincón and Junguito 2007). Some isolated regions, such as the Chocó or the eastern plains, have yet to be fully integrated with the rest of the country economically or politically.[4] Commenting on this issue in 1912, Rufino Gutierrez argued

[3] In the literature on state formation in the nineteenth century United States, there is a heavy emphasis on the critical role of federal and local government (e.g., Novak 2008), and similar concerns have emerged in the literature on Latin America (see, e.g., Soifer 2012).

[4] One of the main purposes of the 1991 Constitution was to increase the extent of decentralization in Colombia and in the process to contribute to local state-building. It mandated transfers from the central government to the local level, which would be used for public good provision at the municipality level. Despite these major institutional changes in the late twentieth century, large swathes of Colombia still have very weak state presence. Moreover,

> *… in most municipalities there was no city council, mayor, district judge, tax collector… even less for road-building boards, nor whom to count on for the collection and distribution of rents, nor who may dare collect the property tax or any other contribution to the politically connected…*
>
> — (Gutierrez 1920, our translation)

There are several historical root causes of state weakness in Colombia. During the colonial period, Spain restricted migration to its American colonies so that the settler population was very small and did not constitute a powerful voice pushing for a more effective colonial state. The colonial state used direct methods to extract rents from indigenous people, such as tribute and forced labor, rather than developing a tax system that would later become the foundation of state capacity. The topography of the country also constrains the reach of the state. The Andean Cordillera splits the country into a patchwork of relatively disconnected regions. Furthermore, Colombians resisted the Bourbon attempts at state centralization in the late eighteenth century so that, uniquely in the Americas, the Spanish were not able to set up their new system (see Paquette 2012; Phelan 1978; and McFarlane 1993, for Colombia). Though as a consequence of these reforms, the province of *Nueva Granada* became a viceroyalty in 1717 and then again in 1739, the colonial state remained absent throughout most of the territory, except in and around a few cities and towns. For example, in 1794, the capital Bogotá and the major slave and gold trading port Cartagena housed 70 percent of all crown employees in the viceroyalty.

After independence, the colonial fiscal system was continued until the Liberals' rise to power in 1850 (Jaramillo, Meisel, and Urrutia 2006). The Liberal regime cut tariffs and abolished monopolies, causing a fiscal crisis and a significant downsizing of the already emaciated state (Deas 1982). In the mid-nineteenth century, Colombia adopted a federal system, further weakening the attempts of national state-building. During this federal period, each state had its own army, so that even the monopoly of violence of the national state was not attempted until the end of the War of a Thousand Days in 1903. Palacios and Safford (2002, p. 27) describe state weakness in Colombia during this epoch as follows:

> *In the decade of the 1870s, an attempt to use national funds to build a railroad that would benefit the east triggered intense antagonism in the west and the [Caribbean] coast… as a result, small, poorly financed and often failed projects proliferated…*

As a consequence of this pervasive state weakness, there was little local public good provision in most of Colombia before the 1930s. Systematic local public good provision became possible only after the decentralization initiated in the mid-1980s, and deepened with the 1991 Constitution. The geographically-varied lack of state capacity, combined with recent decentralization of some public services to municipalities, makes the study of the implications of local state capacity on public goods provision and prosperity in Colombia particularly relevant.

during the 1990s and early 2000s the national state lost control of large areas of the country to private armies of guerrillas and paramilitaries.

II. A Simple Model of State-Building in a Network

Building on the literature on network games (e.g., Ballester, Calvó-Armengol, and Zenou 2006; Calvó-Armengol, Patacchini, and Zenou 2009; Bramoulle, Kranton, and D'Amours 2014; and Allouch 2015) we now develop a simple game-theoretic model of the determination of local and national state. The economy consists of a network of municipalities and a national state. Each municipality is a node in this network, municipalities sharing a border are connected, and all links are undirected. Several dimensions of public goods and prosperity in each municipality depend on local state capacity, the national state's capacity there, and the spillover effects of state capacity from neighboring municipalities. The national state has heterogeneous preferences over prosperity across municipalities. All municipalities and the national state simultaneously choose their levels of state capacity to maximize their payoff, which is a function of the relative costs and benefits of state capacity. This model determines the equilibrium distribution of local and national state capacity across municipalities, and hence the equilibrium distribution of prosperity.

A. *Network Structure and Preferences*

Let i denote a municipality, and $\mathbf{F}$ be an $n \times n$ matrix with entries f_{ij} given by

$$f_{ij} = \frac{1}{1 + \delta_1 d_{ij}(1 + \delta_2 e_{ij})},$$

where d_{ij} denotes the distance along the geodesic connecting the centroids of municipalities i and j, and e_{ij} is a measure of variability of altitude along the geodesic connecting the centroids of municipalities i and j. The parameters f_{ij}s allow for differential decay of spillovers between municipalities depending on topographic features of the landscape, an important feature in the Colombian context since topographic conditions are highly variable and rapidly changing.

Let $N(i)$ denote the set of municipalities connected to i, which will be the set of municipalities that create spillovers on i. In our baseline, these will be the municipalities that are adjacent to i, though we also experiment with alternative definitions of the set $N(i)$ as described below.

The matrix $\mathbf{N}(\boldsymbol{\delta})$ denotes the symmetric matrix with entries n_{ij} representing both the presence of a link between two municipalities and the strength of any spillovers that may take place along that link:

$$n_{ij} = \begin{cases} 0 & \text{if } j \notin N(i) \\ f_{ij} & \text{if } j \in N(i) \end{cases}.$$

We allow several dimensions of prosperity in a municipality to depend upon own state capacity and neighboring state capacity in the following way:

$$p_i^j = \kappa_i s_i + \phi s_i \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} + \gamma^j \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} + u_i^j, \tag{1}$$

where p_i^j is the jth dimension/index of prosperity in municipality i, $s_i \in [0, \infty)$ is municipality i's state capacity, and $\mathbf{N}_i(\boldsymbol{\delta})$ is the ith row of the network matrix, with $\mathbf{s}$

denoting the full column vector of state capacity levels. In addition, κ_i is the effect of municipality i's state capacity on its own prosperity, which we model as a function of historical and other characteristics of a municipality:

$$(2) \qquad \kappa_i = g(\mathbf{c}_i \varphi + \mathbf{x}_i \beta) + \varsigma_i^D + \tilde{\xi}_i .$$

Here $\mathbf{c}_i$ and $\mathbf{x}_i$ are vectors of historical and contemporary municipality characteristics, $g(\cdot)$ is an arbitrary smooth function, the ς_i^Ds denote a full set of department fixed effects, and $\tilde{\xi}_i$ represents unobserved (to the econometrician) heterogeneity. We assume it is observed by all the players in the game, so that we have a game of complete information.[5] The parameter ϕ captures any interaction (or cross) effects between own prosperity and neighbors' state capacity, while γ^j is the direct effect of neighboring state capacity on prosperity outcome j. Finally, the u_i^js denote the error term in equation (1), and are modeled as a function of observable covariates as well:

$$(3) \qquad u_i^j = \mathbf{x}_i \tilde{\beta}_u^j + \tilde{\varsigma}_i^{Dj} + \epsilon_i^j ,$$

where ϵ_i^j is a mean zero random component. Relative to (2), this equation excludes the variables in the vector $\mathbf{c}_i$, which will be the exclusion restrictions discussed in detail below (and in addition also imposes linearity, which is for simplicity). Throughout the theoretical and empirical analysis below, we allow for arbitrary spatial correlation of the random components, $\tilde{\xi}_i$ and ϵ_i^j, which is important given the potentially spatially correlated nature of the omitted factors that might affect state capacity or outcomes at the municipality level.

Notice that though γ^j is allowed to vary across the different dimensions of prosperity, the cross effects and own effects are imposed to be the same for all these dimensions (i.e., ϕ and κ_i do not vary by j). This is because, as we will see below, these parameters will be identified from the best response equations, which do not depend on the dimension of prosperity we are considering. These restrictions are plausible in view of the fact that the p_i^js are standardized z-scores.

B. *The General Case*

Our general model allows state capacity in municipality i to be a constant elasticity of substitution (CES) composite of both locally chosen $l_i \in [0, \infty)$, and nationally chosen state capacity, $b_i \in [0, \infty)$:

$$(4) \qquad s_i = \left[\alpha l_i^{\frac{\sigma-1}{\sigma}} + (1-\alpha) b_i^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \qquad \sigma > 0.$$

[5] Observed and unobserved heterogeneous effects of state capacity on own prosperity are quite plausible in this context, since various geographic, historical, political, and social factors will create variation in the effectiveness of state capacity, for example, because there is greater need for the local state to provide health care or public services in some municipalities, or because patronage appointments driven by the highly clientelistic nature of local Colombian politics (e.g., Dávila Ladrón de Guevera and Leal Buitrago 2010) reduce the impact of measured state presence on prosperity in some municipalities. The random component of these heterogeneous effects, $\tilde{\xi}_i$, which is allowed to be arbitrarily correlated with elements in $g(\cdot)$, is also plausible for another reason: as we will see below, without this random component, best response equations would be deterministic, which would not be a reasonable empirical specification.

We use a reduced-form representation of decisions within municipalities focusing on costs and benefits of state capacity (and thus essentially ignore political economy factors). Each municipality i decides its own state capacity l_i, taking as given the choices of its neighbors and the national state to maximize

$$U_i = \frac{1}{J} \sum_j p_i^j - \frac{\theta}{2} l_i^2, \tag{5}$$

where J is the total number of prosperity outcomes. Preferences of the national state are

$$W_i = \sum_i \left\{ U_i \zeta_i - \frac{\eta}{2} b_i^2 \right\}, \tag{6}$$

where the ζ_is are the heterogeneous weights that the national state puts on each municipality, determined by political economy factors, for example, depending on the distribution of swing voters (e.g., Stromberg 2008), or on who is in control of local politics (e.g., Acemoglu, Robinson, and Santos 2013).[6] Throughout, we focus on Nash equilibria of this simultaneous-moves game.

The first-order conditions for the municipalities and the national state determine the equilibria of this game. The conditions with respect to l_i give the best response of the state capacity choice of municipality i as

$$\alpha \left[\frac{s_i}{l_i}\right]^{\frac{1}{\sigma}} \left[\kappa_i + \phi \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}\right] - \theta l_i \begin{cases} \leq 0 & \text{if } l_i = 0 \\ = 0 & \text{if } l_i > 0 \end{cases}, \tag{7}$$

which is written in complementary slackness form. The sign of ϕ determines whether this is a game of strategic substitutes ($\phi < 0$) or strategic complements ($\phi > 0$).

For the national state, the first-order conditions with respect to each b_i yield

$$(1-\alpha)\left[\frac{s_i}{b_i}\right]^{\frac{1}{\sigma}} \left\{ \zeta_i\left[\kappa_i + \phi \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}\right] + \phi \mathbf{N}_i(\boldsymbol{\delta})(\mathbf{s} * \boldsymbol{\zeta}) + \frac{1}{J} \sum_j \gamma^j \mathbf{N}_i(\boldsymbol{\delta})\boldsymbol{\zeta} \right\} - \eta b_i \begin{cases} \leq 0 & \text{if } b_i = 0 \\ = 0 & \text{if } b_i > 0 \end{cases}, \tag{8}$$

where $*$ designates element-by-element multiplication. Notice from equation (8) that for any set of nonnegative weights $\boldsymbol{\zeta}$ such that $\zeta_k > 0$ for at least one $k \in N(i)$ for each i, the conditions $\phi > 0$ and $\gamma^j > 0$ for all j are sufficient for $b_i > 0$ in any equilibrium. In other words, if spillovers are positive and the game is one of strategic complements, the only way the national level could allocate no state presence in municipality i is if both this municipality's weight and the weights of all of its neighbors are zero. As we will describe below, in our data both local and national

[6] However, equation (5) rules out situations in which the national state just cares about extracting resources from some municipalities, or those in which there is an explicit competition between local and national states or politicians.

state capacity choices are strictly positive for all municipalities. This will allow us to focus on interior equilibria.[7]

The next proposition draws on Allouch (2015), who establishes that for network games with nonlinear best responses, a bound on the slope of the best responses is a sufficient condition for uniqueness. This bound is a function of the lowest eigenvalue of the network matrix $\mathbf{N}(\boldsymbol{\delta})$, which quantifies the extent to which the spillovers across agents are spread through the network structure. Adapting this result to our setting and denoting the smallest eigenvalue of the matrix $\mathbf{N}(\boldsymbol{\delta})$, which is always negative, by λ_{min}, we have the following:

PROPOSITION 1 (Allouch 2015): *If for every player* $1 + \frac{1}{\lambda_{\min}(\mathbf{N}(\boldsymbol{\delta}))} < \left(\frac{\partial l_i}{\partial \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}}\right)^{-1} < 1$, *then the game has a unique Nash equilibrium.*

For the estimated parameter vector $(\alpha, \sigma, \theta, \varphi, \gamma, \boldsymbol{\delta})$, the conditions in Proposition 1 are readily verifiable. Equations (1), (7), and (8) determine the joint equilibrium distribution of local and national state capacity and prosperity.

C. *The Linear Case* ($\alpha = 1$)

Our model simplifies considerably in the case where $\alpha = 1$, which makes national choices irrelevant and implies $s_i = l_i$ in equation (7). In this case, the best response equation (7) becomes linear in neighbors' state capacity:

$$s_i = \frac{\phi}{\theta}\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} + \frac{\kappa_i}{\theta}. \tag{9}$$

In terms of this equation, $\frac{\phi}{\theta}$ is what is referred to as an "endogenous effect" in the peer effects literature: it corresponds to the effect of neighbors' or peers' choices on own choice, while the γ^js in equation (10) are referred to as "contextual effects" (see, e.g., Manski 1993). Even though the key equation of our model, (1), features only contextual effects and no endogenous effects, strategic choices make best responses take the form of an endogenous effect.

Substituting for s_i from (9) into (1), we obtain the observed relationship between prosperity and own and neighbors' state capacity as

$$p_i^j = \theta s_i^2 + \gamma^j \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} + u_i^j. \tag{10}$$

Equation (10) highlights that the identification of the impact of own state capacity on prosperity, κ_i, and of the interaction effect, ϕ, requires some care: because of the best response of municipality i, the parameters κ_i and ϕ drop out of the relationship between prosperity and state capacity, and cannot be identified from a regression of p_i^js on state capacity. Instead, such a regression can only identify (in addition to

[7] Existence of pure-strategy equilibria can be guaranteed straightforwardly either if $\phi > 0$, so that this is a game of strategic complements, or if $\alpha < l_i^{\frac{\sigma+1}{\sigma}} s_i^{\frac{\sigma-1}{\sigma}}$ for all l_i and s_i that are a solution to (7), ensuring quasi-concavity and thus enabling us to apply Kakutani's fixed point theorem. Proposition 1 provides sufficient conditions for existence and uniqueness of pure-strategy equilibria.

the spillover parameters γ^j) the cost parameter θ. Our empirical approach, detailed below, will overcome this difficulty as well.[8]

With $\alpha = 1$, the existence of pure strategy equilibria follows immediately from concavity and Kakutani's fixed point theorem, and uniqueness of an interior (positive) equilibrium, where all municipalities choose a positive investment in state capacity, is also guaranteed, since such an equilibrium is given by the solution to a set of linear equations. However, multiple equilibria with some municipalities choosing zero investment may exist unless the sufficient condition for uniqueness in Proposition 1 is satisfied.[9]

Equations (9) and (10) determine the joint distribution of local state capacity and prosperity across municipalities, and will be the focus of the first part of the paper. The just-explained identification challenge notwithstanding, the parameters (θ, ϕ, γ, $\boldsymbol{\delta}$) can be identified if these two equations are estimated simultaneously (and of course with the appropriate sources of variation, which we discuss in detail in Section IV): the parameter θ is identified from (10), and given this parameter, ϕ can be recovered from the endogenous effect estimated in equation (9), and the local average of the κ_is from the intercept in equation (9).

III. Data

For our empirical implementation, the data we use, summarized as $\{(\mathbf{p}_i, l_i, b_i, \mathbf{x}_i, \mathbf{c}_i)_{i=1}^n, \mathbf{D}, \mathbf{E}, \mathbf{A}\}$, include cross-sectional information on several dimensions of prosperity $\mathbf{p}_i$, local (l_i) and national (b_i) choices of state capacity, municipality characteristics $\mathbf{x}_i$, and colonial state presence characteristics $\mathbf{c}_i$. In addition, $\mathbf{D}$, $\mathbf{E}$, and $\mathbf{A}$ are $n \times n$ matrices containing the geodesic distances between the centroids of all pairs of municipalities, an index of variability in altitude along these geodesics, and the adjacency status of each pair of municipalities, respectively. We describe the nature and sources of these data below.

The *Fundacion Social* (FS), a Colombian NGO, collected and put together detailed data on state presence at the municipality level in 1995. Out of a total of 1,103 municipalities in Colombia, FS collected data for 1,019 of them. The two municipalities in the Department of San Andrés, an archipelago in the Caribbean comprised of several smaller islands and located 775 km from the mainland, are excluded from the sample. The remaining 1,017 municipalities comprise our main sample and the number of nodes in our network (though depending on data availability some specifications have fewer observations).

Descriptive statistics are presented in Table 1. For each municipality, FS records the number of municipality (local) public employees, the number of national state

[8] Note also that in equation (10) the spillovers and feedbacks between municipality choices within the network game lead to a quadratic reduced-form relationship between own state capacity and prosperity, so linear regressions may lead to misspecification, though we will see below that marginal effects from the estimation of "naïve" linear regressions, when properly instrumented, are similar to our structural estimates.

[9] A closely related sufficient condition for equilibrium follows from the work of Calvó-Armengol, Patacchini, and Zenou (2009) and Bramoulle, Kranton, and D'Amours (2014), and takes the form $|\lambda_{\min}(\mathbf{N}(\boldsymbol{\delta}))| < \left(\frac{|\phi|}{\theta}\right)^{-1}$. Yet another way to ensure uniqueness is by noting that when $\phi > 0$ (so that we have a game of strategic complements), $\kappa_i \geq 0$ for all i is sufficient to rule out $l_i = 0$, and then uniqueness follows from the uniqueness of an interior equilibrium noted above.

Table 1—Descriptive Statistics

	Variables	Mean	Median	SD
State capacity	Local-level state agencies	21.6	10.0	105.1
	Local-level municipality employees	99.6	20.0	843.4
	National-level municipality employees	1,038.9	220.0	7,900.2
Prosperity	Life quality index	49.8	48.0	9.9
	Public utilities coverage rate	53.7	53.4	21.5
	Fraction of population above poverty line	56.4	57.2	14.3
	Secondary enrollment rate	56.9	56.4	23.5
	Primary enrollment rate	96.8	100.0	9.5
	Vaccination coverage rate	45.2	43.8	16.8
Historical variables	Colonial state officials	5.7	0.0	122.9
	Colonial state agencies	0.6	0.0	0.9
	Distance to royal roads (km)	26.1	13.8	34.6
	Population in 1843 (000)	2.9	2.9	2.1
Network variables	Number of neighbors (degree)	5.5	5.0	1.8
	Geodesic distance to neighbors (km)	27.8	22.7	17.7
	Geodesic variability in elevation to neighbors	0.8	0.7	0.5
	Betweenness centrality	0.011	0.003	0.021
	Bonacich centrality	86.4	74.3	67.2
	Local clustering coefficient	0.45	0.40	0.18
Covariates	Distance to current highway (km)	3.1	1.5	6.5
	Longitude	−74.8	−74.8	1.5
	Latitude	5.6	5.5	2.4
	Surface area (sq km)	669.3	273.5	1,425.1
	Elevation (mts)	1,206.7	1,265.0	897.7
	Average annual rainfall (mm)	1,894.6	1,630.5	1,067.1
	Population (000)	37.4	13.8	200.5
	Number of municipalities			1,019

Note: Please see the text for variable definitions and sources.

public employees, the number of police stations, courts, notary offices, Telecom offices, post offices, agricultural bank branches, public hospitals, public health centers, public health posts, public schools, public libraries, fire stations, jails, deed registry offices, and tax collection offices.

Because our theoretical framework stresses and exploits the difference between local and national state capacities, we rely on the Colombian legislation (in particular, Law 60 of 1993 and Articles 287, 288, and 311–321 of the 1991 Constitution) to establish the presence and the number of employees of agencies which are decided at the local level, and those which are decided at the national level. Police, courts, and public hospitals fall under the responsibility of the national state. The location of agricultural bank branches was also partly determined centrally. All other agencies are under the jurisdiction of the municipality. Because, as noted in the introduction, our focus is on the "infrastructural" features of state capacity, we construct two measures of local state capacity l_i: (i) the number of municipality-level bureaucrats, which excludes police officers, judges, all other judicial employees, and public hospital employees, and (ii) the total count of municipality state agencies (notary offices, Telecom offices, post offices, health centers, health posts, schools, libraries, fire stations, jails, deed registry offices, and tax collection offices). We treat these two variables as alternative measures of local state capacity, and proxy national state capacity, b_i, with the number of national public employees in the municipality.

Municipalities have three main revenue sources to finance public spending and investment in state infrastructure and bureaucracy: local taxes (mainly industry and commerce tax, and property tax), royalties from mining activities, and transfers from the national state. The bulk of national state transfers ("situado fiscal") are allocated to each municipality using a fixed rule (geographically, this allocation is at the departmental level). These resources directly enter into the municipality's budget. Though the law stipulates that at least 60 percent of these transfers must go to education and at least 20 percent to health (Law 60 of 1993), it also grants full discretion to the municipality on their specific allocation and use. In particular, mayors (who are elected officials since 1988) propose a budget which is implemented if approved by the elected municipality council.

To measure local prosperity (and public goods), we collected available data from various sources. The Centro de Estudios sobre Desarrollo Economico (CEDE) at Universidad de los Andes provided us with average 1992–2002 primary and secondary school enrollment rates. From the OCHA group at the United Nations, we collected data on aqueduct, sewage, and electricity household coverage rates in 2002, and on vaccination rates in 2002. Finally, from the Colombian national statistics bureau (DANE) we have data on the fraction of the population in poverty (under the poverty line) in 1993 and 2005, and on a life quality index for 1998. Based on these data, we focus on four prosperity outcomes which are likely to depend on local state capacity: (i) the life quality index p_i^1; (ii) the average public utilities coverage in 2002 (aggregating aqueduct, sewage, and electricity) p_i^2; (iii) the population above the poverty line in 2005 p_i^3; and (iv) the secondary school enrollment rate p_i^4. All of our prosperity measures are standardized z-scores (observation minus mean divided by standard deviation). We focus on these four prosperity outcomes because, although they are positively correlated, as Figure 1 shows the shape of each distribution is significantly different, suggesting that each of these dimensions of prosperity contains some independent information.

We will use two other measures of local public goods, primary school enrollment and vaccination coverage, and two historical outcomes, historical literacy and school enrollment rates from the 1918 national census, as falsification exercises. The reasoning for these falsification exercises is explained below.

We built the adjacency matrix of municipalities $\mathbf{A}$ based on the Colombian National Geographic Institute (IGAC). Using Arc-GIS geo-referenced data, we computed the geodesic ("as the bird flies") distance between the centroid of each pair of municipalities d_{ij}, and organized this data in matrix $\mathbf{D}$. Also using Arc-GIS and geo-referenced topographic data for Colombia, we computed e_{ij}, the index of the variability of altitude along the geodesic connecting the centroid of every pair of municipalities, capturing the frictions that a more uneven path connecting two municipalities imposes over the opportunities for contact and spillovers between them.[10] We organize these data into the matrix $\mathbf{E}$.

[10] More specifically, we divided each geodesic into a number of intervals for a given altitude range along the geodesic itself and computed the average altitude of each of the intervals. The e_{ij} is then computed as the variance of the average altitude across intervals, where each interval is appropriately weighted by its length.

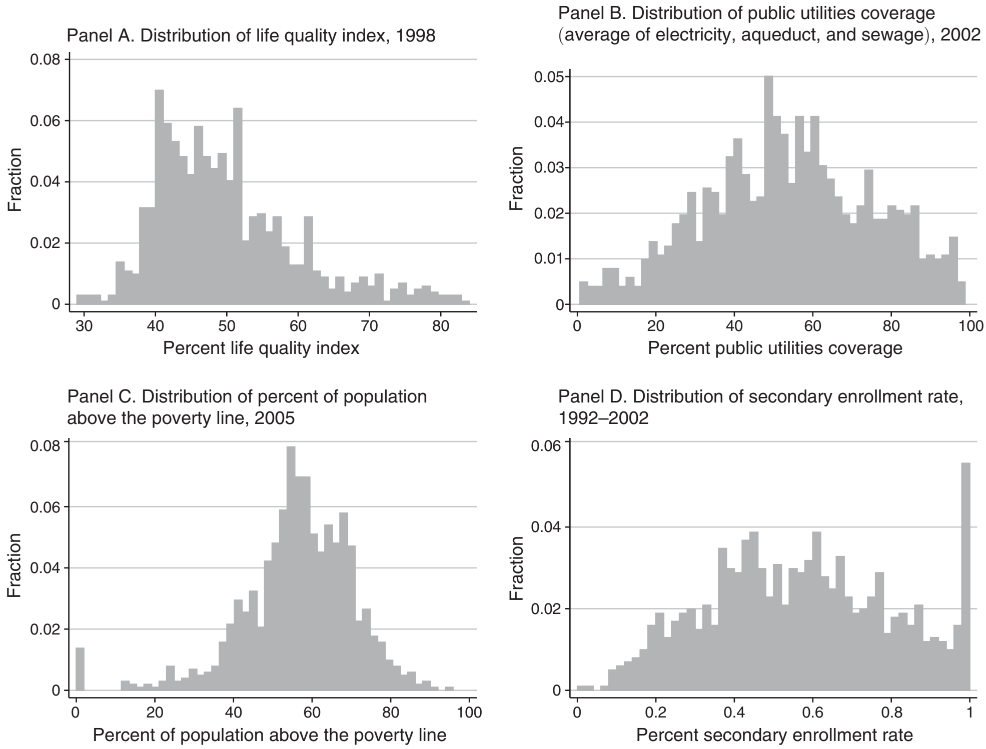

Figure 1. Distribution of Prosperity Outcomes

Notes: The figure plots the empirical distributions for the four prosperity outcomes in the sample of Colombian municipalities. Panel A presents the distribution of the life quality index in 1998. Panel B presents the distribution of the public utilities coverage (average of aqueduct, electricity, and sewage) in 2002. Panel C presents the distribution of the fraction of the population above the poverty line in 2005. Panel D presents the distribution of the average 1992–2002 secondary enrollment rate.

The several dimensions of Spanish colonial state presence we utilize come from historical data originally collected by Durán y Díaz (1794),[11] which specify the location of officials and state administrations. Of particular interest, Durán y Díaz (1794) has a complete record of every colonial official and of several state agencies throughout the viceroyalty. From this document we compiled municipality-level data on the number of crown employees, and indicators on the presence of an *alcabala*,[12] a tobacco or playing cards *estanco*,[13] a liquor or gunpowder *estanco*, and a post office. In addition to these variables, we collected information from historical maps in Useche Losada (1995) which depict the location of colonial royal roads. We geo-referenced these maps using Arc-GIS, and computed the distance between the centroid of each municipality and the closest royal road. Based on these data,

[11] This source is located at the National Library in Bogotá and contains a full account of state officials, salaries, the military, tariffs, taxes, and fiscal revenue for all of the Viceroyalty of *Nueva Granada* in the late eighteenth century. We thank Malcolm Deas for pointing us to this document.

[12] The *alcabala* was a sales tax (usually at 2 percent). The indicator denotes the presence of the local agency in charge of collecting the tax.

[13] An *estanco* was a state monopoly over the sale of a particular good, which also often allocated production rights and regulated quantities. The indicator denotes the presence of the local agency in charge of administering the *estanco.*

we then constructed three measures of colonial state presence: (i) the number of crown employees, denoted by c_i^1; (ii) a count of the number of agencies (between 0 and 4) reported by Durán y Díaz, denoted by c_i^2; and (iii) the distance to the closest royal road, denoted by c_i^3. We also collected population data from the 1843 national census, which we use as an instrument for current population in specifications where we allow for current population to be endogenous.

Finally, our main covariates included in all specifications (in the vector $\mathbf{x}_i$) are distance to a current highway, longitude, latitude, surface area, altitude, and average annual rainfall (all obtained from CEDE) as well as (log) population in 1995 (obtained from the Colombian National Statistical Institute, the DANE). In some specifications, we also use the following additional covariates: the density of primary, secondary, and tertiary rivers (from CEDE), and the distribution of land in each municipality by quality, coded as the share of each of eight qualities, and by land type, classified as under water, valley, mountain, hill, and plain (obtained from IGAC).

IV. Empirical Strategy and Results: The Linear Case

Our structural model fully determines the cross-sectional distribution of equilibrium state capacity choices and prosperity outcomes.[14] Our empirical strategy has multiple components. In this section, we first discuss the exclusion restrictions implied by our use of several historical variables as instruments in the context of the linear case where $\alpha = 1$. The same arguments also apply to the general model studied in the next section. We then turn to various estimation strategies and empirical findings. As a preview, we find municipalities' state capacity investment decisions are strategic complements, and that the complementarity is weak enough that our parameter estimates are always consistent with the network game having a unique equilibrium. Our results indicate that all of our prosperity outcomes are strongly dependent on the overall levels of state capacity in a municipality, and that state capacity spillovers are significant.

A. *Exclusion Restrictions*

In addition to the identification problem encapsulated in equation (10) discussed above, we face the standard challenges resulting from endogeneity and omitted variable biases (in view of the fact that state capacity is endogenously determined) and the problems associated with the estimation of contextual and endogenous effects (e.g., Manski 1993). To discuss these problems and our strategy for dealing with them, let us substitute for (2) and (3) into (9) and (10) to obtain the equations we will estimate in our empirical work (for the $\alpha = 1$ case). The best response equation is

$$s_i = \frac{\phi}{\theta}\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} + \frac{1}{\theta}g(\mathbf{c}_i\boldsymbol{\varphi} + \mathbf{x}_i\boldsymbol{\beta}) + \varsigma_i^D + \xi_i, \tag{11}$$

[14] One could suppose that our cross-sectional data reflect the resting point of a dynamical process, for example, reflecting some sort of adaptive dynamics. If these dynamics are driven by the best responses of the model outlined above, then the conditions for uniqueness in Proposition 1 or in footnote 9 also ensure convergence (and global stability) of the dynamical process to the Nash equilibrium characterized above.

where $\xi_i \equiv \tilde{\xi}_i/\theta$, and recall that the ς_i^Ds are department fixed effects. The prosperity equation is (one for each dimension of prosperity indexed by j):

$$(12) \qquad p_i^j = \theta s_i^2 + \gamma^j \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} + \mathbf{x}_i \tilde{\boldsymbol{\beta}}^j + \tilde{\varsigma}_{is}^{jD} + \epsilon_i^j.$$

The standard endogeneity problem (for the case of $\alpha = 1$) is a simple consequence of the fact that the error term in (12) may be correlated with s_i, i.e., $\text{cov}(s_i, \epsilon_i^j) \neq 0$. There are also good reasons to suspect that spillover effects—the contextual effects in (12)—cannot in general be estimated consistently with OLS because of correlation of the error term in this equation with neighbors' state capacity, i.e., $\text{cov}(\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}, \epsilon_i^j) \neq 0$. The main reason for such a correlation is that the omitted influences on prosperity are likely to be spatially correlated; in other words, assuming spatial independence of the error terms in this setting would be highly implausible.

As already noted, the estimation of the own and cross effects of state capacity further necessitates the joint estimation of the best response equation (11), and the same spatial correlation concerns applied to this equation, i.e., $\text{cov}(\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}, \xi_i) \neq 0$, imply that the endogenous effects in this equation cannot be estimated consistently with OLS either.

Our strategy for dealing with both sets of concerns is to rely on historical sources of variation in state capacity represented by the vector $\mathbf{c}$. We argue that colonial state presence likely altered the relative costs and benefits of subsequent investments in local state presence and thus κ_i (from equation (2)). In addition, these colonial variables are also arguably unrelated to current prosperity outcomes except through their impact on state capacity, i.e., $\text{cov}(\mathbf{c}, \epsilon_i^j) = 0$.

The main reason why we believe this exclusion restriction is plausible is that the location of the colonial state was determined by a variety of idiosyncratic factors that are broadly unrelated to current determinants of prosperity and have now ceased to have any direct relevance to economic prosperity (or public goods provision). This is most clear for the royal roads network, which was the main investment in communications infrastructure during the colonial period (see Useche Losada 1995). This road network, partially inherited from precolonial roads and partially built under Spanish authority for a variety of different reasons including pilgrimage, involved steep flights of steps unsuited to horse or cart traffic (see Langebaek et al. 2000). The considerable challenges of converting colonial royal roads into modern motorways meant that much of this network was not converted to railroads or highways and was subsequently abandoned (see Pachón and Ramírez 2006). As a result, though the location of these roads reflects accurately the presence of the colonial state and thus the regions where the Spanish authorities were more interested in controlling the territory, distance to these roads should have no direct effect on present-day public goods or prosperity (especially since we also control for the current road network). Although it is possible that the location of these roads may have influenced prosperity during early colonial times and this prosperity has persisted, we will provide evidence against this channel explaining our results as well.

Figure 2 shows that our measures of colonial state presence, the size of the crown bureaucracy, and the number of state agencies, concentrate around specific areas, beyond which the colonial state was mostly absent. This reflects the colonial settlement strategy, which aimed at achieving several different objectives. For example,

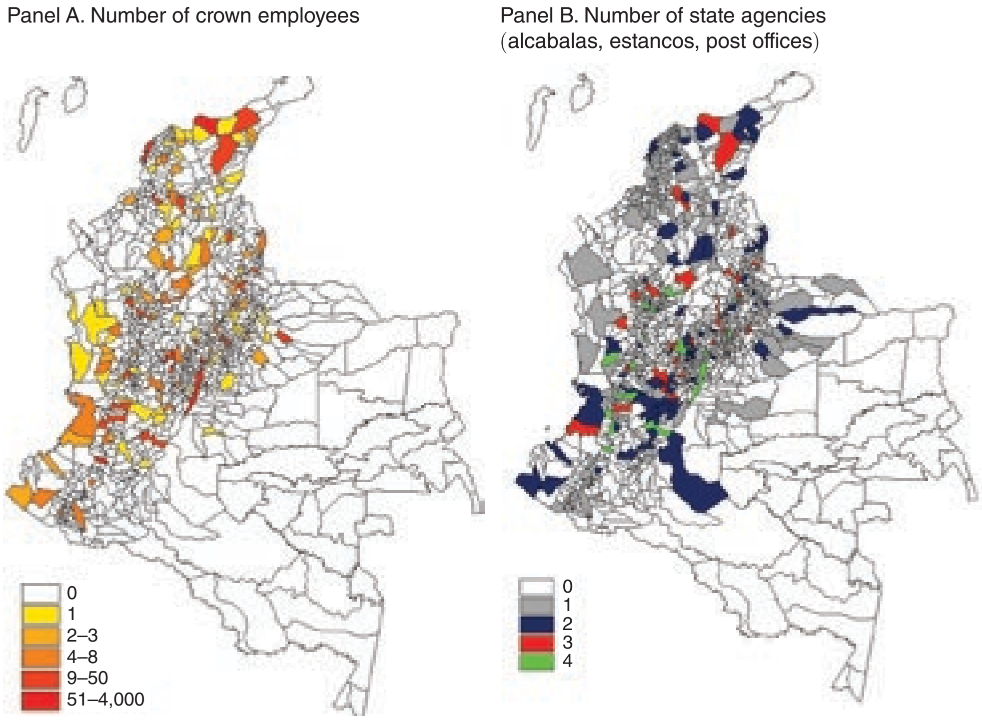

Figure 2. Colonial State Presence, 1794

Notes: Panel A presents the current municipality-level spatial distribution of crown employees in 1794. Panel B presents the current municipality-level spatial distribution of the count of colonial state agencies in 1794, including *alcabalas*, tobacco and playing cards *estancos*, liquor and gunpowder *estancos*, and post offices.

in regions heavily involved in gold mining during the seventeenth and eighteenth centuries, the presence of colonial officials and crown agencies was narrowly related to taxation functions and followed the gold reserves. In regions with higher densities of Spanish settlers and their descendants, on the other hand, the demand for public services such as legal adjudication and market regulation translated into a different type of colonial state. Finally, in strategically located places, such as the Caribbean coast or key outposts along the Magdalena River (the main communications channel at the time), the presence of the Spanish colonial state was related to military objectives, for instance the provision of services to the Spanish fleet. Just like the royal roads network, none of these factors are relevant any longer, and therefore, though they influence the costs and benefits of building and maintaining local state capacity, they should have no direct effect on present-day prosperity except through state capacity.

Critically for our empirical strategy, the exclusion restriction $\mathrm{cov}\left(\mathbf{c}, \epsilon_i^j\right) = 0$ also implies that these colonial variables should also be uncorrelated with the error terms in the prosperity equations of neighbors, i.e., $\mathrm{cov}\left(\mathbf{N}_i(\boldsymbol{\delta})\mathbf{c}, \epsilon_i^j\right) = 0$ and in fact, $\mathrm{cov}\left(\mathbf{N}_i^k(\boldsymbol{\delta})\mathbf{c}, \epsilon_i^j\right) = 0$, where $\mathbf{N}_i^k(\boldsymbol{\delta})$ denotes the ith row of the kth integer power of the matrix $\mathbf{N}(\boldsymbol{\delta})$ (e.g., $\mathbf{N}^2(\boldsymbol{\delta})$ is the matrix of neighbors of neighbors). Intuitively, if colonial state presence and distance to royal roads of a municipality has no direct

Table 2—Within Department Correlations of Historical State Presence Variables Averaged across Departments

Distance to royal roads			Colonial officials			Colonial state agencies		
Own	Neighbors' average distance	Neighbors of neighbors' average distance	Own	Neighbors' average distance	Neighbors of neighbors' average distance	Own	Neighbors' average distance	Neighbors of neighbors' average distance
1.000								
0.283	1.000							
0.045	0.615	1.000						
−0.095	−0.072	−0.047	1.000					
−0.146	0.039	0.060	−0.061	1.000				
−0.044	0.063	0.072	−0.062	−0.070	1.000			
−0.135	−0.039	−0.017	0.545	−0.006	−0.002	1.000		
−0.208	0.250	0.283	−0.053	0.490	0.008	0.022	1.000	
−0.193	0.244	0.334	−0.036	0.031	0.408	0.078	0.289	1.000

Note: Correlations reported are the average across departments of the correlations for each department.

effect on public goods and prosperity in that municipality, it should also have no impact on the same outcomes in neighboring municipalities.[15] The same reasoning can further be applied to the best response equation, (11), so that we should also have $\mathrm{cov}(\mathbf{N}_i^k(\boldsymbol{\delta})\mathbf{c}, \xi_i) = 0$ for any integer k.

One concern with the strategy utilized here is that even if the argument for the validity of the colonial variables as instruments for own state capacity is plausible, they may happen to be spatially correlated (a particularly likely outcome for historical and geographic variables), making the lack of correlation with neighbors' error terms less plausible. In the Colombian setting, however, the Spanish state's heterogeneous objectives and its strategy of locating bureaucracies and agencies in particular cities that had control and jurisdiction over surrounding areas meant that towns with relatively high levels of colonial state presence typically had neighbors with relatively low state presence, and hence the spatial correlation of the colonial state is very weak or negative (see Figure 2).

Table 2 confirms this by presenting the within-department spatial correlation matrix of our three colonial state presence variables. Own colonial state employees are weakly negatively correlated with neighbors' and neighbors of neighbors' colonial state employees (−0.061 and −0.062 respectively). Similarly, own colonial state agencies are basically uncorrelated with neighbors' and neighbors of neighbors' colonial state agencies (0.022 and 0.078 respectively). Perhaps somewhat more surprisingly, the same is also true of the distance to royal roads variable: the correlation between own and neighboring distance to royal roads is only 0.28, and the correlation falls to 0.045 between own and neighbors of neighbors' distance to royal roads. In conjunction with the colonial state presence variables that are spatially negatively correlated, this pattern alleviates any concerns resulting from spatially correlated instruments leading to biased estimates.

[15] Crucially for this argument, the network structure of municipalities, given by the administrative map of Colombia, physical distances, and variability of altitude, are taken as exogenous. This is plausible in view of the fact that about 85 percent of Colombian municipalities were created before 1900.

B. *Instrumental-Variables Estimates*

We propose several alternative estimation strategies, all relying on the exclusion restrictions outlined above. The first and most straightforward approach we pursue is to fix $\boldsymbol{\delta}$ and let $g(\cdot)$ be approximated by a linear function, enabling the estimation of equations (11) and (12) separately using linear IV. Specifically, we use six instruments for $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$ in our benchmark specification (11): neighbors' crown employees, number of neighbors' colonial agencies, neighbors' distance to royal roads, and neighbors of neighbors' crown employees, number of neighbors of neighbors' colonial agencies, and neighbors of neighbors' distance to royal roads. Our model is overidentified, enabling us to perform overidentification tests to verify the (internal) validity of our instruments (below we also report estimates using only subsets of the instruments).

Table 3 presents the estimates for equation (11), where we impose $\boldsymbol{\delta} = (1, 1)$ and assume $g(\cdot)$ to be a linear function: $g(\mathbf{c}_i \boldsymbol{\varphi} + \mathbf{x}_i \boldsymbol{\beta})/\theta = a + \mathbf{c}_i \boldsymbol{\varphi} + \mathbf{x}_i \boldsymbol{\beta}$. In our benchmark estimates, our vector of covariates $\mathbf{x}_i$ includes longitude, latitude, surface area, elevation, rainfall, a dummy for department capital, distance to a current highway, and current (1995) population. We measure state capacity alternately as the number of public agencies (columns 1–3) or the number of municipality employees (columns 5–7). For ease of comparison, all reported values are average marginal effects. Throughout, all standard errors are corrected for spatial correlation using the Conley (1999) adjustment, adapted to our network structure,[16] and for the reported marginal effects, they are computed using the delta method.

Columns 1 and 5 present OLS estimates as a benchmark. Columns 2 and 6 report the instrumental variables estimates for the same equation (with log population treated as an exogenous covariate). Finally, columns 3 and 7 treat population as endogenous, instrumenting it using the 1843 population (we also include a dummy for municipalities without population data in the 1843 census). The bottom panel of the table includes the first-stage estimates for $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$, showing a strong positive correlation of neighbors' state capacity with neighbors' historical variables (positive for colonial state presence and negative for distance to royal roads), and unsurprisingly, a somewhat weaker relationship with neighbors of neighbors' historical variables. At the bottom, we also report overidentification tests for the validity of the instruments, which never reject the null hypothesis that the instruments are valid.

All of our estimates in Table 3 show a positive and precisely estimated slope for the best response equation, which yields a positive interaction effect ϕ and implies that the game between municipalities exhibits strategic complementarities. Interestingly, the IV estimates are always close to the OLS ones. Though neighbors' colonial state officials, colonial state agencies, and distance to royal roads all are

[16] The robust spatial correlation-corrected variance matrix of the IV estimator takes the form

$$(\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\hat{\mathbf{W}}\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X}(\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X})^{-1}, \text{ where}$$

$$\hat{\mathbf{W}} = \boldsymbol{\Omega} * \mathbf{I} + \sum_{j=1}^{t} \frac{t+1-j}{t+1} \left(\boldsymbol{\Omega} * \mathbf{N}^t(\delta) + [\boldsymbol{\Omega} * \mathbf{N}^t(\delta)]'\right),$$

t is the highest network degree at which we truncate spatial correlation (we truncate the spatial correlation at second-degree adjacency, in practice allowing for arbitrary decaying spatial correlation between neighbors and neighbors of neighbors), $\boldsymbol{\Omega}$ is the outer product of the residuals, and $*$ denotes element-by-element multiplication.

TABLE 3—CONTEMPORARY STATE EQUILIBRIUM BEST RESPONSE

State capacity measured as log of:	Equilibrium best response							
	Number of state agencies				Number of municipality employees			
	OLS	IV	IV	Sys. GMM	OLS	IV	IV	Sys. GMM
Panel I	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ds_i/ds_j	0.016	0.017	0.019	0.020	0.021	0.022	0.022	0.016
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)
$ds_i/d(\mathit{colonial\ state\ officials}_i)$	0.127	0.128	0.108	−0.040	0.129	0.130	0.105	0.087
	(0.031)	(0.031)	(0.033)	(0.050)	(0.043)	(0.043)	(0.047)	(0.069)
$ds_i/d(\mathit{colonial\ state\ agencies}_i)$	0.003	0.001	−0.016	0.096	0.017	0.017	−0.002	0.085
	(0.033)	(0.033)	(0.033)	(0.055)	(0.058)	(0.059)	(0.060)	(0.085)
$ds_i/d(\mathit{distance\ to\ royal\ roads}_i)$	0.008	0.010	0.007	0.074	−0.035	−0.035	−0.038	−0.036
	(0.019)	(0.019)	(0.021)	(0.034)	(0.034)	(0.035)	(0.036)	(0.044)
Panel II	First stage for $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$							
Neighbors' colonial state officials		0.320	0.338			0.556	0.637	
		(0.096)	(0.100)			(0.143)	(0.155)	
Neighbors' colonial state agencies		1.275	1.242			1.673	1.631	
		(0.126)	(0.131)			(0.211)	(0.223)	
Neighbors' distance to royal roads		−1.031	−0.992			−1.497	−1.456	
		(0.219)	(0.223)			(0.278)	(0.287)	
Neighbors of neighbors' colonial state officials		0.209	0.269			0.311	0.427	
		(0.170)	(0.177)			(0.240)	(0.258)	
Neighbors of neighbors' colonial state agencies		0.649	0.568			1.085	0.937	
		(0.181)	(0.190)			(0.264)	(0.281)	
Neighbors of neighbors' distance to royal roads		0.178	0.172			0.268	0.296	
		(0.169)	(0.173)			(0.231)	(0.236)	
First-stage R^2		0.681	0.671			0.681	0.658	
F-test for excluded instruments		17.0	145.6			19.55	171.0	
F-test p-value		0.000	0.000			0.000	0.000	
Overidentification test: Test statistic		4.053	6.350			4.399	5.775	
χ^2 p-value		0.542	0.385			0.494	0.449	
log population	Control	Control	Instrum	Instrum	Control	Control	Instrum	Instrum
Observations	975	975	975	963	1,017	1,017	1,017	1,003

Notes: All reported estimates are average marginal effects. All models include department fixed effects and the following vector of controls: longitude, latitude, surface area, elevation, annual rainfall, distance to current highway, and a department capital dummy. Columns 1–4 use the log number of local state agencies as the measure of state capacity, and columns 5–8 use the log number of municipality employees as the measure of state capacity. Panel I reports the estimates of the best response equation, and panel II reports the first stage for the instrumental variables models of columns 2, 3, 6, and 7. In the models reported in columns 2 and 6, log population is treated as exogenous. In the models reported in columns 3, 4, 7, and 8, log population is instrumented using 1843 population. Models in column 4 are estimated with GMM as a system together with those reported in columns 4, 8, 12, and 16 of Table 4A. Models in column 8 are estimated with GMM as a system together with those reported in columns 4, 8, 12, and 16 of Table 4B. Standard errors reported in parentheses are robust to arbitrary heteroskedasticity and allow for arbitrary spatial correlation within the network following Conley (1999), adapted to the network structure as described in the text. For models with more than one endogenous right-hand-side variable, the F-test is corrected following Angrist and Pischke (2009).

statistically significant with the right sign in the first stage, only the colonial state officials variable is significant in the best response equation (but when only one of these variables is used, it is consistently significant with the right sign as we see in online Appendix Table 3). The estimate in column 3, 0.020 (s.e. = 0.003),

Table 4A—Prosperity and Public Goods Structural Equation

	State capacity measured as: log of number of municipality state agencies							
	Prosperity equation							
	Life quality index				Public utilities coverage			
	OLS	IV	IV	Sys. GMM	OLS	IV	IV	Sys. GMM
Panel I	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
dp_i/ds_i	0.802	0.394	0.389	0.314	0.602	0.563	0.567	0.314
	(0.044)	(0.135)	(0.143)	(0.041)	(0.037)	(0.127)	(0.134)	(0.041)
dp_i/ds_j	0.015	0.024	0.025	0.025	0.022	0.020	0.020	0.027
	(0.004)	(0.006)	(0.006)	(0.004)	(0.004)	(0.006)	(0.006)	(0.003)
Panel II	First stage for s_i^2							
F-test for excluded instruments		31.23	35.39			31.01	35.06	
F-test p-value		0.000	0.000			0.000	0.000	
First-stage R^2		0.670	0.655			0.670	0.655	
First-stage linear model	First stage for $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$							
F-test for excluded instruments		526.7	523.7			524.6	522.1	
F-test p-value		0.000	0.000			0.000	0.000	
First-stage R^2		0.769	0.770			0.769	0.770	
log population	Control	Control	Instrum	Instrum	Control	Control	Instrum	Instrum
Observations	973	973	973	963	975	975	975	963

(*Continued*)

implies that moving the number of state agencies of a neighbor from the median (10) to the mean (21) leads to a 1.5 percent increase in own state agencies at the median of the distribution.[17] Notice that this is only the direct ("partial equilibrium") response, and does not take into account the equilibrium feedbacks that take place through network effects as other municipalities also respond because of strategic complementarities.

Columns 6 and 7 of Table 3 present the results of the IV estimate of the slope of the best response equation with the alternative measure of state capacity, municipality employees. The estimates in this case have very similar magnitudes and precision to those using the number of local state agencies, and the first stages are also very comparable.

For the prosperity equation (12), we have two first stages, one for s_i^2 and one for $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$. We use the same set of instruments as for the best response equation (11), but also exploit the nonlinear reduced-form relationship between prosperity and state capacity by including a quartic in these instruments.[18] Marginal effects from the estimation of equation (12) are depicted in Tables 4A and 4B, which also present p-values for the joint significance of the set of instruments in both first stages for equation (12). We again present benchmark OLS and IV results from the estimation of each of our four prosperity outcomes equations separately. Columns 1–3 present

[17] $10.15 = \exp((0.02)\ln(22/11) + \ln(11)) - 1$, which is a 1.5 percent increase from the median state capacity of 10.

[18] The results are similar if we only use a quadratic in these instruments as shown in online Appendix Table 3.

TABLE 4A—PROSPERITY AND PUBLIC GOODS STRUCTURAL EQUATION (*Continued*)

	State capacity measured as: log of number of municipality state agencies							
	Prosperity equation							
	Not in poverty				Secondary enrollment			
Panel I	OLS (9)	IV (10)	IV (11)	Sys. GMM (12)	OLS (13)	IV (14)	IV (15)	Sys. GMM (16)
dp_i/ds_i	0.520	0.342	0.353	0.314	0.515	0.178	0.223	0.314
	(0.038)	(0.141)	(0.147)	(0.041)	(0.049)	(0.179)	(0.186)	(0.041)
dp_i/ds_j	0.019	0.021	0.021	0.021	0.023	0.036	0.035	0.035
	(0.004)	(0.006)	(0.006)	(0.003)	(0.005)	(0.007)	(0.007)	(0.004)
Panel II	First stage for s_i^2							
F-test for excluded instruments		31.01	35.06			30.46	35.70	
F-test p-value		0.000	0.000			0.000	0.000	
First-stage R^2		0.670	0.655			0.675	0.662	
First-stage linear model	First stage for $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$							
F-test for excluded instruments		524.6	522.1			579.3	583.1	
F-test p-value		0.000	0.000			0.000	0.000	
First-stage R^2		0.769	0.770			0.771	0.773	
log population	Control	Control	Instrum	Instrum	Control	Control	Instrum	Instrum
Observations	975	975	975	963	965	965	965	963

Notes: All reported estimates are average marginal effects. All models include department fixed effects and the following vector of controls: longitude, latitude, surface area, elevation, annual rainfall, distance to current highway, and a department capital dummy. Panel I reports the estimates of the prosperity equation for each of the four outcomes, and panel II reports the F-tests for joint significance of the excluded instruments in the first stages for the instrumental variables models of columns 2, 3, 6, 7, 10, 11, 14, and 15. The life quality index is for 1998, the public utilities coverage (aqueduct, electricity, and sewage) is for 2002, the fraction of the population above the poverty line is for 2005, and the secondary enrollment rate is the 1992–2002 average. All prosperity outcomes are standardized. In the models reported in columns 2, 6, 10, and 14, log population is treated as exogenous. In the models reported in columns 3, 4, 7, 8, 11, 12, 15, and 16, log population is instrumented using 1843 population. Models in columns 4, 8, 12, and 16 are estimated with GMM as a system together with those reported in column 4 of Table 3. Standard errors reported in parentheses are robust to arbitrary heteroskedasticity and allow for arbitrary spatial correlation within the network following Conley (1999), adapted to the network structure as described in the text. For models with more than one endogenous right-hand-side variable, the F-test is corrected following Angrist and Pischke (2009).

results for the life quality index, columns 5–7 for utilities coverage, columns 9–11 for the fraction of the population above the poverty line, and columns 13–15 for the secondary school enrollment rate. Table 4A presents the estimates for the models using the number of agencies, and Table 4B shows the estimates for the models using the number of municipality employees. Once again, we first control for population and subsequently instrument it with historical (1843) population. In all cases except for secondary schooling, we find both strong own effects that are highly significant and precisely estimated spillover effects. The results for secondary schooling are less stable and significant only in a few specifications, partly reflecting the fact that secondary schooling is at 100 percent for several municipalities as Figure 1 shows.[19] Across outcomes and specifications, we find an own marginal effect $(2\theta\bar{s})$

[19] We will see that the more efficient GMM estimator, which we present in the next subsection, consistently leads to more precise and statistically significant effects for secondary schooling as well.

Table 4B—Prosperity and Public Goods Structural Equation

	State capacity measured as: log of number of municipality employees							
	Prosperity equation							
	Life quality index				Public utilities coverage			
Panel I	OLS (1)	IV (2)	IV (3)	Sys. GMM (4)	OLS (5)	IV (6)	IV (7)	Sys. GMM (8)
dp_i/ds_i	0.478	0.247	0.222	0.210	0.263	0.395	0.310	0.210
	(0.023)	(0.092)	(0.090)	(0.023)	(0.022)	(0.111)	(0.103)	(0.023)
dp_i/ds_j	0.015	0.020	0.022	0.020	0.020	0.013	0.017	0.019
	(0.003)	(0.005)	(0.005)	(0.003)	(0.002)	(0.005)	(0.005)	(0.002)
Panel II	First stage for s_i^2							
F-test for excluded instruments		13.68	27.44			13.28	27.42	
F-test p-value		0.000	0.000			0.000	0.000	
First-stage R^2		0.571	0.576			0.570	0.575	
First-stage linear model	First stage for $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$							
F-test for excluded instruments		351.3	459.4			344.4	457.4	
F-test p-value		0.000	0.000			0.000	0.000	
First-stage R^2		0.759	0.758			0.759	0.758	
log population	Control	Control	Instrum	Instrum	Control	Control	Instrum	Instrum
Observations	1,014	1,014	1,014	1,003	1,017	1,017	1,017	1,003

(*Continued*)

that is an order of magnitude larger than the spillover effect.[20] IV estimates are somewhat smaller than OLS estimates, and very similar regardless of whether log population is treated as exogenous or endogenous.[21]

C. *System GMM*

Separately estimating equations (11) and (12) is in general inefficient because the system of $J + 1$ equations imposes several cross-equation restrictions due to their joint dependence on θ, ϕ, and $\boldsymbol{\delta}$. Moreover, the shape of the function $g(\cdot)$, which determines the intercept of the best response as a function of the covariates, $\mathbf{x}_i$, and historical variables, $\mathbf{c}_i$, is unknown and we would like to estimate it more flexibly. To achieve these objectives, we estimate equations (11) and (12) as a system using a semi-parametric GMM approach building on Ichimura and Lee (1991). Following this methodology, we created moment conditions using the orthogonality of our

[20] The average spillover effect is computed as $\gamma^j \bar{n}_i$, where $\bar{n}_i$ is the average number of "weighted" neighbors of a municipality, with f_{ij}s as weights (the average of $\bar{n}_i$ across municipalities is 0.03). Because this spillover is on more than one municipality, in the quantitative exercise in Table 5 the partial equilibrium direct effect and spillovers are roughly of the same order of magnitude.

[21] In all specifications, at our estimated parameters, the uniqueness condition from Proposition 1 is comfortably satisfied. This still leaves the question of whether, for a different set of parameters, there might be multiple equilibria and we may incorrectly estimate a parameter vector implying uniqueness. We believe this is unlikely, since our estimates are far from the values that would imply multiplicity, and as also noted in footnote 9, since $\phi > 0$, the fairly natural condition that $\kappa_i \geq 0$, which we explicitly check from our GMM estimation in the next subsection (see Figure 3), is also sufficient to guarantee uniqueness.

TABLE 4B—PROSPERITY AND PUBLIC GOODS STRUCTURAL EQUATION (*Continued*)

	State capacity measured as: log of number of municipality employees							
	Prosperity equation							
	Not in poverty				Secondary enrollment			
	OLS	IV	IV	Sys. GMM	OLS	IV	IV	Sys. GMM
Panel I	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
dp_i/ds_i	0.233	0.305	0.275	0.210	0.222	0.144	0.216	0.210
	(0.021)	(0.119)	(0.111)	(0.023)	(0.025)	(0.138)	(0.133)	(0.023)
dp_i/ds_j	0.019	0.013	0.014	0.016	0.020	0.024	0.022	0.024
	(0.003)	(0.005)	(0.005)	(0.002)	(0.003)	(0.006)	(0.006)	(0.003)
Panel II	First stage for s_i^2							
F-test for excluded instruments		13.28	27.42			14.89	29.61	
F-test p-value		0.000	0.000			0.000	0.000	
First-stage R^2		0.570	0.575			0.585	0.597	
First-stage linear model	First stage for $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$							
F-test for excluded instruments		344.4	457.4			378.2	495.3	
F-test p-value		0.000	0.000			0.000	0.000	
First-stage R^2		0.759	0.758			0.767	0.768	
log population	Control	Control	Instrum	Instrum	Control	Control	Instrum	Instrum
Observations	1,017	1,017	1,017	1,003	1,006	1,006	1,006	1,003

Notes: All reported estimates are average marginal effects. All models include department fixed effects and the following vector of controls: longitude, latitude, surface area, elevation, annual rainfall, distance to current highway, and a department capital dummy. Panel I reports the estimates of the prosperity equation for each of the four outcomes, and panel II reports the F-tests for joint significance of the excluded instruments in the first stages for the instrumental variables models of columns 2, 3, 6, 7, 10, 11, 14, and 15. The life quality index is for 1998, the public utilities coverage (aqueduct, electricity, and sewage) is for 2002, the fraction of the population above the poverty line is for 2005, and the secondary enrollment rate is the 1992–2002 average. All prosperity outcomes are standardized. In the models reported in columns 2, 6, 10, and 14, log population is treated as exogenous. In the models reported in columns 3, 4, 7, 8, 11, 12, 15, and 16, log population is instrumented using 1843 population. Models in columns 4, 8, 12, and 16 are estimated with GMM as a system together with those reported in column 8 of Table 3. Standard errors reported in parentheses are robust to arbitrary heteroskedasticity and allow for arbitrary spatial correlation within the network following Conley (1999), adapted to the network structure as described in the text. For models with more than one endogenous right-hand-side variable, the F-test is corrected following Angrist and Pischke (2009).

instruments and the residuals in equations (11) and (12). Semi-parametric GMM estimation enables us to explicitly include the cross-equation restrictions, to allow for the network links to depend nonlinearly on topographic features, and to estimate $g(\cdot)$ semi-parametrically.[22] To identify $\boldsymbol{\delta}$ in this case, we include as additional moment conditions the products of functions of geographic characteristics d_{ij} and

[22] Following Ichimura and Lee (1991), we use a flexible semi-parametric index-function approach to estimate $g(\cdot)$ by constructing the conditional expectation of the unknown function using only the empirical distribution. To smooth out the distribution, we use a density kernel that gives greater weights to closer observations. In particular, we compute:

$$E[g(\mathbf{c}_i\boldsymbol{\varphi} + \mathbf{x}_i\boldsymbol{\beta})] = \frac{\sum_{j=1}^{n}\left[s_j - \frac{\phi}{\theta}\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} - \varsigma_i^p\right]K\left(\frac{(\mathbf{c}_i - \mathbf{c}_j)\boldsymbol{\varphi} + (\mathbf{x}_i - \mathbf{x}_j)\boldsymbol{\beta}}{a_n}\right)}{\sum_{k=1}^{n} K\left(\frac{(\mathbf{c}_i - \mathbf{c}_j)\boldsymbol{\varphi} + (\mathbf{x}_i - \mathbf{x}_j)\boldsymbol{\beta}}{a_n}\right)},$$

where $K(\cdot)$ is the kernel taken to be the normal distribution in the baseline, j denotes observations, and i is the grid point.

e_{ij} (the average distance of each municipality to neighboring municipalities and the average variation in elevation along geodesics connecting municipality i to its neighbors) with the residuals from the structural equations.[23]

For ease of comparison with our IV estimates, the (system) GMM estimates are also presented in Tables 3, 4A, and 4B. The results in column 4 of Table 3 are jointly estimated with the results of columns 4, 8, 12, and 16 of Table 4A, and column 8 of Table 3 is jointly estimated with columns 4, 8, 12, and 16 of Table 4B. Marginal effects based on GMM estimates are remarkably similar to the linear IV estimates, but are more precise. This partly reflects the fact that by estimating the full system of five equations jointly, we are imposing the restriction that the coefficient of s_i^2 is the same for all of our prosperity outcomes, leading to a gain in efficiency (and this explains why the estimate for the own effect is the same across columns in Tables 4A and 4B).[24]

Figure 3 presents our estimate of $g(\mathbf{c}_i\varphi + \mathbf{x}_i\beta)/\theta$. Over most of its range, the function is very precisely estimated. Recall that in our model, $g_i(\cdot) = \kappa_i$, is proportional to the average effect of own state capacity on prosperity. The figures show that this function is positive for all its relevant range and is decreasing monotonically. Finally, online Appendix Figure 1 presents scatterplots of the observed and predicted values of the endogenous variables from the GMM estimates, which all depict a very good fit.

D. *Counterfactuals*

To assess the quantitative magnitudes of our estimates, Table 5 presents the results of a counterfactual experiment showing the implications of increasing local state presence in all municipalities below median local state presence to the median

[23] Letting $\psi = (\theta, \phi, \gamma, \varphi, \beta, \varsigma, \tilde{\beta}, \tilde{\varsigma})$, our semi-parametric system GMM estimator is given by

$$\min_{\psi, \delta} \left[\sum_{i=1}^{n} \mathbf{Z}_i(\delta)'\mathbf{q}_i(\psi, \delta)\right]' \left(\sum_{i=1}^{n} \mathbf{Z}_i(\delta_0)'\hat{\mathbf{W}}_i\mathbf{Z}_i(\delta_0)\right)^{-1} \left[\sum_{i=1}^{n} \mathbf{Z}_i(\delta)'\mathbf{q}_i(\psi, \delta)\right],$$

where $\mathbf{q}_i(\psi, \delta) = [\epsilon_i^1, \dots, \epsilon_i^J, \xi_i]'$, $\hat{\mathbf{W}}_i = \hat{\mathbf{u}}_i\hat{\mathbf{u}}_i' + \sum_{j=1}^{t} \frac{t+1-j}{t+1+20}(\boldsymbol{\Omega}_{ij} + \boldsymbol{\Omega}_{ij}')$, $\boldsymbol{\Omega}_{ij} = \dfrac{\sum_{j \in N^t(i)} f_{ij}\hat{\mathbf{u}}_i\hat{\mathbf{u}}_j'}{|N^t(i)|}$, t is the highest network degree at which we truncate spatial correlation (in practice we allow spatial correlation between neighbors and neighbors of neighbors), $\hat{\mathbf{u}}_i$s are vectors of residuals from the first-stage estimation given by $\hat{\mathbf{u}}_i = \mathbf{q}_i(\psi_0, \delta_0)$ and $(\psi_0, \delta_0) = \arg\min_{\psi,\delta}\left[\sum_{i=1}^{n} \mathbf{Z}_i(\delta)'\mathbf{q}_i(\psi, \delta)\right]'\left(\sum_{i=1}^{n}\mathbf{Z}_i(\mathbf{1})'\mathbf{Z}_i(\mathbf{1})\right)^{-1}\left[\sum_{i=1}^{n} \mathbf{Z}_i(\delta)'\mathbf{q}_i(\psi, \delta)\right]$. Moreover,

$$\mathbf{Z}_i(\delta) = \begin{bmatrix} \mathbf{I}_J \otimes \mathbf{z}_i^p(\delta) & \mathbf{0} \\ \mathbf{0} & \mathbf{z}_i^{BR}(\delta) \end{bmatrix}$$

is the matrix of instruments for observation i, $\mathbf{z}_i^p(\delta)$ is the vector of instruments for the prosperity equations, and $\mathbf{z}_i^{BR}(\delta)$ is the vector of instruments for the best response equation. These are exactly the same as the set of instruments we used with the linear IV strategy in the previous subsection.

The analytic spatial correlation consistent asymptotic variance for this estimator is given by

$$\left(\left[\sum_{i=1}^{n} \mathbf{Z}_i\left(\hat{\delta}\right)'\nabla_{\psi,\delta}\mathbf{q}_i\left(\hat{\psi}, \hat{\delta}\right)\right]'\left(\sum_{i=1}^{n} \mathbf{Z}_i(\delta_0)'\hat{\mathbf{W}}_i\mathbf{Z}_i(\delta_0)\right)^{-1}\left[\sum_{i=1}^{n} \mathbf{Z}_i\left(\hat{\delta}\right)'\nabla_{\gamma,\delta}\mathbf{q}_i\left(\hat{\gamma}, \hat{\delta}\right)\right]\right)^{-1}.$$

Notice that this estimator allows for both arbitrary spatial and cross-equation correlation. The choice of weights for the spatial correlation terms must be such that they approach 1 as $t \to \infty$, and $\left(\sum_{i=1}^{n}\mathbf{Z}_i(\delta_0)'\hat{\mathbf{W}}_i\mathbf{Z}_i(\delta_0)\right)^{-1}$ is positive definite.

[24] The conditions for a unique equilibrium in Proposition 1 are again easily satisfied at our GMM estimates.

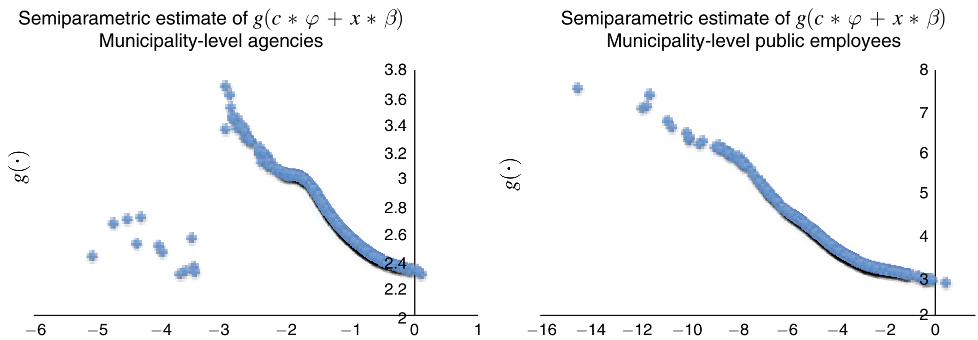

FIGURE 3. ESTIMATED $g(\mathbf{c}_i\varphi + \mathbf{x}_i\beta)$ FUNCTION

Notes: The figure plots the GMM estimates of $g(\cdot)$, the intercept of the best response equation. The left-hand-side panel presents the estimate for the model using municipality agencies as the measure of local state capacity. The right-hand-side panel presents the estimate for the model using municipality public employees as the measure of local state capacity.

TABLE 5—EXPERIMENT: IMPLICATIONS OF MOVING ALL MUNICIPALITIES BELOW MEDIAN STATE CAPACITY TO MEDIAN

	Panel IA. Partial equilibrium change				*Panel IB. General equilibrium change*			
			Fraction due to				Fraction due to	
Panel I. Linear model	From	To	Own effect	Spillovers	From	To	Direct effect	Network effects
Local agencies	10	10			10	20.6		
Life quality index	48.0	49.0	53.4%	46.6%	48.0	58.2	9.8%	90.2%
Utilities coverage	53.3	57.2	51.7%	48.3%	53.3	73.7	18.9%	81.1%
Percent not in poverty	57.1	60.0	57.1%	43.0%	57.1	68.3	25.5%	74.5%
Secondary enrollment	56.6	59.2	45.5%	54.5%	56.6	82.4	10.1%	89.9%

Panel II. Nonlinear model (under SMM parameter estimates)	*Panel IIA. Partial equilibrium change* From	To	*Panel IIB. General equilibrium change* From	To
Local agencies	10	10	10	23.4
Life quality index	48.0	51.0	48.0	60.2
Utilities coverage	53.3	56.8	53.3	63.4
Percent not in poverty	57.1	61.8	57.1	71.3
Secondary enrollment	56.6	59.0	56.6	61.5

Notes: This table reports results from an experiment that takes all municipalities below median state capacity to the median, using the estimated parameters of the models measuring state capacity as the number of local state agencies. Panel I reports the medians of the empirical and counterfactual distributions using the structural parameters of the linear model estimated with GMM as a system. Panel II reports the medians of the empirical and counterfactual distributions using the structural parameters of the nonlinear model estimated with SMM. Panels IA and IIA report the medians for the partial equilibrium exercise where municipalities' best responses are held fixed. Panels IB and IIB report the full equilibrium responses (when all municipalities best respond to the increase in state capacity among the municipalities below median state capacity). The life quality index is for 1998, the public utilities coverage (aqueduct, electricity, and sewage) is for 2002, the fraction of the population above the poverty line is for 2005, and the secondary enrollment rate is the 1992–2002 average.

of the distribution. Panels IA and IB in the table present the results using the GMM estimates reported in this subsection (the third and fourth panels contain estimates from the general model and will be discussed in the next subsection). The first panel depicts the partial equilibrium effects (holding the response of other municipalities constant) and shows significant and sizable impacts on the quality of life index, the

Table 6—Placebo Exercise: Nationally Determined Prosperity and Public Goods Outcomes Structural Equation

State capacity measured as log of	Number of municipality state agencies				Number of municipality employees			
	Prosperity equation							
	Primary enrollment		Vaccination coverage		Primary enrollment		Vaccination coverage	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Panel I	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
dp_i/ds_i	−0.049	0.198	0.015	0.260	−0.007	0.355	0.013	0.134
	(0.051)	(0.207)	(0.046)	(0.199)	(0.027)	(0.154)	(0.025)	(0.143)
dp_i/ds_j	0.001	−0.002	0.004	−0.002	0.000	−0.011	−0.002	−0.005
	(0.005)	(0.007)	(0.005)	(0.008)	(0.003)	(0.007)	(0.003)	(0.006)
Panel II	First stage for s_i^2							
F-test for excluded instruments		36.41		35.06		29.33		27.42
F-test p-value		0.000		0.000		0.000		0.000
First-stage R^2		0.663		0.655		0.597		0.575
	First stage for $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$							
F-test for excluded instruments		585.0		522.1		490.5		457.4
F-test p-value		0.000		0.000		0.000		0.000
First-stage R^2		0.773		0.770		0.768		0.758
Observations	963	963	975	975	1,004	1,004	1,017	1,017

Notes: All reported estimates are average marginal effects. All models include department fixed effects and the following vector of controls: longitude, latitude, surface area, elevation, annual rainfall, distance to current highway, and a department capital dummy. Columns 1–4 report estimates for models using the number of municipality agencies as the measure of state capacity, and columns 5–8 report estimates for models using the number of municipality employees as the measure of state capacity. Panel I reports the estimates of the prosperity equation for each of the two placebo outcomes, and panel II reports the F-tests for joint significance of the excluded instruments in the first stages for the instrumental variables models of columns 2, 4, 6, and 8. The primary enrollment rate is the 1992–2002 average, and vaccination coverage is for 1998. All prosperity outcomes are standardized. In the models reported in columns 2, 4, 6, and 8, log population is instrumented using 1843 population. Standard errors reported in parentheses are robust to arbitrary heteroskedasticity and allow for arbitrary spatial correlation within the network following Conley (1999), adapted to the network structure as described in the text. For models with more than one endogenous right-hand-side variable, the F-test is corrected following Angrist and Pischke (2009).

fraction of the population above poverty, utilities coverage, and secondary school enrollment. For example, the median fraction of the population above poverty increases from 57 percent to 60 percent. The table also indicates that about 57 percent of this is due to direct effects, so that spillover effects are not implausibly large, though still sizable. The second panel then factors in the full equilibrium responses through network effects. Now the quantitative magnitudes are much larger—reflecting the positive responses due to strategic complementarities. For example, the median fraction above poverty now rises to 68 percent, implying that the network effects are now 5–10 times as large as the own effects. This is indicative of the importance of network effects in this setting.

E. *Falsification Exercises*

We now report two falsification exercises, supporting the validity of the exclusion restrictions used in our analysis so far. The first exercise, reported in Table 6, investigates whether own and neighbors' local state presence is correlated with two outcomes, primary school enrollment and vaccination coverage. The Colombian

Constitution mandates universal primary school enrollment, and the descriptive statistics in Table 1 show the very high average levels of primary enrollment and the small variation across municipalities. Vaccination efforts, on the other hand, are directly operated by the Ministry of Health. Because of their highly centralized control, we expect that these two aspects of local public goods should not depend as much—or at all—on local state capacity.[25] The results in Table 6 indicate that these variables are indeed unaffected by own and neighbors' local state presence, bolstering our confidence in the exclusion restrictions and the estimates reported so far.

The second exercise, reported in Table 7, examines whether the reduced-form correlation between neighbors' historical variables (colonial state presence and royal roads) and current prosperity outcomes, which is at the root of our main findings, may reflect persistent unobservables affecting historical and current prosperity or the very persistent effects of early location of the colonial state on prosperity. In particular, we would like to rule out the possibility that our historical variables impacted historical prosperity, which then persisted and affected both current local state presence and current prosperity. Data on literacy and school enrollment from the 1918 national census, which are available for around 70 percent of the municipalities in our sample, are useful to shed light on these concerns. The extreme absence of the state from much of Colombia before the 1930s and the fact that systematic reliance on local state capacity for public goods provision was initiated with the decentralization of the mid-1980s and especially the 1991 Constitution imply that under our hypothesis—that our estimates measure the effect of contemporary local state presence on public goods and prosperity today—we should not find a strong correlation between neighbors' historical variables and our literacy and school enrollment data for 1918. Table 7 confirms this. The top panel of the table presents the key reduced-form relationship underlying our IV estimates in Tables 4A and 4B between our four key prosperity outcomes and the excluded instruments in these tables (but focusing on the sample of 683 municipalities with the historical data on prosperity). Consistent with the results presented so far, there is a strong and robust positive relationship between neighbors' state presence and current prosperity. The pattern in the bottom panel, which presents analogous reduced-form estimates for the 1918 outcomes, is quite different, however. Though a few of the estimates have a similar size, they often have the opposite of the expected sign and none are statistically significant. This pattern is reassuring and supports our interpretation that the effects of colonial state presence and royal roads variables on current prosperity and public goods provision are working primarily through current, or at the very least recent, presence of the local state.

F. *Specification Tests*

Table 8 presents OLS and IV results from a misspecified but simpler model where own state capacity enters linearly. This is similar to the type of equation estimated in most of the rest of the peer effects literature. The estimates reported in Table 8 are still significant and quantitatively very comparable to those in Table 4 (e.g., with state capacity measured with the number of agencies, the estimates in Table 4 are

[25] The main reason why they might still depend on local state capacity is that the lack of local capacity may hinder the efforts of the national state or thwart its clear directives.

Table 7—Placebo Exercise: Current versus Historical Prosperity

	Correlation between current prosperity and instruments			
	Reduced form			
	Life quality index OLS	Public util. coverage OLS	Not in poverty OLS	Sec. enrollment OLS
Panel I	(1)	(2)	(3)	(4)
Neighbors' colonial state officials	−0.286	−0.521	0.192	0.349
	(0.403)	(0.400)	(0.499)	(0.570)
Neighbors' colonial state agencies	1.779	1.316	1.819	1.654
	(0.540)	(0.564)	(0.526)	(0.757)
Neighbors' distance to royal roads	−1.352	−1.645	−0.800	−1.634
	(0.362)	(0.342)	(0.307)	(0.473)
F-test for joint significance of instruments	12.53	10.26	7.59	9.38
F-test p-value	0.000	0.000	0.000	0.000
Control for log population	Yes	Yes	Yes	Yes
Observations	683	683	683	683

	Correlation between historical (1918) prosperity and instruments			
	Reduced form			
	Literacy rate in 1918		Schooling rate in 1918	
	OLS	OLS	OLS	OLS
Panel II	(1)	(2)	(3)	(4)
Neighbors' colonial state officials	0.719	0.837	−0.579	−0.541
	(0.522)	(0.519)	(0.569)	(0.581)
Neighbors' colonial state agencies	−0.479	−0.545	1.553	1.532
	(0.697)	(0.692)	(0.936)	(0.945)
Neighbors' distance to royal roads	−0.350	−0.377	−0.383	−0.392
	(0.654)	(0.646)	(0.696)	(0.697)
F-test for joint significance of instruments	0.98	1.25	1.57	1.56
F-test p-value	0.401	0.289	0.194	0.197
Control for historical 1843 population	No	Yes	No	Yes
Observations	683	683	683	683

Notes: All reported estimates are average marginal effects. Panel I reports the estimates of a reduced-form regression of the four prosperity outcomes on neighbors' colonial state, and panel II reports the estimates of a reduced form regression of the historical (1918) prosperity outcomes on neighbors' colonial state. Models in panel I include department fixed effects and the following vector of controls: longitude, latitude, surface area, elevation, annual rainfall, distance to current highway, and a department capital dummy. Models in panel II do not control for the distance to a current highway. In the models of columns 2 and 4 in panel II, historical (1843) population is included as an additional control. All prosperity outcomes are standardized. All models use the restricted sample of municipalities for which 1918 data is available. Standard errors reported in parentheses are robust to arbitrary heteroskedasticity and allow for arbitrary spatial correlation within the network following Conley (1999), adapted to the network structure as described in the text.

between 0.23 and 0.56, while those in Table 8 are between 0.1 and 0.36). This suggests that both our general qualitative and specific quantitative aspects are not overly dependent on functional forms.[26]

[26] The results are no longer similar, however, if one were to try to directly estimate equation (1) including the cross effects, i.e., the term $\phi s_i \mathbf{N}_i(\delta)\mathbf{s}$, to infer ϕ as well as the own and the spillover effects. This difference is exactly what our theory predicts: given the form of the equilibrium summarized by equations (11) and (12), it

TABLE 8—PROSPERITY AND PUBLIC GOODS "NAÏVE" EQUATION

	State capacity measured as log of number of municipality state agencies							
	Prosperity equation (linear on s_i)							
	Life quality index		Public util. coverage		Not in poverty		Secondary enrollment	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Panel IA	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
dp_i/ds_i	0.669	0.145	0.556	0.360	0.457	0.199	0.426	0.106
	(0.044)	(0.096)	(0.035)	(0.083)	(0.038)	(0.096)	(0.051)	(0.118)
dp_i/ds_j	0.015	0.031	0.021	0.024	0.019	0.025	0.023	0.038
	(0.004)	(0.006)	(0.003)	(0.005)	(0.004)	(0.005)	(0.005)	(0.007)
Panel IB	First stage on s_i							
F-test for excluded instruments		65.40		65.17		65.17		67.70
F-test p-value		0.000		0.000		0.000		0.000
First-stage R^2		0.427		0.426		0.426		0.429
	First stage on $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$							
F-test for excluded instruments		625.5		625.9		625.9		678.5
F-test p-value		0.000		0.000		0.000		0.000
First-stage R^2		0.770		0.770		0.770		0.773
Observations	973	973	975	975	975	975	965	965
	State capacity measured as log of number of municipality employees							
	Prosperity equation (linear on s_i)							
	Life quality index		Public util. coverage		Not in poverty		Secondary enrollment	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Panel IIA	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
dp_i/ds_i	0.465	0.112	0.288	0.279	0.240	0.196	0.216	0.143
	(0.024)	(0.069)	(0.022)	(0.067)	(0.023)	(0.074)	(0.028)	(0.092)
dp_i/ds_j	0.014	0.025	0.018	0.017	0.018	0.016	0.020	0.024
	(0.003)	(0.005)	(0.002)	(0.004)	(0.003)	(0.004)	(0.003)	(0.005)
Panel IIB	First stage on s_i							
F-test for excluded instruments		44.88		44.61		44.61		47.97
F-test p-value		0.000		0.000		0.000		0.000
First-stage R^2		0.438		0.437		0.437		0.451
	First stage on $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$							
F-test for excluded instruments		529.0		526.9		526.9		571.5
F-test p-value		0.000		0.000		0.000		0.000
First-stage R^2		0.758		0.758		0.758		0.768
Observations	1,014	1,014	1,017	1,017	1,017	1,017	1,006	1,006

Notes: All reported estimates are average marginal effects. All models include department fixed effects and the following vector of controls: longitude, latitude, surface area, elevation, annual rainfall, distance to a current highway, and a department capital dummy. Panels IA and IIA report the estimates of a linear-in-state-capacity prosperity equation for each of the four outcomes, and panels IIA and IIB report the F-tests for joint significance of the excluded instruments in the first stages for the instrumental variables models of all even-numbered columns. Models in panel IA use the log number of state agencies as the measure of state capacity. Models in panel IIA use the log number of municipality employees as the measure of state capacity. The life quality index is for 1998, the public utilities coverage (aqueduct, electricity, and sewage) is for 2002, the fraction of the population above the poverty line is for 2005, and the secondary enrollment rate is the 1992–2002 average. All prosperity outcomes are standardized. In all models reported in even-numbered columns, log population is instrumented using 1843 population. Standard errors reported in parentheses are robust to arbitrary heteroskedasticity and allow for arbitrary spatial correlation within the network following Conley (1999), adapted to the network structure as described in the text. For models with more than one endogenous right-hand-side variable, the F-test is corrected following Angrist and Pischke (2009).

should *not* be possible to estimate the own and cross effects separately by estimating (1), so we find this result reassuring.

Table 9—Specification Test: Correlations between Residuals and Network Centrality Statistics

	State capacity measured as log of number of municipality state agencies				
Panel I	Best response equation residuals	Life quality index equation residuals	Utilities coverage equation residuals	% not in poverty equation residuals	Secondary enrollment equation residuals
Betweeness centrality	−0.04 [0.199]	0.01 [0.710]	0.00 [0.993]	0.01 [0.669]	0.02 [0.642]
Bonacich centrality	0.03 [0.283]	0.03 [0.305]	0.01 [0.670]	0.01 [0.769]	0.03 [0.394]
Local clustering	0.07 [0.020]	0.01 [0.861]	0.05 [0.116]	0.02 [0.527]	0.03 [0.326]
p-value of F-test for joint significance	[0.080]	[0.506]	[0.278]	[0.550]	[0.338]

	State capacity measured as log of number of municipality public employees				
Panel II	Best response equation residuals	Life quality index equation residuals	Utilities coverage equation residuals	% not in poverty equation residuals	Secondary enrollment equation residuals
Betweeness centrality	−0.005 [0.874]	0.012 [0.714]	−0.012 [0.711]	0.002 [0.947]	0.015 [0.632]
Bonacich centrality	0.038 [0.239]	0.040 [0.210]	−0.016 [0.626]	−0.012 [0.717]	0.029 [0.356]
Local clustering	0.076 [0.017]	−0.005 [0.878]	0.050 [0.118]	0.032 [0.317]	0.022 [0.487]
p-value of F-test for joint significance	[0.071]	[0.463]	[0.358]	[0.507]	[0.393]

Notes: This table reports the correlation coefficients between the residuals of the benchmark IV models in column 3 of Table 3, and columns 3, 7, 11, and 15 of Table 4A (panel I), and in column 7 of Table 3, and columns 3, 7, 11, and 15 of Table 4B (panel II), with the betweenness centrality, the Bonacich centrality network, and the local clustering statistics. The associated p-values are in square brackets. The table also reports p-values of the F-tests for joint significance of the three network centrality statistics in a regression of the residuals on these statistics.

Table 9 presents the correlation coefficients between the residuals from the estimates of equations (11) and (12) and three commonly-used measures of network centrality, the betweenness and the Bonacich centrality statistics, and the local clustering coefficient (Jackson 2008). Since the equilibrium levels of state capacity in our game are functions of the centrality measures (e.g., Ballester, Calvó-Armengol, and Zenou 2006; Bramoulle, Kranton, and D'Amours 2014), misspecification is likely to lead to a correlation between residuals and these centrality measures. Table 9 shows that there is essentially no correlation between these variables.

G. *Robustness*

Online Appendix B, Tables 1–10 show that our results are also robust to a series of variations. For brevity, we focus on linear IV estimates of equation (12) for our four prosperity outcomes. In panel I of online Appendix Table 1 we estimate the model without controlling for the distance to a current highway, which is a useful robustness check against the potential endogeneity of the location of current highways. In panel II, we control for a range of additional geographic covariates, including the density of primary, secondary, and tertiary rivers, and the full distribution of land by quality and type as described in Section III. The results in this table are quite similar to our baseline estimates.

Online Appendix Table 2 presents robustness exercises related to the network structure itself. In panel I we combine our IV strategy with Bramoulle, Djebbari, and Fortin's (2009) approach of using neighbors of neighbors' characteristics. If our historical instruments were potentially spatially correlated but our specification of the network captured the full set of spillovers, using the third-degree neighbors' historical variables as instruments (instead of our benchmark first and second-degree neighbors' historical variables) would lead to consistent estimates—even though our baseline estimates may have been biased. In panel II we present the results of redefining the meaning of a link, by considering both adjacent and second-degree adjacent municipalities as connected to check whether allowing longer-range spillovers has a meaningful impact on our results. Finally, in panel III we allow for links to exist between every pair of municipalities with decaying link strength according to matrix $\mathbf{F}$. Reassuringly, in all three cases, the results are very similar to our baseline estimates (if anything, they become more precisely estimated).

In online Appendix Table 3 we look at the sensitivity of our estimates to using subsets of our colonial state presence instruments. In panel I we exclude all functions of distance to royal roads from the instrument set, and in panel II we only use neighbors' distance to the royal roads as instruments. As anticipated by the overidentification tests reported above, our estimates remain quite stable. In addition, when only the royal roads instruments are used, we can see more transparently that neighbors' distance to royal roads is significant with the right sign in the best response equation. In panel III we use only a quadratic rather than a quartic in our historical variables as instruments for the nonlinear outcome equation. Standard errors in this case are slightly larger but the results are still quite similar to our baseline estimates.

Online Appendix Tables 4–6 further probe the sensitivity of our results to functional form restrictions. In online Appendix Table 4 we include additional quadratic terms in (1). This has little effect on the implied quantitative magnitudes, and the quadratic effects of neighbors' state capacity themselves flip signs across outcomes, and are insignificant in six out of the eight specifications. Online Appendix Table 5 includes additional contextual effects from covariates of neighbors in the best response equation (i.e., adding $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{x}$ on the right-hand side of (2)). This implies that we can only use the historical characteristics of neighbors of neighbors as instruments. The results from this exercise are also very similar to our baseline estimates. Online Appendix Table 6 presents results from including contextual effects on the prosperity equation (neighbors' geographic variables), which again have little impact on our estimates of own or spillover effects.

Another concern is that some areas of Colombia have been under the control of guerrillas and paramilitaries, creating a general lawlessness, potentially reducing the effectiveness of the local and national state in these areas. In online Appendix Table 7, we show that our results are not driven by municipalities most likely to suffer from such lawlessness. Excluding municipalities with historically high levels of violence as measured by paramilitary attacks during the 1998–2004 period from our sample (panel I) or from the network entirely (panel II) leaves our results largely unchanged.

A related concern is the role of capital cities as the source of spillovers. To show that our results are not driven by capital cities, online Appendix Table 8 presents the

Table 10—Contemporary State Equilibrium Best Response

	Controlling for national-level bureaucracy	
	Equilibrium best response equation	
State capacity measured as log of number of	Municipality state agencies IV (1)	Municipality employees IV (2)
ds_i/ds_j	0.018	0.017
	(0.003)	(0.001)
$ds_i/d(\textit{colonial state officials}_i)$	0.102	0.002
	(0.030)	(0.007)
$ds_i/d(\textit{colonial state agencies}_i)$	−0.014	0.010
	(0.032)	(0.008)
$ds_i/d(\textit{distance to royal roads}_i)$	0.008	−0.010
	(0.020)	(0.004)
Observations	975	1,017

Notes: All reported estimates are average marginal effects of the best response equation. All models include department fixed effects and in addition to the number of national-level public employees, the following vector of controls: longitude, latitude, surface area, elevation, annual rainfall, distance to a current highway, and a department capital dummy. Column 1 uses the log number of local state agencies as the measure of state capacity, and column 2 uses the log number of municipality employees as the measure of state capacity. The first stages of the instrumental variables models are omitted. Log population is instrumented using 1843 population. Standard errors reported in parentheses are robust to arbitrary heteroskedasticity and allow for arbitrary spatial correlation within the network following Conley (1999), adapted to the network structure as described in the text.

estimates of the prosperity equation without these cities, which are very similar to the baseline.

Online Appendix Table 9 makes an attempt at unbundling our measures of local state agencies. We separate them into four distinct types: health-related, regulation-related, services-related, and education-related. We then reestimate the best response equation for each subset of agencies. Reassuringly, we find not only similar strategic complementarities to our baseline results, but also that each dimension of state capacity appears to be responding to variation in neighbors' state capacity in the same dimension (e.g., health-related agencies respond positively to health-related agencies of neighbors, not to other agencies of neighbors).

H. *Controlling for National Bureaucracy*

As a preparation for the results in the next section, in Tables 10 and 11 we also control for the national state's employees (bureaucrats). In our baseline estimates, these employees are effectively included in the error term and if they are correlated with our instruments, this could lead to inconsistent estimates. The results are very similar to our baseline, and are in fact more precisely estimated, which is plausible as the omission of national bureaucracy from our baseline models likely created additional residual variance.

TABLE 11—ROBUSTNESS EXERCISES: PROSPERITY AND PUBLIC GOODS OUTCOMES STRUCTURAL EQUATION

	Controlling for national-level bureaucracy			
	Prosperity equation			
	log of number of municipality state agencies			
	Life quality index IV	Utilities coverage IV	Not in poverty IV	Secondary enroll. IV
Panel I	(1)	(2)	(3)	(4)
dp_i/ds_i	0.520	0.685	0.441	0.274
	(0.107)	(0.122)	(0.134)	(0.170)
dp_i/ds_j	0.018	0.017	0.018	0.032
	(0.005)	(0.005)	(0.005)	(0.007)
Observations	973	975	975	965
	Prosperity equation			
	log of number of municipality employees			
	Life quality index IV	Utilities coverage IV	Not in poverty IV	Secondary enroll. IV
Panel II	(5)	(6)	(7)	(8)
dp_i/ds_i	0.320	0.541	0.355	0.238
	(0.080)	(0.096)	(0.102)	(0.133)
dp_i/ds_j	0.017	0.011	0.012	0.021
	(0.004)	(0.004)	(0.004)	(0.005)
Observations	1,014	1,017	1,017	1,006

Notes: All reported estimates are average marginal effects. All models include department fixed effects and in addition to the number of national-level public employees, the following vector of controls: longitude, latitude, surface area, elevation, annual rainfall, distance to a current highway, and a department capital dummy. Panel I uses the log number of local state agencies as the measure of state capacity, and panel II uses the log number of municipality employees as the measure of state capacity. The first stages of the instrumental variables models are omitted. Log population is instrumented using 1843 population. The life quality index is for 1998, the public utilities coverage (aqueduct, electricity, and sewage) is for 2002, the fraction of the population above the poverty line is for 2005, and the secondary enrollment rate is the 1992–2002 average. Standard errors reported in parentheses are robust to arbitrary heteroskedasticity and allow for arbitrary spatial correlation within the network following Conley (1999), adapted to the network structure as described in the text.

V. General Case

In this section, we turn to the general model which relaxes the assumption that $\alpha = 1$ and reintroduces endogenous choices by the national state. Our objective is to estimate whether national and local state capacities are complements or substitutes and investigate whether fully allowing for the endogenous determination of national state capacity affects the extent of direct and spillover effects of state capacity. The reason why we view those presented in the previous section as our main results is that estimates from this more general model lead to very similar qualitative and quantitative patterns.

A. *Empirical Strategy*

Our empirical strategy relies on the same historical sources of variation (and same exclusion restrictions), but combines them with the first-order conditions of our more general model. In this case, we have two sets of first-order conditions, one for the national state, corresponding to equation (8) in the general model, and the other for the local state, corresponding to equation (7). The national state's first-order condition is

$$(13)\qquad h_b(l_i, \mathbf{p}_i, b_i \,|\, \boldsymbol{\zeta}) \equiv (1-\alpha)\left[\frac{s_i}{b_i}\right]^{\frac{1}{\sigma}} \times$$

$$\left\{\frac{\theta}{\alpha}\,\zeta_i l_i\left[\frac{l_i}{s_i}\right]^{\frac{1}{\sigma}} + \mathbf{N}_i(\boldsymbol{\delta})\left[\left(\phi\mathbf{s} + \frac{1}{J}\sum_j \gamma^j \boldsymbol{\iota}\right) * \boldsymbol{\zeta}\right]\right\} - \eta b_i = 0,$$

while the local state's first-order condition now becomes

$$(14)\quad h_\xi(l_i, \mathbf{p}_i, b_i) \equiv \frac{\theta}{\alpha}\,l_i\left[\frac{l_i}{s_i}\right]^{\frac{1}{\sigma}} - \phi\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} - g(\mathbf{c}_i\boldsymbol{\varphi} + \mathbf{x}_i\boldsymbol{\beta}) - \varsigma_i^D = 0,$$

where $\boldsymbol{\iota}$ is a column vector of 1s, and overall state capacity s_i is defined as in equation (4). In addition, we rewrite the prosperity equation (1), in this case after substituting for $\kappa_i s_i + \phi s_i \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$ from (14):

$$(15)\qquad h_{\epsilon^j}(l_i, \mathbf{p}_i, b_i) \equiv p_i^j - \frac{\theta}{\alpha}\,l_i s_i\left[\frac{l_i}{s_i}\right]^{\frac{1}{\sigma}} - \gamma^j\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} - \mathbf{x}_i\tilde{\boldsymbol{\beta}}^j - \tilde{\xi}_i^{jD} = 0.$$

These three equations summarize the moment conditions for the general model. They show that this general model is identified up to a scaling (η is not separately identified from α) and $\alpha = 1$ makes the first-order condition of the national state, (13), vanish. However, the parameters α and σ can be identified from equations (14) and (15). Motivated by this observation, we first take the national state's choices as predetermined and estimate these parameters based only on the variation coming from equations (14) and (15). We then estimate the entire system (13)–(15), by imposing the CES parameter estimates from the first step.

B. *GMM with Predetermined National Choices*

When national state capacity choices, the b_is, are treated as predetermined in the network game between municipalities, the model reduces to equations (14) and (15). Then, conditional on the b_is, these equations can be estimated straightforwardly by GMM. The GMM estimator is analogous to the one we utilized in the previous section (see footnote 23), with the difference that the moment condition implied by the best response equation is now given by (14).

The GMM estimates are reported in the first column of Table 12. To compute standard errors, we again use the spatial correlation consistent variance-covariance estimator in footnote 23. The table presents the estimates when we use the number of state agencies as our measure of state capacity. The elasticity of substitution between local and national state, σ, is estimated as 0.11 (standard error $=$ 0.006). This implies that local and national state presence are highly complementary inputs: α is estimated to be 0.90 (standard error $=$ 0.013), and the estimate for the interaction effect ϕ indicates that local state capacity choices are again strategic

Table 12—Stuctural Parameter Estimates

National-level state capacity Parameter	Predetermined Estimates (system GMM) (1)	Endogenous Estimates (simulated GMM) (2)
ϕ	0.006 (0.0001)	0.004 (0.005)
γ (Life quality index)	0.870 (0.114)	1.017 (0.119)
γ (Public utilities)	0.933 (0.101)	1.087 (0.105)
γ (Not in poverty)	0.738 (0.086)	0.937 (0.083)
γ (Secondary enrollment)	1.212 (0.135)	1.344 (0.147)
θ	0.024 (0.009)	0.011 (0.006)
$E[\kappa_i]$	0.0026 [0.0002]	0.0005 [0.00008]
η		0.010 (0.007)
$\pi 1$ (Historical electoral variability)		0.540 (0.071)
$\pi 2$ (Betweenness centrality)		0.318 (0.251)
$\pi 3$ (Bonacich centrality)		−0.268 (0.069)
$\pi 4$ (Local Clustering)		−0.856 (0.009)
CES parameters		
α	0.909 (0.013)	
σ	0.114 (0.006)	
Observations	963	962

Notes: The table reports structural parameter estimates of the nonlinear model, using the log of the number of municipality agencies as the measure of local state capacity. Column 1 presents the parameters of the model estimated with GMM as a system that takes national-level state capacity as predetermined. Column 2 presents the SMM estimates of the model where national state capacity is endogenous. The estimates of the CES parameters, α and σ, reported at the bottom are estimated separately by GMM taking national state capacity choices as predetermined. Analytic standard errors in parentheses are robust to arbitrary heteroskedasticity and allow for arbitrary spatial correlation within the network following Conley (1999), adapted to the network structure as described in the text. Estimates in square brackets are standard deviations across the sample of municipalities.

complements and the magnitude of strategic complementarities is very similar to that in the linear model. The table also presents the average effect of own state capacity on public goods and prosperity, κ_i, and its standard deviation, recovered from the estimation of the function $g(\mathbf{c}_i \varphi + \mathbf{x}_i \boldsymbol{\beta})$.[27]

[27] The condition for uniqueness in Proposition 1 is again comfortably satisfied. In particular, we have $1 + \frac{1}{\lambda_{\min}(\mathbf{N}(\boldsymbol{\delta}))} = -3.25 < \min\left\{\left(\frac{\partial l_i}{\partial \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}}\right)^{-1}\right\} = 0.006 < \max\left\{\left(\frac{\partial l_i}{\partial \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}}\right)^{-1}\right\} = 0.244 < 1.$

C. *Estimation of the Full Model by Simulated Method of Moments*

We next estimate the full model given by equations (13), (14), and (15). Relative to the estimates in the previous subsection, this involves imposing the additional restrictions that national state capacities satisfy the first-order condition as given in equation (8).

Because national state's weights, the ζ_is, are unobserved, we model them as a function of a vector of observable characteristics related to within-network centrality of the municipalities, political variables, and an unobserved component,

$$\zeta_i = \exp(\mathbf{v}_i \boldsymbol{\pi} + \omega_i).$$

In addition to a constant, $\mathbf{v}_i$ here includes four variables: the three network centrality statistics already used in Table 9, the betweenness centrality, the Bonacich centrality, and the local clustering coefficient, as well as a proxy for the extent of historical political competitiveness of the municipality, which we measure as the standard deviation of the Liberal Party's elections share across the 1974–1994 presidential elections.

Because the national state's first-order conditions involve the full vector of unobserved weights for each municipality, we use a simulated method of moments (SMM) estimator derived from the moment conditions implied by (13), (14), and (15). The SMM estimator is similar to our GMM estimator, except that we have $\mathbf{q}_i(\psi, \boldsymbol{\delta}) = \left[h_{\epsilon^1}(l_i, \mathbf{p}_i, b_i), \ldots, h_{\epsilon^J}(l_i, \mathbf{p}_i, b_i), h_{\xi}(l_i, \mathbf{p}_i, b_i), \hat{h}_b(l_i, \mathbf{p}_i, b_i)\right]'$, where

$$\mathbf{Z}_i(\boldsymbol{\delta}) = \begin{bmatrix} \mathbf{I}_J \otimes \mathbf{z}_i^p(\boldsymbol{\delta}) & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{z}_i^{BR}(\boldsymbol{\delta}) & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{z}_i^{NL}(\boldsymbol{\delta}) \end{bmatrix}.$$

Here $\mathbf{z}_i^{NL}(\boldsymbol{\delta})$ is a vector of instruments for the national state's best response equation, including $\mathbf{v}_i$, $\mathbf{x}_i$, historical population, average distance to neighboring municipalities, and average variability of altitude along geodesics to neighboring municipalities. We write the average (simulated) national state's first-order condition as

$$\hat{h}_b(l_i, \mathbf{p}_i, b_i) = \int h_b(l_i, \mathbf{p}_i, b_i \,|\, \boldsymbol{\omega}) f_\omega(\boldsymbol{\omega})\, d\boldsymbol{\omega}.$$

In this equation $f_\omega(\cdot)$ is the joint density of the unobserved component of the national state's random weights, and the vector ψ now also includes η and $\boldsymbol{\pi}$. Notice that the full vector of weights is assumed to be known to all players, so this is still a game of complete information. We also restrict the ζ_is to be nonnegative and in our benchmark assume that $f_\omega(\cdot)$ is a standard normal (our results are robust to using various different densities). This procedure allows us to estimate the national state's weights very precisely.

Estimates for the general model, when measuring local state capacity as the number of state agencies, are presented in the second column of Table 12. The magnitudes of the parameter estimates are remarkably close to the GMM estimates under predetermined national state capacity choices. They also imply that the national state's weights, the ζ_is, are fairly skewed, with a mean of 1.95, a median of 0.93, and a standard deviation of 3.66. This squares well with the idea that the Colombian national state has been narrowly focused on a few areas of the country, leaving large swathes of it unattended. In addition, the parameter vector $\boldsymbol{\pi}$ is estimated precisely, suggesting that a large part of the variation in the national state's weights across municipalities reflects local characteristics of municipalities. In particular, the network characteristics and the historical political competitiveness of municipalities are strong predictors of national weights, and have a significant impact on the variation in national state's choices.

Throughout, the quantitative magnitudes of the estimates are very similar to those from the linear model. For example, the average slope of the best response equation $\left(\text{the average } \frac{\partial l_i}{\partial l_j}|_{h_\xi} \text{ from equation (14)}\right)$ for our SMM estimates is 0.013, compared to the average slopes of the linear best response reported in Table 4, which are between 0.016 and 0.022. Similarly, the average own effect in the prosperity equation $\left(\text{the average } \frac{\partial p_i}{\partial l_i}|_{h_\epsilon} \text{ from equation (15)}\right)$ is 0.21, as compared to our system GMM estimate for the linear model of 0.39 reported in the first row of Table 4A. Finally, the average spillover effects in the prosperity equations $\left(\frac{\partial p_i}{\partial l_j}|_{h_\epsilon}\right)$ are (0.020, 0.022, 0.019, 0.027) for the life quality index, utilities coverage, fraction above the poverty line, and secondary school enrollment rates, respectively, which are also close to the corresponding estimates in the second row of Table 4A, lying between 0.02 and 0.035.

We perform the same counterfactual exercise as in the top two panels of Table 5 and the results are reported in the next two panels of Table 5. Because the best responses are nonlinear, we cannot simply use the estimated parameters (and shocks) to predict the equilibrium outcomes, and need to numerically solve for the equilibrium state capacities to implement this counterfactual experiment. We accomplish this using a Newton-Raphson approximation, and then compute the implied values for $\mathbf{p}_i$ using equation (15). The bottom two panels of Table 5 show that the quantitative results are close to those we obtain from the linear model (with $\alpha = 1$). This is the basis of the statement above that the qualitative and quantitative results from this general model are similar to those from the linear model.

We next perform two counterfactual exercises related to implications of changes in national state capacity. First, in online Appendix Table 10 we investigate the implications of increasing all b_is below the median to the median value. In contrast to the counterfactual experiment in which local state capacity levels were similarly increased, the implied magnitudes are now smaller. The more limited effects of a change in national state capacity are because of the relatively lower dispersion of the distribution of national state capacity in the data and because of the smaller response of local state capacity to these changes. They reiterate that it is local state capacity that is more important for various local prosperity outcomes in Colombian municipalities, justifying our greater emphasis on local state presence.

Second, in online Appendix Table 11, we consider reducing the skewness (asymmetry) of the weights the national state attaches to different municipalities by increasing all ζ_is below the median to the estimated median value. This reduction in skewness, reducing the asymmetry of the weights of different municipalities in the national state's preferences, leads to similar aggregate gains. For example, we see a 3.3 percent increase in the median fraction of population above the poverty line, and a 2 percent increase in median secondary school enrollment rates. Thus we find that the effect of equalizing the national weights in this way has similar implications to directly equalizing national state capacities.

VI. Implications for Optimal Policy

Our structural estimates allow us to provide some preliminary insights on optimal policy, in particular for the optimal allocation of state capacity across municipalities. For this exercise, suppose that the objective is to maximize average prosperity across municipalities. We thus consider the problem of maximizing the population-weighted sum of utilities by reshuffling local state capacity across municipalities (and taking into account the full equilibrium responses of all municipalities). Because we are focusing on a pure reallocation (and ignoring costs of reallocation and differences in relative prices across municipalities), there are no costs in this policy. Mathematically, the problem is

$$\max_{\mathbf{e}\geq 0}\left\{\sum_i w_i \frac{1}{J}\sum_j p_i^j(\mathbf{s})\right\}$$

subject to $\sum_i e_i = 0$, and

$$\mathbf{s} = \left(I - \frac{\phi}{\theta}\mathbf{N}(\boldsymbol{\delta})\right)^{-1}\left(\frac{1}{\theta}\boldsymbol{\kappa} + \mathbf{e}\right),$$

where $\mathbf{e}$ denotes the vector of changes (reallocation) in state capacity, and the w_is are population weights. In Appendix A we show that this problem has an explicit-form solution, where the optimal $\mathbf{e}$ is a function of centrality statistics of the network. Panel I in Table 13 presents the average changes in our prosperity outcomes under the optimal reallocation of local public employees. Average utilities coverage would increase by 4.5 percentage points, the poverty rate would be 3.5 percentage points lower, and secondary school enrollment rates would be 5.6 percentage points higher. These are quite significant changes.

Figure 4 shows the change in the distribution of our four prosperity outcomes following the optimal reallocation of state capacity, documenting both the increase in average prosperity and the compression in the distributions—both of these resulting from greater state capacity now allocated to the poorest municipalities.

The solution in equation (A1) in Appendix A shows that the optimal reallocation is a function of eigenvector centrality. To make the relationship between $\mathbf{e}$ and network position more explicit, we ran a set of regressions of our estimated $\mathbf{e}$ on the same three network statistics used above—betweenness centrality, Bonacich centrality, and local clustering—as well as historical population and our benchmark set of controls. Online Appendix Table 12 presents the results. Our three network statistics are strong predictors of $\mathbf{e}$, both when we use state agencies (columns 1–4) and municipality employees (columns 5–8). Furthermore, the R^2s of these regressions are quite high (around 0.8) in all specifications, highlighting the key role played by

TABLE 13—NORMATIVE EXERCISE: WELFARE GAINS FROM AN OPTIMAL REALLOCATION OF STATE CAPACITY

	Experiment: Reallocation of municipality state capacity according to the optimal policy			
Panel I. Linear model	Average equilibrium change in			
State capacity measured as log of municipality employees	Life quality index	Utilities coverage	% not in poverty	Secondary enroll.
Average change (percentage points)	1.66	3.56	2.08	4.32
Median change (percentage points)	1.40	3.03	1.81	3.49
Panel II. General model	Average equilibrium change in			
State capacity measured as log of state agencies	Life quality index	Utilities coverage	% not in poverty	Secondary enroll.
Average change (percentage points)	2.62	5.88	3.75	6.72
Median change (percentage points)	0.12	0.42	0.12	0.86
Difference relative to prosperity under optimal policy from the linear model when increasing by 25% the coefficient on (percentage points):				
Betweenness	−0.008	−0.015	−0.016	−0.020
Bonacich	−0.008	−0.017	−0.010	−0.020
Local clustering	−0.015	−0.034	−0.020	−0.050

Notes: This table reports the average and median equilibrium changes (after municipalities have best responded to the shock) in each prosperity outcome across the sample of municipalities of an experiment that reallocates municipality state capacity optimally according to equation (A1) using the parameters estimated with GMM as a system. Panel I presents the experiment results on the linear model using the number of municipality public employees as the measure of local state capacity. Panel II presents the results from using the optimal policy from the linear model in the general model, using the number of municipality agencies as the measure of local state capacity. The three bottom rows present the equilibrium change in prosperity outcomes when we increase the weight of each one of the three network centrality statistics in the linear model estimated in online Appendix Table A12 by 25 percent. The life quality index is for 1998, the public utilities coverage (aqueduct, electricity, and sewage) is for 2002, the fraction of the population above the poverty line is for 2005, and the secondary enrollment rate is the 1992–2002 average.

the network structure in the determination of the distribution of prosperity across municipalities.

Finally, we also perform a similar policy exercise with the general model. Because in this case there is no explicit-form characterization of the optimal reallocation, we use the estimates from the regressions of the optimal allocation on network centrality statistics presented in online Appendix Table 12 to generate predicted values for the $\mathbf{e}_i$s. We then compute numerically the Nash equilibrium starting from this allocation, and obtain estimates of the predicted prosperity outcomes. We present the results of this exercise in the bottom panel of Table 13 using the number of state agencies as our measure of local state capacity. The magnitude of the changes is very similar to that from the linear model, even if larger for average and smaller for median changes. This is because in the general model the optimal reallocation of state capacity induces further equilibrium responses by both the local and the national levels, amplifying changes among richer municipalities (but also having somewhat smaller effects among poorer municipalities). The three bottom rows then present the equilibrium changes in prosperity outcomes when we depart from the optimal linear policy by making either one of the network centrality statistics 25 percent more important in the linear model estimated in online Appendix Table 12. This exercise leads to very small changes in prosperity, showing that welfare in the general model is very flat around the optimal policy from the linear model.

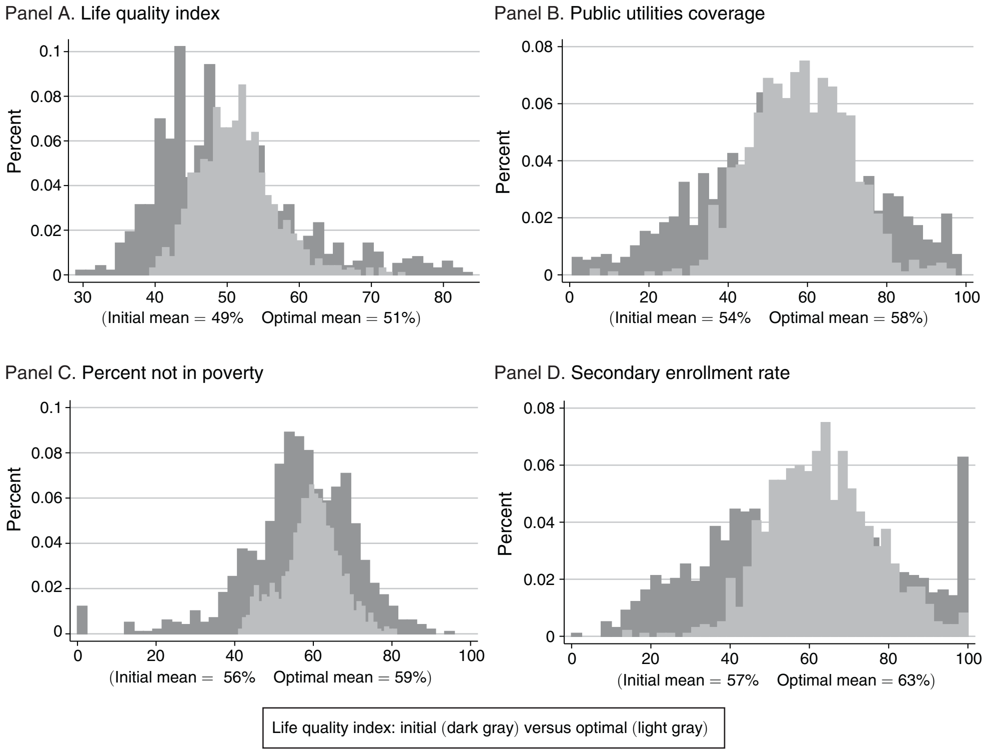

Figure 4. Change in the Distribution of Prosperity Following the Optimal Reallocation of Bureaucracy

Notes: The figure plots the predicted (light gray) empirical distributions for the four prosperity outcomes following the optimal reallocation of local state capacity (measured as the number of public employees), overlayed over the actual distributions (dark gray). Panel A presents the distributions for the life quality index in 1998. Panel B presents the distributions of the public utilities coverage (average of aqueduct, electricity, and sewage) in 2002. Panel C presents the distributions for the fraction of the population above the poverty line in 2005. Panel D presents the distributions for the average 1992–2002 secondary enrollment rate.

VII. Conclusions

In this paper we developed a framework for estimating the direct and spillover effects of local state capacity, and applied it in the Colombian context. We modeled the determination of local and national state capacity as a network game, where each municipality, anticipating the choices and spillovers created by other municipalities and the decisions of the national state, invests in local state capacity, and the national state chooses the allocation of its employees across different areas to maximize its own objective.

We estimated the parameters of this model, which show large (but plausible) direct and spillover effects of local state capacity, using linear IV, GMM, or SMM. In all of our estimations, we exploited both the structure of the network of municipalities, determining which municipalities create spillovers on which others, and the historical roots of local state capacity as the source of exogenous variation for identifying both own and spillover effects. These are related to the presence of colonial royal roads and the historical presence of the colonial state—factors which we argue are unrelated to current provision of public goods and prosperity in a municipality and its neighbors, except through their impact on local state capacities.

Our estimates imply that local state presence is indeed a first-order determinant of current prosperity, but much of this impact works through network effects. For example, bringing all municipalities below median state capacity to the median, without taking into account equilibrium responses of other municipalities, would increase the median fraction of the population above the poverty line from 57 percent to 60 percent. Approximately 57 percent of this is due to direct effects and 43 percent due to spillovers. However, if we take the equilibrium responses of other municipalities into account, there are further network effects, reflecting the strategic complementarities in local state capacity decisions. Once these adjustments are made, the median of the fraction of the population above poverty would increase to 68 percent—a much larger impact than the partial equilibrium effects. This indicates not only that network effects are important, but also suggests why the national government must play a central role in effective state-building: local state-building will lead to major under-provision of state capacity (and thus public goods) because municipalities do not take into account these network effects.

We view our paper as a first step in the modeling and estimation of the direct and spillover effects of local state capacity. There are several interesting and important research directions. First, our results have focused only on some aspects of local state capacity. The typical view of the Weberian rational bureaucracy also stresses such things as meritocracy and predictability of the bureaucracy, which would be interesting to investigate at the local level as well. Second, and more importantly, we have not addressed another aspect of Weberian state capacity: the monopoly of violence. This is a central issue in Colombia, where the state often lacks this monopoly of violence. Third, our approach has been reduced-form in one crucial dimension: we have abstracted from political economy interactions. Though, we believe, this is reasonable as a first step, political economy factors are likely to be critical for the nature of some of these spillovers. In fact, we conjecture that underpinning the strategic complementarities documented in this paper is, in part, the pressure that high state capacity in one municipality puts on politicians in neighboring municipalities. Another important political economy dimension in the Colombian context is the control of politicians or armed groups over certain municipalities with very different objectives, and their ability to do so may depend on outcomes in neighboring municipalities. Finally, an important next step would be to apply a similar approach to other settings in which law enforcement and policing are determined at the local level and create different types of spillovers on neighbors.

Appendix A

A. *Slope of the Best Response Equation*

Implicitly differentiating equation (7) with respect to $\mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}$ yields

$$\frac{\partial l_i}{\partial \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}} = \alpha\sigma\,\frac{\phi}{\theta}\,\frac{1}{(\sigma+1)\left[\frac{l_i}{s_i}\right]^{\frac{1}{\sigma}} - \alpha\left[\frac{l_i}{s_i}\right]}.$$

When $\alpha = 1$, $\frac{\partial l_i}{\partial \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}} = \frac{\phi}{\theta}$. More generally, the denominator of this expression is strictly positive: this can be seen by noting that $(\sigma + 1)\left[\frac{l_i}{s_i}\right]^{\frac{1}{\sigma}} - \alpha\left[\frac{l_i}{s_i}\right] > 0$ is equivalent to

$$\sigma + 1 > \frac{\alpha l_i^{\frac{\sigma-1}{\sigma}}}{\alpha l_i^{\frac{\sigma-1}{\sigma}} + (1-\alpha) b_i^{\frac{\sigma-1}{\sigma}}},$$

which is satisfied in view of the fact that $\sigma \geq 0$ and $\alpha \in (0, 1)$, and implies

$$\text{sign}\left(\frac{\partial l_i}{\partial \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s}}\right) = \text{sign}(\phi).$$

B. *Optimal Reallocation of State Capacity*

In the optimal reallocation problem, define $\mathbf{M} \equiv \left(I - \frac{\phi}{\theta}\mathbf{N}(\boldsymbol{\delta})\right)^{-1}$, and recall that for a given equilibrium vector of state capacities $\mathbf{s}$, equilibrium prosperity is given by

$$p_i^j = \theta s_i^2 + \gamma^j \mathbf{N}_i(\boldsymbol{\delta})\mathbf{s} + \mathbf{x}_i \tilde{\boldsymbol{\beta}} + \tilde{\varsigma}_i^D + \epsilon_i^j.$$

So the problem above can be rewritten as

$$\max_{\mathbf{e} \geq \mathbf{0}} \sum_i w_i \left\{\theta\left[\mathbf{M}_i\left(\frac{1}{\theta}\boldsymbol{\kappa} + \mathbf{e}\right)\right]^2 + \overline{\gamma}\mathbf{N}_i(\boldsymbol{\delta})\mathbf{M}\left(\frac{1}{\theta}\boldsymbol{\kappa} + \mathbf{e}\right) + \mathbf{x}_i\tilde{\boldsymbol{\beta}} + \tilde{\varsigma}_i^D + \epsilon_i^j\right\}$$

$$+ \lambda\left(0 - \sum_i e_i\right),$$

where λ is the Lagrange multiplier on the constraint $\sum_i e_i = 0$, and $\mathbf{M}_i$ represents the ith row of matrix $\mathbf{M}$. The first-order condition of this problem with respect to each e_t takes the form

$$2\left[\mathbf{1}_N Diag(\mathbf{M}_t)\mathbf{M}\boldsymbol{\kappa} + \theta\mathbf{1}_N Diag(\mathbf{M}_t)\mathbf{M}\mathbf{e}\right] + \overline{\gamma}\mathbf{1}_N\mathbf{N}(\boldsymbol{\delta})\mathbf{M}_t' - \frac{\lambda}{w_t} = 0,$$

where $\mathbf{1}_N$ is an $N \times 1$ row vector of 1s, and $Diag(\mathbf{M}_t)$ is an $N \times N$ matrix with $\mathbf{M}_t$ in its diagonal and 0s off the diagonal. Thus we have a system of $N + 1$ linear equations (the N first-order conditions plus the budget constraint) with $N + 1$ unknowns (the N e_is plus λ).

Define the scalar $g_t \equiv 2 \cdot \mathbf{1}_N Diag(\mathbf{M}_t)\mathbf{M}\boldsymbol{\kappa}$, and $\mathbf{g} \equiv [g_1, g_2, \ldots, g_N]'$. Also define the scalar $h_t \equiv \overline{\gamma}\mathbf{1}_N\mathbf{N}(\boldsymbol{\delta})\mathbf{M}_t'$, and $\mathbf{h} \equiv [h_1, h_2, \ldots, h_N]'$. Finally define the $1 \times N$ vector $\mathbf{q}_t \equiv 2\theta\mathbf{1}_N Diag(\mathbf{M}_t)\mathbf{M}$, and $\mathbf{Q} \equiv \left[\mathbf{q}_1', \mathbf{q}_2', \ldots, \mathbf{q}_N'\right]'$. We can then express the N first-order conditions in matrix form as:

$$\mathbf{Q}\mathbf{e} - \tilde{\mathbf{w}}\lambda = -\mathbf{g} - \mathbf{h},$$

where $\tilde{\mathbf{w}}$ is the vector of inverse population weights, and the constraints can be written as

$$\begin{bmatrix} 0 & 1 \quad 1 \quad \dots \quad 1 \\ -\tilde{w}_1 & \\ -\tilde{w}_2 & \\ \vdots & \mathbf{Q} \\ -\tilde{w}_N & \end{bmatrix} \begin{bmatrix} \lambda \\ \mathbf{e} \end{bmatrix} = \begin{bmatrix} 0 \\ -\mathbf{g} - \mathbf{h} \end{bmatrix}.$$

Defining the matrix of the left-hand side as $\mathbf{B}$, the solution to this system is

$$\begin{bmatrix} \lambda \\ \mathbf{e} \end{bmatrix}^{*} = \mathbf{B}^{-1} \begin{bmatrix} 0 \\ -\mathbf{g} - \mathbf{h} \end{bmatrix}. \tag{A1}$$

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