CHAPTER TEN

Spatial Targeting of Poverty Hotspots

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Introduction

The opportunities available to any child depend on many factors; the level of education, health and early nutrition, parental income, and social class all are factors that have been well documented.[1] But the dominant determinant is geography: where a child is born.[2] This geography, in turn, has many dimensions: in which country the child is born, whether in an urban or rural environment, and whether in a fast-developing or a lagging region.

The stickiest poverty over time is associated with people born in rural, lagging regions in low- and lower middle-income countries. These regions have characteristics that make development difficult. They are places where there may be some combination of conflict, ethnic fragmentation, malaria prevalence, high risk of natural disasters, and fragile ecosystems that have low soil resilience subject to significant degradation. They are places that are distant from high-density urban areas where jobs and a range of social and infrastructure services provide

1. For parental income, see Mayer (2002) and Dahl and Lochner (2012); for education, see Psacharopoulos and Patrinos (2018) and Isaacs and Roessel (2008); for health and nutrition, see Holding and Kitsao-Wekulo (2004), Liu and Raine (2016); and for social class, see Narayan and others (2018).

2. See World Bank Group (2009).

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opportunities. They are places with substantial concentrations of poverty. These are the places we identify as "poverty hotspots."

In this chapter, we ask two basic questions: (i) where are these poverty hotspots, and (ii) how many people live in them? This is a prelude to a policy discussion on spatial targeting—the deliberate focusing of policy interventions in a specific area. We believe a greater focus on spatial targeting is indispensable for taking seriously the idea of "leave no one behind."

We start with a thought experiment. What would a global map of the world look like with shaded areas for all poverty hotspots, defined as subnational regions (districts or provinces within a country) that are on track to have a per capita GDP of $4,900 or less in 2011 PPP terms in 2030?[3]

We find 840 poverty hotspots globally, from a universe of 3,609 districts, states, and provinces. They are in 102 countries. All of the thirty-four current low-income countries have at least one hotspot (even if more than half of these also have one or more prosperous regions). Similarly, thirty-nine of forty-six lower middle-income countries have at least one poverty hotspot, along with eighteen of fifty-two upper middle-income countries assessed. Eight of the sixty-nine high-income countries assessed have poverty hotspots by our measure (three countries are not classified by the World Bank).

These broad facts support our contention that there is considerable unevenness in economic development within countries, and that subnational spatial targeting may be necessary to reduce these disparities. Country targeting, the tool most commonly used by aid agencies, is too blunt to deal with the unevenness of progress within countries.

What can be done? Broadly speaking, there are two types of solutions to address poverty hotspots. Let people move, or develop the places faster. Both are inherently difficult. Migration, even within a country, can have high personal costs, and, in theory, the impact on those left behind is ambiguous. Those who remain can benefit from remittances and, potentially, from less population pressure on limited natural resources. On the other hand, they can suffer if migrants are more dynamic, entrepreneurial, and hard-working. If migrants leave, taking scarce capital from their families with them, they can depress their source areas even more.

The reality is that migration is a complex decision, dependent on many factors. As shown later in the chapter, we estimate that more than 1 billion people

3. The threshold of $4,900 is chosen by triangulating macroeconomic and microeconomic reasoning. At the macro level, it corresponds to the income level below which the extreme poverty headcount rate typically remains above 20 percent. At the micro level, it roughly corresponds to a level of daily household expenditure where the probability of falling below the national poverty line in a middle-income country is less than 10 percent (Lopez-Calva and Ortiz-Juarez 2015).

live in poverty hotspots, and the population in these areas has been growing and is expected to continue to grow for the next couple of decades, reaching 1.7 billion people in 2030. This increase reflects the fact that fertility rates are high among poor families. Natural population growth outweighs out-migration in most poor places. So out-migration, while in theory a very long-run potential solution, is not the answer for poverty hotspots in the timeframe of Agenda 2030.

The alternative is to accelerate the economic growth of poverty hotspots, but this is difficult to do in an economically efficient way. In most countries, growth is most efficient when it builds on market forces of agglomeration, specialization, and trade. These conditions favor urban centers. Market forces, if left unattended, can, therefore, result in persistent disparities across regions, which is why we find hotspots in the first place. While there is sound analytical evidence for conditional spatial convergence (the idea that poorer places grow faster than richer places, all other things being equal), in practice, many things are not equal. Infrastructure, human capital, urbanization, institutional factors, and exposure to shocks and disease all play a role in concentrating economic activity and human settlements in some places at the expense of others.

What is the right policy response to this? Some countries have experimented with targeting physical infrastructure and improving connectivity of lagging regions, others with investing in human capital. Spatial subsidies for production in lagging regions have also commonly been used.[4] Special economic zones relax infrastructure and regulatory burdens in specific places. But these interventions tend to be expensive and may not reflect an efficient use of public funds.

It is fair to say that there is no single blueprint, but a range of interventions might help accelerate growth in specific places. Luckily, subnational spatial analysis offers more opportunity to identify the correlates of growth than do cross-country regressions. The subnational analysis in this chapter has more than 3,600 data points in a cross-section. With cross-country analysis, a typical data set would be under 150 data points.

The data suggest that poverty hotspots have characteristics that distinguish them from other places. First, the level of initial human capital—health and probably education—is low and seems to be correlated with subsequent low rates of income growth. We say "probably" for education because, unfortunately, the data on subnational educational attainment is very spotty—some countries have it, others do not—and it is not easily comparable across countries. Second, several indicators of physical infrastructure and market connectivity, like accessibility to a nearby city or the distance to the capital, are poor in hotspots and this has

4. The European Union is perhaps the best example: see European Committee of the Regions (2018).

a significant impact on growth. Third, hotspots display an inability to reduce the incidence or impact of shocks, such as conflict-related deaths, or improving resilience to weather-related shocks, like droughts. Finally, although our focus here is on subnational spatial targeting, many hotspots are in countries that themselves are growing slowly. These national growth drivers (including institutional and governance quality) clearly have an important bearing on what can be achieved at the subnational level.

Each poverty hotspot can be associated with one or more of these types of growth constraints. In this chapter, we do not pretend to reach any definitive conclusions, but rather aim to illustrate how a geospatial approach can suggest new and better insights for policymaking. Further refinement of the methodology and data will, undoubtedly, yield additional insights. Our conclusion, however, is that there is already enough evidence to support a far better data-driven approach to spatial targeting than is currently in use. We illustrate the benefits of taking a spatial approach with some examples of what is now being done, but our main conclusion is that more spatial targeting is needed. In fact, we conclude with the observation that aid, at least in the case of the World Bank, which is one of the few major aid agencies that has geocoded its projects, is allocated roughly evenly to poverty hotspots and non-poverty hotspots. If the hotspots are, indeed, revealing of where the major problems really lie, then a reallocation of aid to focus more on poverty hotspots could be a powerful tool to ensure no one is left behind.

Why Do Some Places Develop while Others Do Not?

Economic activity is unevenly distributed across space. Even as national incomes converge, many pockets within and across countries show widening disparities. What explains persistent stagnation in some places and such rapid development in others?

Macroeconomists have long grappled with this question. Some claim that poor countries will inevitably catch up with their rich counterparts over time.[5] Others stress that it is endogenous factors—policies, institutions, and country specifics—that put certain areas on the fast-track to economic growth.[6] Separate strands of thought emphasize the deep geographic roots of growth, considering that variables such as climate type, temperature, precipitation, and soil suitability play a role in agricultural productivity and trade.[7]

Building on this debate, Vollrath (2019) offers a perspective on the uneven

5. See absolute convergence theory.
6. See conditional and club convergence theory.
7. Henderson and others (2018).

distribution of nightlights across the globe.[8, 9] Drawing on the work of Michaels and Rauch (2013), Vollrath asks a simple question: Is the world more like France or more like Britain? French patterns of urbanization, Vollrath explains, are likely the vestiges of Julius Caesar's city planning in 46 B.C. Modern-day French urban centers rest on the foundations of old Roman towns and forts, hinting at the role that historical events or institutions play in global development. By comparison, British cities are more likely to be organized around areas with navigable waterways. Following the collapse of the Western Roman Empire, medieval towns across modern-day Britain were abandoned and fell into decay. When the British economy revived, activity became concentrated in trade-suitable geographies that were quite different from those that existed in Roman times. The key insight of this work is that economic growth across the world depends on both historical and geographic factors.

Henderson and others (2018) find that geography predicts nearly half of the distribution of economic activity across the world, in keeping with the British model.[10] They conclude that variables associated with agricultural productivity hold the greatest explanatory power, although trade-related characteristics such as proximity to the coast and navigable waterways are significant as well. Other scholars have also documented the link between geography and economic growth: Gallup, Sachs, and Mellinger (1999), Gallup and Sachs (2001), and Sachs and Malaney (2002) argue for the direct effects of geography on income growth via channels such as agricultural productivity, disease burden, and transport costs; Myrdal (1968), Kamarck (1976), and Masters and McMillan (2001) document high correlations between income per capita and climate and temperature; Sachs and Warner (2001) reaffirm the curse of natural resources; and the UN Millennium Project (2005) notes the effect of adverse agronomic conditions, transport risk, and malaria ecology.

Henderson and others' research emphasizes the role institutions play in promoting or hindering economic growth: North (1990) famously made the argument for institutional determinants of growth; Hall and Jones (1999) illustrate the effects of differing government policies and institutions on output per worker; and Acemoglu, Johnson, and Robinson (2001) argue that colonization patterns explain large differences in income per capita across countries, citing on the one hand "extractive" European powers, and on the other hand "Neo-Europes" that replicated European institutions by ensuring property rights and checks on power.

8. Nightlights are commonly used as a proxy for human economic activity.
9. Vollrath (2019).
10. Henderson and others (2018) quoted in Vollrath (2019).

Despite fissures in the literature, most would concede that uneven economic development is the product of two forces: geography and institutions. In this chapter, we operate on this premise: disparities across regions are likely due to environmental and sociopolitical differences that directly or indirectly affect human and physical capital accumulation, exposure to human and natural shocks, and rule of law. Although geographic determinants of poverty are difficult to overcome with available policy levers, the literature provides hope that spatially targeted policy interventions can set countries, communities, and people on track to greater economic prosperity and well-being.

Subnational Poverty Hotspots

It is well known that subnational areas within countries exhibit substantial inequality in wealth and development across a number of dimensions.[11] Most of these dimensions, including the multidimensional aspects of poverty, are correlated with per capita income levels and so, as a shorthand, we try to identify those areas in the world trending toward the lowest GDP per capita in 2030. These areas, by definition, start today as very poor areas and have low recent growth rates, a feature that in our baseline scenario we assume to continue to 2030, partly because of the low underlying trend growth in each hotspot's respective national economy. We look at all subnational units in the world, with boundaries given by the first-level disaggregation in the Database of Global Administrative Areas (GADM-1). In other words, we look at all administrative units just below the national level, consisting of 3,609 subnational cantons, districts, governorates, prefectures, provinces, and states, in all countries in the world.

We start our identification of poverty hotspots by looking at initial levels of GDP per capita in subnational areas. These data are taken from Ghosh and others (2010) and reproduced by AidData in an online database of subnational variables.[12] Ghosh and others obtain subnational GDP per capita data by allocating national GDP to subnational areas based on luminosity from nighttime lights, adjusted to take into account caps on urban centers that are present in the most common, merged stable lights source available from the National Oceanic and Atmospheric Administration (NOAA). They also factor in estimates for the informal economy made by Schneider (2009a, 2009b) and use a separate method for assigning agricultural output across subnational areas. Combining these estimates with spatial estimates of population through the LandScan™

11. See, for example, Gennaioli and others (2014).
12. See Goodman and others (2019).

Global Population Database allows for the calculation of an annual figure for subnational GDP per capita.

Unfortunately, AidData published subnational GDP per capita for only a single year: 2006. To bring this up to date, and to make forecasts, we turn to an alternative openly-available data set that looks at subnational growth rates, provided by Kummu and others (2018). They provide data for subnational incomes for each year between 1990 and 2015, based on a compilation of other research. We take the Kummu growth rate of each subnational unit from 2006 to 2015 to update our base year to 2015.

The second step is to derive a forecast of subnational growth from 2015 to 2030. We do this by establishing a relationship between subnational and national growth rates and then taking forecasts for national growth from the International Monetary Fund (IMF). Using the Kummu data, we obtain a relationship between subnational income growth in each country and the national growth rate and assume it stays constant over time. In other words, if subnational region "a" in country "j" grows faster (or slower) than the national average during 2006 to 2015, we assume it will grow faster (or slower) than the national average by the same amount during the period 2015 to 2030. In this way, we link subnational growth to national growth.

National growth forecasts out to 2024 are taken from the IMF World Economic Outlook April 2019 database. We assume countries will grow at the same rate between 2024 and 2030 as forecast by the IMF for the six-year period from 2018 to 2024. Equipped with national growth rates for the period 2015 to 2030, a GDP per capita baseline value in 2015 and a relationship between subnational growth and national growth, we project subnational GDP per capita to 2030.[13]

We define "poverty hotspot" income areas as those with annual GDP per capita of less than $4,900 in 2011 PPP dollars in 2030. This threshold approximately doubles the current threshold definition used by the World Bank to designate countries as "low income," when adjusted to convert from the Atlas Method of national income actually used by the World Bank to 2011 purchasing power parities.

The map in figure 10-1 shows subnational hotspots within national boundaries. We note four "clusters" of 2030 hotspots.

- *Tropical Africa:* The largest cluster extends from the Sahel to northern Angola, and the southern borders of Zambia, Zimbabwe, and Mozambique.

13. Further details are provided in the appendix to this chapter.

- *Tropical Latin America:* This range is a scattering of areas including parts of Central America (including all of Nicaragua), Haiti, the Caribbean coast of Venezuela and most of its central and southern regions, part of Ecuador and Colombia, Suriname and French Guiana, and northeastern Brazil.
- *Central-South Asia:* This includes subnational areas stretching from Tajikistan and Kyrgyzstan to most of Afghanistan, northwestern Pakistan, Kashmir on both sides of the line of control, much of Nepal, the Indian states of Bihar and Manipur, and parts of Bangladesh and Myanmar.
- *Southeast Asia-Western Oceania:* This area includes sections of Cambodia, Vietnam, the Philippines, Indonesia (Aceh and Bengkulu provinces of Sumatra, some of the Lesser Sunda and Molucca Islands, and Timor), East Timor, much of Papua New Guinea, and the Solomon Islands.

In addition to these areas, there are other more scattered zones: Syria, Mongolia, Russia's Altai Republic, North Korea, and most of western Yemen. OECD countries and China do not display any hotspot regions.

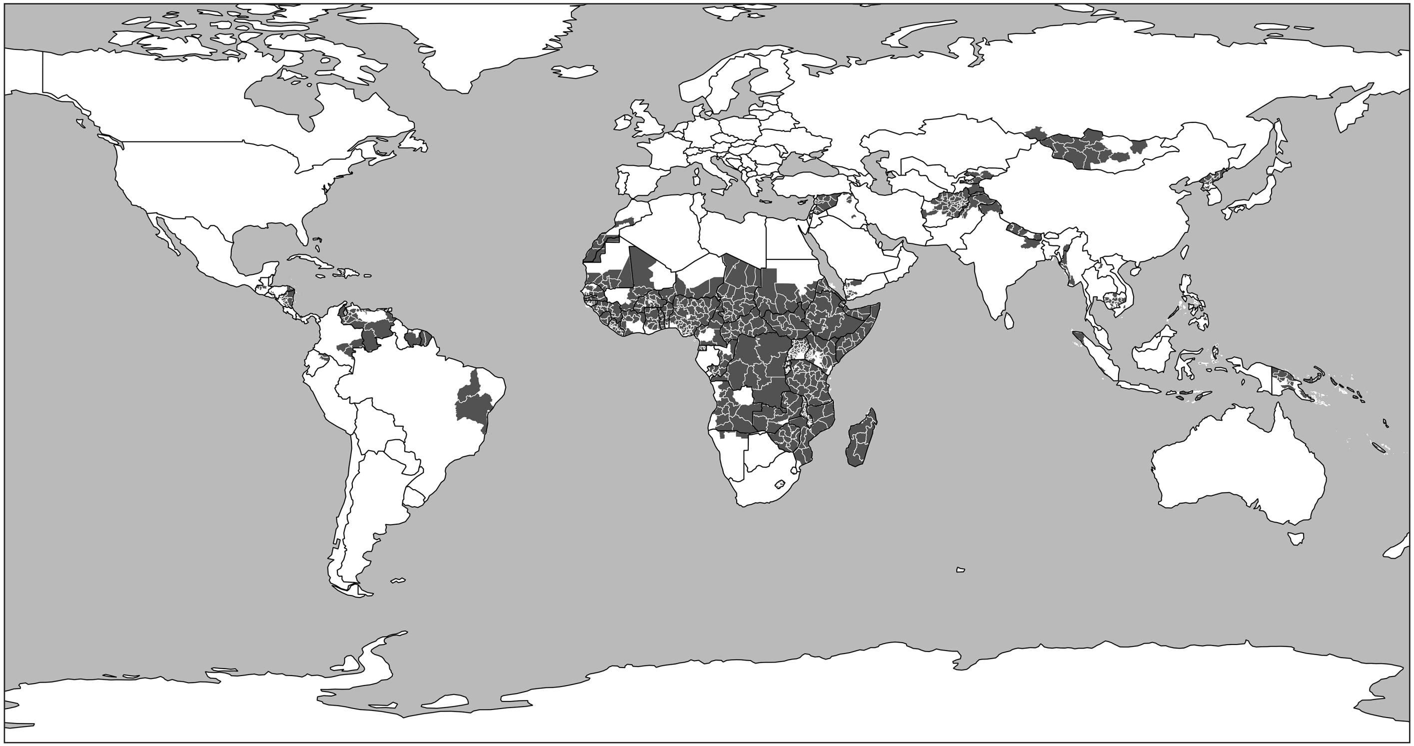
The map shows 840 poverty hotspots globally, of a universe of 3,609 districts, states, and provinces (for 157 districts, there are no available data). Around 1.2 billion people live in these hotspots. Although we have not attempted to construct poverty estimates for subnational regions (this would require some estimate of income distribution within each region), we feel confident that most households in extreme poverty in 2030 will be found in these places.

One hundred and two countries, about half the number in the world, have at least one region with an income level at or below $4,900, but in seventy-eight of these countries at least one other region also has a higher income. In other words, in a majority of developing countries, there are likely to be both "poverty hotspots" and prosperous areas in 2030. Even among today's low-income countries, our forecasts suggest that over half the countries will have some prosperous regions, above the $4,900 threshold. Similarly, thirty-eight of forty-six lower middle-income countries could have at least one region that qualifies as a poverty hotspot, along with eighteen of fifty-two upper middle-income countries. Eight high-income economies have at least one hotspot.

The Correlates of Poverty Hotspots

Poverty hotspots have a number of characteristics that distinguish them from other places. Table 10-1 shows how poverty hotspots compare to other places in developing countries. The hotspots are poor, with average per capita income levels of less than $2,000, compared to $11,000 in other developing country regions. They have far slower per capita income growth (0.8 percent in 2006–15

Figure 10-1: Subnational Poverty Hotspots, 2030



compared to 4.9 percent in non-hotspot places). They have lower human development scores and far poorer infrastructure. They have substantially higher deaths from civil conflict, although violence has lessened since the 1990s at about the same rate as other places. They have less exposure to drought but, as we will show, the impact of drought is likely to be severe (table 10-1).

Policy Issues for Spatial Targeting of Poverty Hotspots

Any discussion of spatial targeting of policy interventions has to start with an understanding of what factors are likely to influence income growth levels in specific places. We use the annualized change in nighttime luminosity per capita

Table 10-1. Characteristics of Poverty Hotspots and Other Regions within Developing Countries

	Hotspot	Other
Mean GDP per capita 2006, 2011 PPP ($)	1,858	7,317
Mean GDP per capita 2015, 2011 PPP ($)	2,005	11,238
Growth rate 2006–15, Annual (%)	0.8	4.9
Mean World Bank Aid commitments per capita (1989–2014 total) ($)	129.1	103.7
Mean HDI	0.47	0.66
Mean number of battle deaths 1989–2000 per 100K population	160	80
Mean number of battle deaths 2013–17 per 100K population	23	8
Growth rate in deaths (%)	–85	–91
Soil quality index	4.9	4.6
Mean drought events	0.5	1.0
Mean distance to roads (m)	11,709	7,122
Mean travel time to cities (minutes)	549	314
Total population, 2015 (billions)	1.2	4.7
Total population, 2030 (billions)	1.7	5.5
Population growth rate, annual 2015–30 (%)	2.4	1.0
Mean air temp 1980–2014 (degrees Celsius)	23	18
Mean annual precipitation 1980–2014 (mm)	100	90

Source: Author's calculations. See appendix for data sources.

over the period 2003 to 2013 as a proxy for GDP per capita growth and regress this on a number of subnational variables. We chose to base the analysis on subnational administrative units, which vary considerably in size, rather than grid cells that have a fixed spatial area, because much of the data are more easily accessible for administrative units, and, in the final analysis, the policy choices to be made will likely be implemented through administrative units. As a robustness check, we do the regressions separately using the entire sample of countries and for developing countries only, and with and without country fixed effects. The results, and the data sources, are summarized in the appendix to this chapter.

There seems to be strong empirical evidence that while certain places indisputably face geographic constraints—such as extreme temperatures, inhospitable soil, and proximity to the national border—other variables within the purview of policymaking also hold significant explanatory power. Human capital, infrastructure and connectivity, shock-readiness, and governance all impact the extent to which a region develops or lags, suggesting that public officials have at their disposal a powerful antidote to poverty: inclusive policies and institutions.

Most of the variables in the regression have the expected signs. Consistent with other studies, the initial level of GDP per capita is negatively related to growth. Our best point estimate of this conditional convergence is that for every doubling of initial GDP per capita, the expected subsequent annual growth rate in the region falls by between 0.9 percentage points (a coefficient of –0.013) and 1.4 percentage points (a coefficient of –0.02). Other significant variables include the rule of law, an index of soil suitability, various measures of infrastructure adequacy, malaria ecology, a broader measure of human development, exposure to drought or flood, and the change in conflict-related deaths. Some of these variables are linked to each other so coefficients must be carefully interpreted; the human development index contains elements of both health and income, which are, in turn, proxied by other variables in the regression. Access to a major city is closely but inversely correlated with distance to a road. Exposure to floods has a positive sign—most floods occur around river banks and replenish good alluvial soil, so they can carry a benefit.[14] The only surprise in the data is that being close to the coast does not seem to matter in a significant way.

Our purpose in doing these regressions is not to craft precise point estimates in the correlations or to identify specific policy interventions but, rather, to gain insight into the type of intervention that could potentially be expected to yield

14. Indeed, a robustness check in the regression interacting soils and floods shows this positive relationship between the two.

positive results. In our mind, the regression analysis shows that four classes of intervention could be important: (i) human development; (ii) infrastructure and connectivity; (iii) resilience to shocks; and (iv) governance and institutions. In each of these cases, we highlight actual examples of where governments have used geo-referenced spatial data to assist efforts to alleviate subnational constraints to development.

Human Capital

Human capital, defined as the "productive wealth embodied in labor, skills, and knowledge," is central to accelerating development in lagging places.[15] Aid organizations and governments alike tend to focus on improving access to education and ensuring the population has adequate health and nutrition services.

In our regressions, we use the initial year value of the Human Development Index (HDI) from the United Nations Development Program (UNDP), calculated from gridded data at five arc-minute resolution, averaged at the subnational level.[16] Additionally, we control for malaria as a proxy for disease burdens. Malaria ecologies are commonly associated with low-growth areas due to effects on the poverty, productivity, and health of the population. Malaria and other diseases affect the economy through adverse consequences for childhood development and the quality of human capital for decades.[17] We use a malaria "temperature suitability" score rather than the actual prevalence of malaria, so as to avoid endogeneity. The regression results suggest there is strong evidence that the initial level of human capital is important in ensuing regional growth.

Several governments have used high-quality, granular data on education and health to improve human capital. Providing evidence from two experiments on information exposure at the village-level in India, Pandey and others (2007, 2009) report that access to information has positive effects on human capital. The experimental studies randomly assigned exposure to information regarding citizen responsibilities and rights having to do with education, health, and governance services. Pandey and others conclude that the exposure resulted in greater participation in school management, better child health outcomes, improved student learning outcomes, and more frequent village council meetings.[18]

15. United Nations (1997).

16. Kummu and others (2018). The HDI includes the level of GDP per capita, which is separately included as an independent variable in the regressions. Unfortunately, the data do not permit us to identify the education and health components individually, so there is multicollinearity between the HDI variable and the level of GDP per capita variable. This does not bias the coefficients or the predictions of the model, but requires caution in interpretation.

17. Holding and Kitsao-Wekulo (2004).

18. BenYishay and Parks (2019).

Another example comes from Papua New Guinea. There, the rainy climate, limited infrastructure, and isolated geography create a fertile ground for the spread of malaria. However, the World Health Organization reports that malaria incidence halved between 2004 and 2017 as a result of increased funding for diagnosis and treatment of the infection, as well as near-universal distribution of long-lasting insecticidal nets.[19] High-quality and timely surveillance aided planners in determining where the most vulnerable populations reside and how best to target bed net distribution. One particular m-health initiative was instrumental in strengthening malaria surveillance across provinces. The mobile application provides a secure online platform for healthcare professionals that maps in real-time the outbreak of malaria at a village level, as well as the availability of treatment and diagnostics in nearby health facilities. The cases are geocoded and uploaded on average nine days from the date of testing. Rosewell and others (2017) conclude that using these mobile and geospatial technologies has strengthened the National Health Information System (NHIS) in Papua New Guinea through greater integration and accessibility of subnational data.

In Ethiopia, one problem has been how to decide where to build schools. Despite heavy government investments in the education sector, the overall level of education in Ethiopia remains low, with illiteracy rates for women in rural areas at over 50 percent, compared to 16 percent in urban centers.[20] The gender disparity is high: over half of Ethiopian women, defined as ten-years-old and above, were illiterate in 2013 as compared with 32 percent of men. In collaboration with the U.S. Department of Labor, the International Rescue Committee (IRC) began an initiative to build schools and train teachers to increase access to, and improve the quality of, schooling. The project required that implementers locate schools within walking distance of children out-of-school, near other networks of formal primary schools, and in close proximity to main roads.[21] IRC Ethiopia built a geographic database of demographic data and primary school location, among other variables, to map the construction of schools. Highly disaggregated data permitted a nuanced understanding of where schools could be built to reach the highest number of out-of-school children. Similar school mapping projects are underway globally, including one led by UNICEF Innovation.[22]

Each of these examples suggests that using geospatial data to allocate resources to reach those furthest behind can be a successful strategy for building human development. We would simply add that such efforts should not be considered

19. World Health Organization (2017).
20. United Nations Development Programme (2018).
21. ESRI (2009).
22. See UNICEF, "School Mapping," www.unicef.org/innovation/school-mapping.

just sector-by-sector, but perhaps also should involve a coordinated push across a range of interventions in the most disadvantaged places.

Infrastructure and Connectivity

In their seminal report *Reshaping Economic Geography* (2009), the World Bank argues that distance—or the time and cost required to connect economic production hubs—is a critically important correlate of growth. The better the infrastructure and connectivity, the greater the mobility of labor and goods.

We use several spatial measures of infrastructure to account for the impact of connectivity on subnational development. We use data on the distance to a road (a proxy for road density) at the beginning of the period, the distance to the national border (areas close to the border can be far from the heart of the national economy), the distance to a coastline (coastlines can offer opportunities to engage in international trade), the travel time in minutes to a city of at least 50,000 people, and the travel time to the capital city. All these variables, except distance to the coast, are significant in our empirical results. There are many other variables associated with connectivity, including access to broadband, financial inclusion, and access to non-transport infrastructure like power and telecommunications. We have not yet found suitable spatial proxies, on a global scale, to include these variables, but would guess that they, too, would prove to be important.

What are the implications for policy? In general, it is easier to anticipate higher benefits when initial access is limited. If a region has a very low density of roads, it is easier to double the existing access than if the region starts off with a high road density. But our analysis reveals only information on the benefits of greater connectivity; it does not include a consideration of cost. For example, building a road in a far-flung region with low population density might be expensive in a cost-benefit calculus. Detailed analysis is required for any given project, but, nevertheless, it is heartening to realize that, on average, investment in connectivity could raise regional growth.

Satellite and luminosity data are making it easier to see and analyze the connective linkages in a region, as well as their proximity to villages and major transport hubs. In this way, planners can identify and evaluate the impact of road projects. A good example of this technique comes from an analysis of new transportation infrastructure in the Palestinian territories. There, Israeli checkpoints and roadblocks result in heavy traffic and delays along major roads, costing Palestinians an estimated US$185 million per year due to extra time and mileage.[23] Protracted conflict also produces routine damage to bridges and roads; during

23. Isaac and Rishmawi (2015), Khalil and others (2015) quoted in Ives and others (2017).

the 2008–09 Israel-Gaza conflict, an estimated 167 kilometers of paved and unpaved roads sustained damage.[24] Several infrastructure projects are underway, including USAID's $900 million investment in the Infrastructure Needs Program (INP) II. To date, the project has funded the construction or rehabilitation of fifty-nine rural road segments in the West Bank.[25] AidData and USAID teamed up to evaluate the effect of road improvements on economic development in the Palestinian territories. Using luminosity as a proxy for economic activity, the team found a statistically significant increase in nighttime lights due to INP II road projects. In communities where multiple road segments were improved, the economic impact was even larger. Their findings suggest that improving roads in rural areas with multiple access points to larger road networks and in more urban, densely-populated areas is an important policy priority.[26]

Exposure to Environmental and Violent Political Shocks

Climate and environmental change pose an increasing risk to the global community: concentrations of CO2 and other long-lived greenhouse gases continue to increase; biodiversity is declining; tropical reefs and oceanic habitats are facing profound losses; and 25 percent of all land is degraded.[27] Addressing environmental shocks is central to accelerating development and ensuring that places are not left further behind. At the same time, and often in interrelated ways, environmental shocks can precipitate political shocks that result in conflict-related deaths.[28]

While short-term fixes are unlikely, policies can support shock-readiness and resilience. Climate resistant architecture[29] and drought technology,[30] for example, can aid communities and individuals facing extreme climates. Land registration and transparency can reduce the risk of conflict.

The severity, duration, and frequency of various shocks affect the resilience of subnational areas and their developmental trajectories. We look at human and natural shocks in the form of political conflict and drought, respectively. Both factors have been associated with persistent underdevelopment and poverty at the national level, with some analyses showing that the two are related—that drought can increase the likelihood of conflict over resources.[31]

24. OCHA (2016) quoted in Ives and others 2017.
25. BenYishay and others (2018).
26. Ibid. (2019).
27. UNEP (2019).
28. Smith in Chandy, Kato, and Kharas (2015).
29. OECD (2018).
30. UN Permanent Missions (2018).
31. Miguel, Satyanath, and Sergenti (2004).

The measurement of conflict is empirically tricky. Violence is decreasing worldwide although the number of civil conflicts is on the rise.[32] According to the OECD, political violence has spread across more than fifty countries in the past decade and a half.[33] But previous conflict is not a good predictor of future conflict. If past conflict has been resolved, then growth can rebound rapidly. On the other hand, if past conflict simply breeds a new round of conflict going forward, then growth can be impeded. What seems to be important is whether the political situation is stabilizing or not. Accordingly, we use the change in the average number of deaths (per 100,000 population) from war, armed conflict, and political violence in a base period (1989 to 2000) compared to a more recent period (2013 to 2017) as an indicator of the "shock" associated with conflict. For natural hazard shocks, we use a measure of the number of drought events from 1981 to 2001. We also add a measure of exposure to floods, although we expect this could be a benefit to growth in areas where land suitability is high for agricultural crop production. Our empirical approach suggests that shocks affect growth. The implication is that policy interventions should try to anticipate and mitigate these effects.

A good example is the use in Mozambique of recreational drones to monitor crop yields. Agriculture is at the fore of economic activity in Mozambique, employing over 80 percent of the labor force.[34] The majority of those in agricultural occupations are smallholder farmers who are highly susceptible to climate shocks and natural disasters, which are not infrequent on Mozambique's arable land. Many of these farmers lack access to actionable information on best use of limited resources (for example, fertilizer, water, and seeds). In response, the Third Eye project has set up a network of recreational drones to increase the provision of highly granular data on crop yield.[35] Sensors on the drones measure the reflection of near-infrared light and visible red light that, when combined, provide a Normalized Difference Vegetation Index (NDVI). By indicating whether vegetation is healthy or under stress, NDVI values show where crops may lack fertilizer or water, or face other constraints. Early data suggests that crop production in Mozambique has increased by 41 percent and water productivity by 55 percent as a result of this information.[36]

New geospatial technologies also could help inform policy interventions in conflict-affected regions. In the Democratic Republic of the Congo (DRC),

32. Blattman and Miguel (2010).

33. OECD. 2016. *States of Fragility: Understanding Violence*. OECD Publishing: p. 20.

34. USAID, "Agriculture and Food Security," www.usaid.gov/mozambique/agriculture-and-food-security.

35. See Third Eye, www.thirdeyewater.com/.

36. African Union & The New Partnership for Africa's Development (NEPAD 2018).

ineffective land management has contributed to violence and protracted conflict that may have had its origins in the late nineteenth century, when Belgian colonial powers introduced new policies on land and forest tenure that superseded the authority of traditional leadership. Competing systems of land management, further complicated by 1970 land use legislation, led to rising tension that produced violence, human rights abuses, and destruction of property. Sharing the Land, an initiative run by Christian Bilingual University of Congo students, sought to address heightened conflict by coupling community organizing principles with geospatial technologies.[37] Using data from satellites, household surveys, and government records, the group compiled, mapped, and publicized land ownership claims in a northern region of the DRC. A USAID blog credits the group with promoting transparent and equitable land ownership practices.[38]

Governance and Institutions

Good governance is a primary driver of economic development and, as discussed earlier, there are limits to what can be achieved at the subnational level if national policies are inadequate. As one proxy for national governance and institutions, we use the rule of law indicator for the year 2000, from the World Bank's Worldwide Governance Indicators database. As a robustness check, we also run the regressions with country fixed effects, a technique that captures, in a summary fashion, a wide range of governance and institutional differences between countries. Unfortunately, we do not have comparable global indicators of subnational governance quality, although these would be helpful in understanding how local level governance can mitigate national shortcomings. We find that the rule of law is highly significant, but in a nonlinear way. Initial small improvements in the rule of law are linked to little difference to growth, and can even be harmful. But further improvements have an exponential, positive association with growth.

Can spatial analysis help improve governance? We believe so. Consider the example of how geo-coded polling in Nigeria is helping build trust in elections. Since Nigeria's transition to democracy in 1999, violence has erupted among political party supporters around the national elections. Violence reached a peak in the span of three days after the 2011 election, when 800 people died in election-related clashes. Building public confidence in Nigeria's Independent National Electoral Commission (INEC) is central to ensuring a credible and

37. See Center on Conflict and Development, "DRC: Sharing the Land," Texas A&M University, https://condevcenter.org/sharing-the-land/.

38. Lobo (2016).

peaceful election cycle.[39] The International Foundation for Electoral Systems (IFES) partnered with INEC to address one dimension of the election process: polling stations. For decades, Nigeria has offered just under 120,000 polling stations despite rapid urbanization and a growing population. To better manage voting points, an IFES GIS and data management specialist devised a database of polling stations that inventories and spatially locates all places reporting election results. This and related data provides electoral stakeholders with a trusted hub of information and informs efforts to roll out additional polling units in congested areas.[40] Though the 2019 Nigerian election was not without logistical hurdles and political violence, use of a single geospatial database of all polling locations, trusted by all stakeholders, likely mitigated tensions in the preparations ahead of elections and in the resolution of disputes in the aftermath.

Accelerating Development in Poverty Hotspots

Using a simple, stochastic simulation method (see appendix for details), we can simulate what might happen to the growth in GDP per capita if policy interventions were to change some of the underlying correlates of growth.

Figure 10-2 summarizes the marginal effects of several variables. For example, doubling road network density within a subnational area will add just over 1 percentage point to annual growth rates. Mitigating the impact of droughts by half adds another percent. An additional percent increase in growth may be achieved by raising the HDI score by 10 percent (at the country level, this would be the equivalent of Rwanda raising its HDI score to that of Angola, Iraq raising its score to that of Thailand, or South Africa raising its score to that of Brazil). Doubling a country's Rule of Law score adds 0.75 percent. Cutting the rate of conflict deaths by half increases growth by an additional 0.5 percent. Finally, increasing the accessibility of urban areas adds about 0.4 percent to growth. These six reforms, therefore, would add 4.5 percent to a subnational region's annual growth over the next ten years. Cumulated over a decade, this is enough to add over 50 percent to a region's GDP per capita.

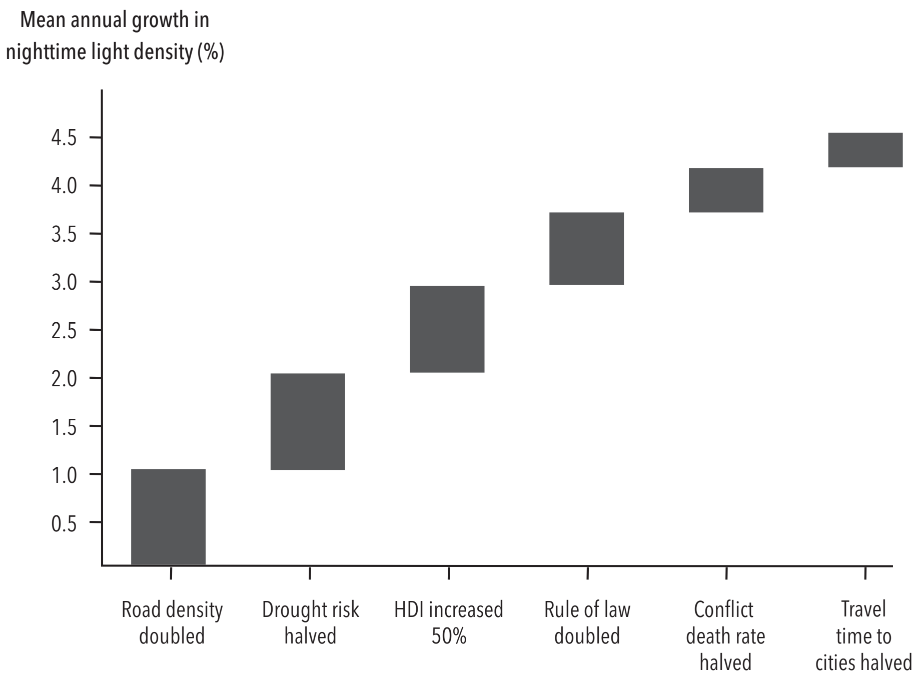
We have given examples of how policy reforms can use geospatial information to achieve greater impact on lagging areas. We also believe the potential for greater use of spatial targeting in allocating public spending is high. While we do not have geo-coded data on domestic public spending, AidData has published geo-located information on World Bank projects.[41] They show that between

39. Verjee and others (2018).

40. International Foundation for Electoral Systems (2015).

41. AidData (2017).

Figure 10-2. Marginal Effects of Changes at the Subnational Level on Growth



Notes: Estimated effects are generated via stochastic simulation of the specification in column 1, Table A2 (Appendix), each of which represents the effect of changes to each of the explanatory variables along the horizontal axis, while setting all other control variables at their sample means.

1989 to 2014, the World Bank committed aid worth $129 per person in poverty hotspot areas and $104 in other developing country areas. This is a small difference compared to the difference in needs; a far greater share of aid should be going to hotspot areas if extreme poverty is to be eradicated by 2030.

Conclusion

By 2030, perhaps 1.7 billion people will still live in places where the average income level leaves them close to being in, or falling into, extreme poverty. A new toolkit of advanced geospatial technologies now permits an ever-more granular understanding of where the most vulnerable reside and what can be done to get them back on track. It is a fallacy to believe that natural migration will move people from poor areas to places that offer more opportunity. At least for the time being, higher fertility rates associated with being poor are pushing population growth rates in poor places above those in more prosperous places, even within each country.

BenYishay and Parks (2019) suggest that the availability and provision of location-specific data can (i) highlight underserved areas, (ii) encourage public officials to allocate resources to areas identified as underserved, and (iii) provide citizens with accountability mechanisms that help ensure that resource allocation is more responsive to local needs. In this chapter, we have taken a first step at identifying the most underserved places in the world, although we freely acknowledge that further work is needed to make this into an actionable tool. We also provide suggestive evidence that aid, from at least one major multilateral donor whose projects have been geo-coded, does not historically have a sufficient bias toward poverty hotspots. Finally, we are encouraged by the proliferation of subnational data that now exists and that could, and should, be more widely disseminated to help citizens benchmark themselves against their neighbors.

Our central takeaway: Spatial targeting offers considerable promise in ensuring that geography will not become destiny for large numbers of people in developing countries.

Appendix

Stochastic Simulation Procedure

Much can be learned about the distributional properties of a random variable by sampling from the underlying probability distribution that generated that variable. We rely on the "Clarify" procedure developed by King, Tomz, and Wittenberg (2000), which uses Monte Carlo simulation of parameter distributions to estimate predicted outcome values. For each coefficient to be estimated in a regression model, 1,000 out-of-sample observations are simulated using the known properties of each independent variable (including mean and standard deviation). The result is a series of randomly generated parameters with the same distributional characteristics as each of the variables in the model—in effect, multiple observations on the initial coefficients. Using these out-of-sample observations, we then generate predicted values of our dependent variable by setting any particular regressor at a particular value, while setting all other regressors at their sample means.

Table 10 A-1. Variable Descriptions and Sources

Variable	Measurement	Source
Nighttime light density	Natural-log mean nightlight luminosity in 30 arc-second resolution averaged within each GADM-1 in 2003 and 2013 polygon divided by GADM-1 population.	DMSP-OLS Nighttime Lights, version 4, NOAA's National Geophysical Data Center.
GDP per capita	2006 GDP data based on nighttime luminosity, converted to 2006 PPP dollars apportioned by population based on LandScan data; 30 arc-second resolution averaged within each GADM-1 polygon in natural logs. Divided by summed population for each GADM-1 polygon using Gridded Population of the World (GPW), v4	Ghosh and others (2010) and Gridded Population of the World (GPW), v4 (SEDAC, CIESIN)
Population density	2005 population count at 15 arc-minute resolution summed within each GADM-1 polygon divided by polygon area	Gridded Population of the World (version 4), NASA's Socioeconomic Data and Applications Center (SEDAC)
Rule of law	2000 rule of law index from Worldwide Governance Indicators	Worldwide Governance Indicators
Normalized difference vegetation index	Difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs), at 30 arc-second resolution averaged within each GADM-1 polygon	Pedelty and others (2007)
Road density	Mean distance (m) to roads between 1980 and 2010 (depending on the country) at 0.5 × 0.5 degree resolution, averaged within each GADM-1 polygon	Global Roads Open Access Data Set, Version 1 (gROADSv1)
Distance to borders	Distance (m) from GADM-1 centroid to nearest international border	Global Administrative Areas (GADM)
Travel time to cities	Travel time (mins.) to the nearest city of 50,000 using land (road/off road) or water (navigable river, lake and ocean) based travel at 5 km × 5 km resolution, averaged within GADM-1 polygons, in natural logs; accessibility is computed using a cost-distance algorithm for travelling between two locations on a regular raster grid	Nelson (2008)
Travel time to capital	Value of average estimated travel time (mins.) to capital city at 5 km × 5 km resolution, averaged within GADM-1 polygons	European Commission

Drought events	Count of area where monthly precipitation is lower than 50% of the median value calculated for the period 1961–90 during at least three consecutive months, summed within each GADM-1 polygon	Global Risk Data Platform
Flood risk	Global risk induced by flood hazard from 1 (low) to 5 (extreme), at 30 arc-second resolution, averaged within GADM-1 polygons	Global Risk Data Platform
Distance to coastline	Haversine distance (m) from GADM-1 centroid to nearest coastline	World Vector Shorelines from A Global Self-Consistent, Hierarchical, High-Resolution Geography Database
Malaria suitability	Temperature suitability index for P. falciparum transmission, 2010, at 5 km × 5 km resolution, averaged within GADM-1 polygons	The Malaria Atlas Project
Conflict deaths	Sum of deaths attributable to war and political conflict georeferenced by incident between 1989 and 2000, summed within GADM-1 polygons, divided by 100,000 GADM-1 population	Uppsala Conflict Data Program
Human Development Index	2005 HDI score in 30 arc-second resolution, averaged within each GADM-1 polygon.	Kummu, Taka, and Guillaume (2018)
World Bank project value per capita	Aid data from World Bank Donor System, geocoded and published by AidData. Covers projects from 1995 to 2014. Version 1.4.2.	AidData GeoQuery (2018)
Mean annual precipitation	Average precipitation per year. Created using UDel Precipitation dataset (v4.01). 1980–2014	UDel Precipitation dataset via GeoQuery (2018)
Mean annual temperature	Average air temperature per year. Created using UDel Precipitation dataset (v4.01). 1980–2014	UDel Precipitation dataset via GeoQuery (2018)

Note: For all variables x with zero values, natural logs are calculated as $\mathrm{Ln}(1 + x)$.

Table 10 A-2. Change in Subnational Economic Activity Per Capita, 2003 to 2013

	(1)	(2)	(3)	(4)
	All countries	**Developing countries**	**All countries**	**Developing countries**
GDP per capita (Ln, 2006)	−0.013***	−0.014***	−0.018***	−0.020***
	(0.002)	(0.002)	(0.004)	(0.005)
Population density (Ln, 2005)	−0.009***	−0.010***	−0.005**	−0.005**
	(0.001)	(0.001)	(0.002)	(0.002)
Human Capital:				
Human Development Index (2005)	0.036**	0.053***	0.020	0.018
	(0.015)	(0.018)	(0.018)	(0.021)
Malaria suitability (Ln)	−0.001	−0.003***	−0.002*	−0.002
	(0.001)	(0.001)	(0.001)	(0.001)
Infrastructure and Connectivity:				
Distance to roads (m, Ln)	−0.005***	−0.009***	−0.003	−0.008**
	(0.002)	(0.002)	(0.002)	(0.004)
Distance to country border (m, Ln)	0.007***	0.009***	0.003*	0.005**
	(0.001)	(0.002)	(0.002)	(0.002)
Distance to coastline (m, Ln)	−0.000	0.000	0.002	0.001
	(0.001)	(0.001)	(0.002)	(0.003)
Travel time to cities (mins., Ln)	0.004**	0.006**	0.005**	0.008**
	(0.002)	(0.003)	(0.002)	(0.003)
Travel time to capital (mins., Ln)	−0.002***	−0.002***	−0.001**	−0.001**
	(0.000)	(0.000)	(0.001)	(0.001)
Exposure to Shocks:				
Difference in conflict deaths, 1989–2000 vs. 2013–2017 (per 100,000, Ln)	−0.003***	−0.003***	0.002	0.002
	(0.001)	(0.001)	(0.001)	(0.001)
Drought exposure (Ln)	−0.004**	−0.005**	−0.001	−0.001
	(0.002)	(0.002)	(0.001)	(0.002)
Flood risk (Ln)	0.023***	0.033***	0.001	0.002
	(0.004)	(0.005)	(0.005)	(0.006)
Normalized difference vegetation index (Ln)	0.007***	0.010***	0.004	0.006
	(0.002)	(0.003)	(0.005)	(0.006)

	(1)	(2)	(3)	(4)
	All countries	**Developing countries**	**All countries**	**Developing countries**
Governance:				
Rule of law (2000)	–0.006***	0.017***		
	(0.002)	(0.004)		
Rule of law^2 (2000)	0.002*	0.019***		
	(0.001)	(0.003)		
N	3,054	2,260	3,054	2,260
n	189	130	189	130
Adjusted/Overall R^2	0.178	0.146	0.143	0.085
$p < F$	0.000	0.000	0.000	0.000
Country-fixed effects	No	No	Yes	Yes

Notes: Dependent variable is log-difference in nighttime luminosity per capita between 2003 and 2013 in annual terms. Estimation is by ordinary least squares (OLS) with standard errors (columns 1 and 2) and errors clustered by *n* countries (columns 3 and 4). Intercepts (all columns) and fixed effects for *n* countries (columns 3 and 4) are estimated but not reported. Developing countries are those with GNI per capita (current dollars, Atlas method) less than $12,055 in 2017.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

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