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Charles Kenny and George Yang

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There is considerable interest in increasing private participation in infrastructure to meet the twin goals of climate mitigation and development in low- and middle-income countries. At the same time, this infrastructure needs to make returns in order to be financially sustainable. This paper reviews evidence on the economics of infrastructure investment and the role of human capital and uses two approaches to provide additional evidence on the link between human capital and infrastructure returns: (i) using estimated returns to individual World Bank infrastructure projects and their relationship to country levels of human capital and (ii) broader approaches linking the macroeconomic impact of infrastructure investment in the presence of varying human capital stocks.

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CENTER FOR GLOBAL DEVELOPMENT
2055 L Street, NW Fifth Floor
Washington, DC 20036

1 Abbey Gardens
Great College Street
London
SW1P 3SE

www.cgdev.org

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Abstract

There is considerable interest in increasing private participation in infrastructure to meet the twin goals of climate mitigation and development in low and middle income countries. At the same time, this infrastructure needs to make returns in order to be financially sustainable. This paper reviews evidence on the economics of infrastructure investment and the role of human capital and uses two approaches to provide additional evidence on the link between human capital and infrastructure returns: (i) using estimated returns to individual World Bank infrastructure projects and their relationship to country levels of human capital and (ii) broader approaches linking the macroeconomic impact of infrastructure investment in the presence of varying human capital stocks.

1 Introduction

Figure 1 illustrates the link between electricity consumption per capita and average years of education per person in a country. Figure 2 illustrates the relationship between electricity consumption per capita and GDP per capita. The figures make clear the tight relationship between infrastructure, human capital and income (which we will use interchangably with GDP per capita at the country level in what follows). It is a relationship founded on interdependence: not least, modern economies need extensive infrastructure and skilled workers to function, while income

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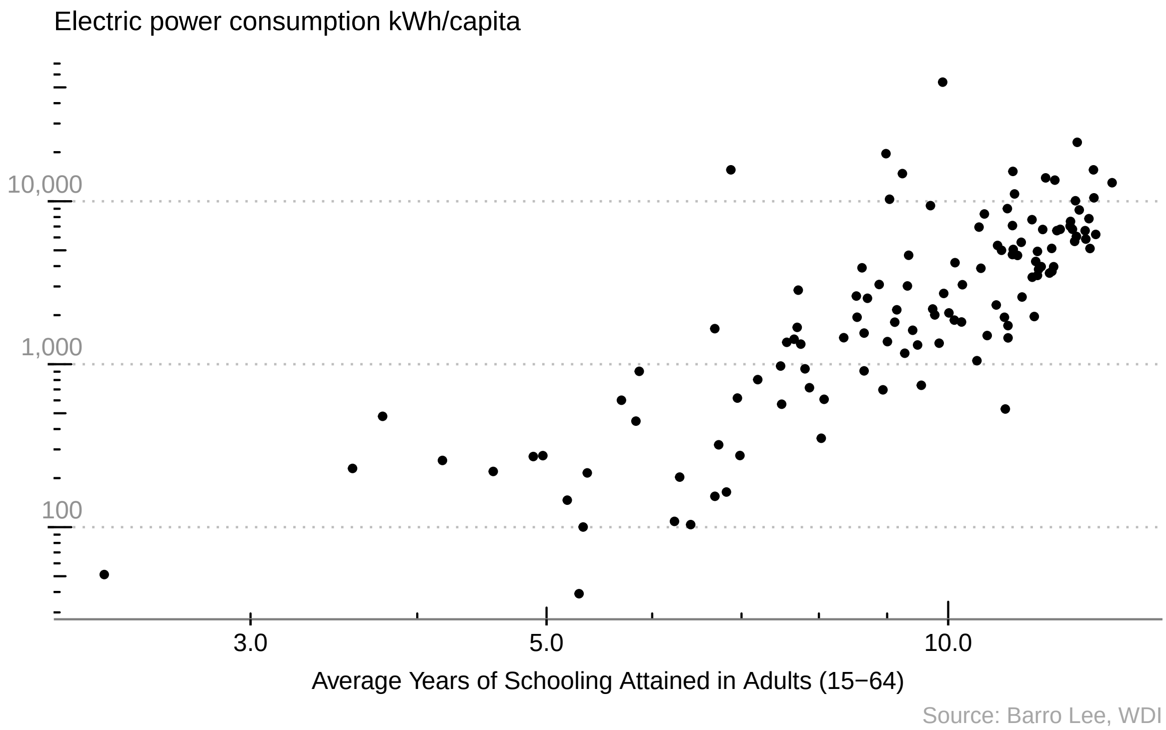
is necessary to pay for infrastructure, health and education services. Again, infrastructure is a key input to human capital: easing access to education and improving the quality of health care.[1] And infrastructure requires a range of technical abilities to operate and exploit. To quote Robert Lucas, "any increase in physical capital must be matched by increases in human capital in order to sustain per-capita income growth."[2]

Figure 1: Years of Schooling vs. Power Consumption



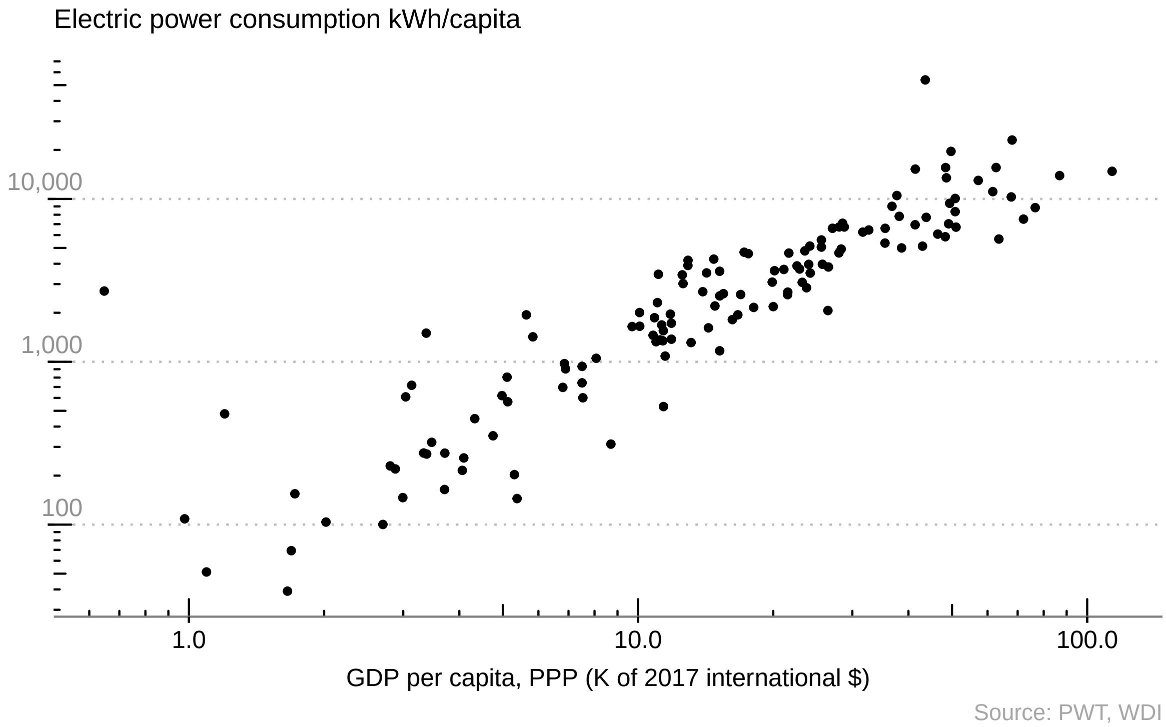
That interdependence, discussed in greater detail below, is why power producers and investors who want to guarantee sustainability of their industry and a market for their product need to be concerned about human capital and the education and health services that generate it in the countries in which they operate. To highlight some of the results presented in greater detail below:

- Expanding access to energy is associated with a larger impact on growth in countries with higher stocks of human capital. The impact of road construction on reducing poverty is 30% larger in areas with 75% secondary school enrollment than in regions with 25% enrollment.

[1]Mu and van de Walle find that a rural road project significantly increased primary enrollment for example Mu, R. and D van de Walle. 2011. "Rural Roads and local Market Development in Vietnam," The Journal of Development Studies, 47(5):709-734, Transport and electricity are also vital to medical supply chains, especially for vaccines that require refrigeration, for example.

[2]Lucas, Robert E. (1993). Making a Miracle, Econometrica. 61: 251–272.

Figure 2: GDP per capita vs. Power Consumption



- Adding a year of education to average years of schooling at a given income is associated with a 14 percent rise in electricity consumption.
- A 17% increase in human capital is associated with a 17% decrease in dirty energy consumption and an 86% increase in clean energy consumption from the average share.
- A one year rise in average years of education in the adult population at a given income is associated with a drop in electricity lost in transmission and distribution equal to 0.8% of total output.
- A one year rise in average years of education in the adult population at a given income is associated with a decline of between 3 and 5 percentage points in the proportion of firms reporting electricity outages.
- A one year rise in average years of education in the adult population at a given income is associated with at least a 1.7 percentage point higher rate of return in World Bank-financed infrastructure projects.

Overall, the evidence is considerable that greater stocks of human capital increase the demand for infrastructure services as well as quality, sustainability and returns of infrastructure investments in developing countries. This suggests infrastructure investors should indeed care about human capital in the countries in which they invest.

2 Infrastructure and Overall Economic Performance

Infrastructure is a central component of modern economies.[3] Hassler, et al note that when energy prices tripled in the 1970s, the energy input share in US production tripled as well –the quantity of energy inputs remained largely unchanged. At least in the short term, a given level of transport and electricity services are simply essential to sustaining output.[4] The story is broadly similar worldwide and over the longer term, with total energy consumption briefly dipping after energy price rises in the mid 1970s and 1980s, but then continuing to rise.[5]

And when infrastructure is a bottleneck, it rapidly rises up the list of critical issues for business. Surveys of manufacturing enterprises worldwide suggest that electricity is the single biggest obstacle to business reported by 54 percent of firms in South Africa, 45 percent in Pakistan, 28 percent in Bangladesh and 27 percent in Nigeria, for example.[6] Perhaps unsurprisingly, 63 percent of firms in South Africa report owning a generator and of those firms, 46 percent of the electricity they use they generate themselves. Looking across 20 African countries, Mensah finds that electricity shortages exert a substantial negative impact on employment by constraining the launch of new businesses, reducing the output and productivity of existing firms, and negatively affecting the trade and export competitiveness of firms.[7]

Given that, it is unsurprising infrastructure projects can be profitable investments. Bitsch et al.s analysis of investment funds supported by the European Bank for Reconstruction and Development suggest that infrastructure deals outperform non-infrastructure deals, despite lower default risk.[8] Data from EBRD infrastructure project financial rates of return similarly suggest these can

[3] Looking at Indian states for 1965–1984, electrification is significantly associated with more rapid manufacturing output growth RUD, J. P. (2012): "Electricity Provision and Industrial Development: Evidence from India," Journal of Development Economics, 97(2), 352–367. See also The Poverty Impact of Rural Roads: Evidence from Bangladesh Shahidur Khandker, Zaid Bakht and Gayatri B. Koolwal Economic Development and Cultural Change, 2009, vol. 57, issue 4, 685-722 although Välilä, T. (2020), 'Infrastructure and Growth: A Survey of Macro-econometric Research', Structural Change and Economic Dynamics, 53, 39–49.

[4] Hassler, J., Krusell, P., Olovsson, C. (2012). *Energy-saving technical change* (No. w18456). National Bureau of Economic Research.

[5] https://ourworldindata.org/energy-production-consumption

[6] https://www.enterprisesurveys.org/en/data/exploretopics/biggest-obstacle

[7] Mensah,Justice Tei. *Jobs ! electricity shortages and unemployment in Africa (English).* Policy Research working paper,no. WPS 8415 Washington, D.C. : World Bank Group."

[8] A Bitsch, Florian; Buchner, Axel; Kaserer, Christoph (2010) : Risk, return and cash flow characteristics of infras-

be high in the developing and emerging markets that the bank covers: an average of 23 percent.[9]

It is also unsurprising that a range of studies suggest strong positive macroeconomic returns to infrastructure investments.[10] One broad-based literature review of statistical studies suggested 63% of the analyses surveyed found a positive and significant link between infrastructure and development outcomes.[11] One of those studies suggested a 10 percent rise in infrastructure assets directly increased GDP per capita by 0.7 to 1 percent.[12]

At the same time, like most investments, infrastructure investments do better in a growing economy.[13] In addition, there is a higher variability to the economic returns to infrastructure in low and middle income countries, consistent with the need for a broader environment conducive to those returns.[14] Time-series results suggest the impact of infrastructure investment varies across countries and sectors and over time, and sometimes point to over-investment as an issue.[15] For example, an infrastructure boom in Africa in the 1960s and 70s ended with the oil and debt shocks, which left many of the investments unsustainable.[16]

More recently, expansions in grid-energy may explain as much as a third (35.4 percent) of growth on average in six African countries in the period 2000-13 as infrastructure expanded to cover yawning supply deficits.[17] And yet, Ghana recently demonstrated the considerable importance

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tructure fund investments, EIB Papers, ISSN 0257-7755, European Investment Bank (EIB), Luxembourg, Vol. 15, Iss. 1, pp. 106-136

[9]Florio, Massimo. "An international comparison of the financial and economic rate of return of development projects." *Available at SSRN 3200931* (1999). http://wp.demm.unimi.it/files/wp/1999/DEMM-1999_006wp.pdf

[10]see a review of some of them in Estache, A. (2007). *Current debates on infrastructure policy* (Vol. 4410). World Bank Publications.)

[11]Straub, S. (2008). Infrastructure and growth in developing countries: Recent advances and research challenges. *World Bank policy research working paper*, (4460). See also Calderón, C., Moral-Benito, E., & Servén, L. (2015). Is infrastructure capital productive? A dynamic heterogeneous approach. *Journal of Applied Econometrics*, *30*(2), 177-198.

[12]A Timilsina, Govinda R. and Hochman, Gal and Song, Ze, Infrastructure, Economic Growth, and Poverty: A Review (May 1, 2020). World Bank Policy Research Working Paper No. 9258, Available at SSRN: https://ssrn.com/abstract=3612420

[13]Investment performs better in growing markets: looking at International Finance Corporation equity investments in developing countries, a one percentage point of GDP growth in each year of the investment is associated with an additional 6.6 percentage points in return over the life of the investment, for example. Cole, S., Melecky, M., Mölders, F., & Reed, T. (2020). *Long-run returns to impact investing in emerging markets and developing economies* (No. w27870). National Bureau of Economic Research

[14]Stephane Straub. Infrastructure and Development: A Critical Appraisal of the Macro-level Literature. The Journal of Development Studies, Taylor & Francis (Routledge), 2011, 47 (05), pp.683-708. 10.1080/00220388.2010.509785. hal-00709551

[15]Égert, Balázs; Kozluk, Tomasz; Sutherland , Douglas (2009) : Infrastructure and growth : empirical evidence, CESifo Working Paper, No. 2700, Center for Economic Studies and ifo Institute (CESifo), Munich

[16]Mold, A. (2012). Will it all end in tears? Infrastructure spending and African development in historical perspective. *Journal of International Development*, *24*(2), 237-254.

[17]The role of energy capital in accounting for Africa's recent growth resurgence S Fried, D Lagakos - International

of not running too far ahead of demand. The country went on a power -plant purchasing spree in 2014, which has led to over-capacity. The Government contracted three emergency power producers and signed 43 power purchase agreements.[18] By 2019, the country was paying $620 million for power it did not need.[19] In response, the government raised industrial tariffs to $0.22/kWh, (among the highest in the world), cancelled 11 contracts and began trying to delay or renegotiate many of the rest, creating significant uncertainty and costs for operators. Similarly, in June 2020, Kenya reportedly planned to invoke force majeure on at least ten power producers in response to a sharp decline in demand.[20]

In the longer term, infrastructure requires an industrial and residential customer base capable of paying for it: more demand for infrastructure services requires either making it cheaper or customers richer. Governments have tried imposing the first approach through tariff limits and subsidies, but these frequently prove unsustainable: translating into long service waiting lists, low service quality and financially distressed operators.[21] The second approach of making consumers richer is the more sustainable model, and we will see it that requires a growing stock of human capital.

3 Infrastructure needs human capital to generate revenues

Infrastructure investments rely on adequate stocks of human capital to create demand and revenues over the longer term because human capital is the underlying force behind economic prosperity. According to World Bank estimates for 2018, human capital as measured accounted for about 64 percent of total global wealth (human and physical capital plus natural resources) compared to 31 percent for 'produced capital' (infrastructure, buildings, equipment).[22]

The role of human as compared to physical capital as the fundamental underpinning for progress can be illustrated by occasions on which the stock of physical capital including infrastructure was considerably diminished by war. Organski and Kugler suggest the economic effects of the two world wars in Europe dissipated after 15–20 years, after which there was a return to prewar

Growth Centre, 2017

[18] https://documents1.worldbank.org/curated/en/293271531711852754/pdf/GHANA-ENERGY-PAD-06252018.pdf

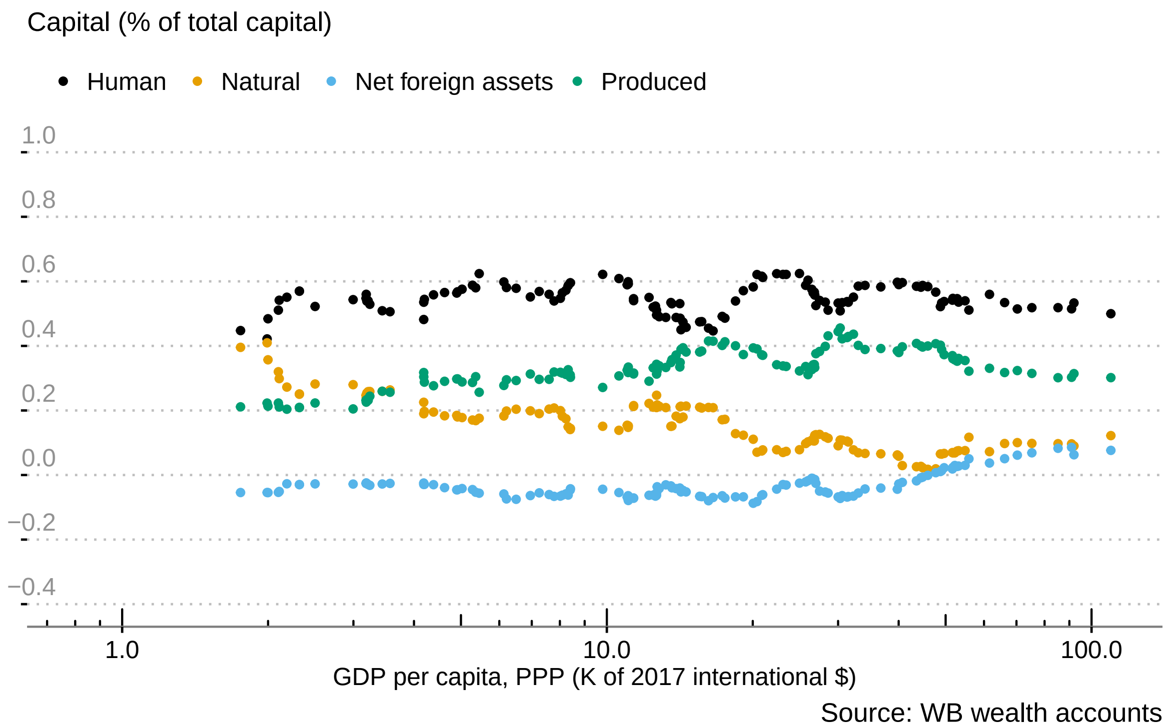
[19] https://www.energyforgrowth.org/blog/secret-electricity-contracts-hurt-consumers-citizens-and-climate/

[20] https://www.energyforgrowth.org/wp-content/uploads/2021/08/The-Case-for-Transparency-in-Power-Project-Contracts_-A-proposal-for-the-creation-of-global-disclosure-standards-and-PPA-Watch.pdf

[21] Vagliasindi, M. (2004). The role of investment and regulatory reforms in the development of infrastructure across transition economies. *Utilities Policy*, *12*(4), 303-314. Kenny, C. (2007). Infrastructure Governance and Corruption: Where Next?.

[22] World Bank. (2021). *The Changing Wealth of Nations 2021: Managing Assets for the Future*. The World Bank.

Figure 3: Capital Share vs. GDP per capita



growth trends.[23] In the Vietnam War, the U.S. dropped more bombs than in the entire of World War II and the Korean war combined, adding up to hundreds of kilograms per capita of high explosives. This destroyed a lot of infrastructure –the Rolling Thunder campaign of the late 1960s destroyed 59 percent of Vietnam's power plants and 55 percent of its major bridges. The campaign also killed people and disrupted education, but a far smaller proportion of human capital was lost.[24] Despite this considerable and disproportionate impact on physical capital stocks and infrastructure in particular, looking at long term outcomes of the bombing, Miguel and Roland "find no robust adverse impacts of U.S. bombing on poverty rates, consumption levels, electricity

[23] Brakman, Steven, Garretsen, Harry, Schramm, Marc, 2004. The strategic bombing of cities in Germany in World War II and its impact on city growth. Journal of Economic Geography 4(1),1–18. See also Przeworski, Adam ,Alvarez, Michael E., Cheibub, Jose Antonio, Limongi, Fernando, 2000. Democracy and Development: Political Institutions and Wellbeing in the World 1950–1990. Cambridge University Press, Cambridge. Organski, A.F.K., Kugler, Jacek, 1977. The costs of major wars: the phoenix factor. American Political Science Review 71(4),1347–1366. Organski, A.F.K.,Kugler, Jacek, 1980. The War Ledger. Univ. of Chicago Press, Chicago. Davis and Weinstein (2002) show that the U.S. bombing of Japanese cities in World War II had no long-run impact on the population of those cities relative to prewar levels, and Brakman et al.(2004) find a similar result for postwar Germany. Davis, Donald, Weinstein, David, 2002. Bones, bombs, and breakpoints: the geography of economic activity. The American Economic Review 92(5),1269–1289.

[24] The estimate from The Encyclopedia of the Vietnam War: A Political, Social, and Military History, 2nd Edition [4 volumes]: A Political, Social, and Military History by Spencer Tucker is that 30,000 civilians died as a result of Rolling Thunder, for eg, compared to a Vietnamese population of around 40 million at the time.

infrastructure, literacy, or population density through 2002."[25]

With regard to businesses, firms with greater access to or investment in human capital frequently make higher returns (which is why they are willing to pay more for educated workers).[26] The importance of human capital to businesses can be illustrated using the infrastructure sector itself. An estimate of skills demanded as part of the expansion of the South African electricity generation and distribution network in the 2010s suggested the program would require 1,400 higher educated engineering, research and project and construction management staff along with 13,000, artisans, 11,000 semi-skilled workers and 6,000 administrative workers.[27]

An expanded skills base is particularly important for new and rapidly growing industrial sectors, and again infrastructure provides an example with renewable energy. Renewables are more labor-intense than large-scale conventional production,[28] but also require different skills (for example PV and solar thermal system installers and maintainers). An analysis of the growth of the renewables sector in Europe up to 2020 suggested that it would create a net increase of between 100,000 and 400,000 jobs, part of overall job creation and destruction of between two to three million jobs.[29] Unsurprisingly, global skills gaps are particularly acute in the renewables sector.[30]

Regulation and governance is also a high-skilled task that is vital to private sector health –again, including the health of infrastructure companies.[31] Bitsch et al.s analysis of European Bank for Reconstruction and Development investment funds indicate that returns are influenced by the

[25]Miguel, E., & Roland, G. (2011). The long-run impact of bombing Vietnam. *Journal of development Economics*, *96*(1), 1-15.

[26]Bouillon, M. L., Doran, B. M., & Orazem, P. F. (1996). Human capital investment effects on firm returns. *Journal of Applied Business Research (JABR)*, *12*(1), 30-41. Blundell, R., Dearden, L., Meghir, C., & Sianesi, B. (1999). Human capital investment: the returns from education and training to the individual, the firm and the economy. *Fiscal studies*, *20*(1), 1-23.

[27]Merrifield, A. An Analysis of the Skills Requirements in the Electricity Value-Chain

[28]Estimates from Brazil of employment in wind farm construction and maintenance suggests the need for 3.5 person-years equivalent for each MW installed between manufacture and first year of operation of a wind power plant, and 24.5 person-years equivalent over the wind farm lifetime Simas, M., & Pacca, S. (2014). Assessing employment in renewable energy technologies: A case study for wind power in Brazil. *Renewable and Sustainable Energy Reviews*, *31*, 83-90.

[29]Lambert, R. J., & Silva, P. P. (2012). The challenges of determining the employment effects of renewable energy. *Renewable and Sustainable Energy Reviews*, *16*(7), 4667-4674

[30]Meyer, M., & Sunjka, B. P. (2019). A skills measurement model for the South African energy sector: Applying the analytic hierarchy process to the South African electric power industry. *South African Journal of Industrial Engineering*, *30*(3), 277-288. B Lucas, Hugo, Stephanie Pinnington, and Luisa F. Cabeza. "Education and training gaps in the renewable energy sector." *Solar Energy* 173 (2018): 449-455. Malamatenios, C. (2016). Renewable energy sources: Jobs created, skills required (and identified gaps), education and training. *Renewable Energy and Environmental Sustainability*, *1*, 23. d

[31]In Europe, for example, transport projects in better governed regions see higher returns B Crescenzi R., Marco Di Cataldo, M. and Rodríguez-Pose, A. (2016) Government quality and the economic returns of transport infrastructure investment in European regions, Journal of Regional Science, DOI: 10.1111/jors.12264

regulatory framework,[32] and cross-country evidence suggests greater education stocks are a factor behind higher institutional quality.[33]

Looking at consumer demand for products including infrastructure services, studies on the returns to education suggest educated people worldwide have higher incomes –earning about nine percent more per year of education.[34] And as people become richer, they buy more energy-using assets including TVs and refrigerators, as well as the electricity to run them.[35] Absent the income, demand does not materialize. A recent analysis of grid extension and off-grid power project failures in Tanzania and Mozambique suggested barriers to success are "related to lack of access to human capital… the rural economy is rudimentary the majority of households cannot pay the connection cost, which equates to months of income for many households."[36] In short, rich consumers buy more. Directly, that means more demand for infrastructure services from households and indirectly it means additional demand for those services from firms and businesses.

Human capital appears to be particularly important to stoke demand for renewable energy (perhaps not surprisingly given that worldwide, educational attainment is the single strongest predictor of climate change awareness).[37] Demand and supply factors linked to human capital will help explain why, looking at energy consumption for a panel of OECD economies over the period 1965–2014, rising human capital is associated with falling energy demand overall but a significantly higher demand for clean energy (a one standard deviation increase in their measure of human capital, which is about 17 percent of the value of the mean level of human capital, is associated with a 17 percent decrease in dirty energy consumption and an 86 percent increase in clean energy consumption from the average share).[38]

[32]A Bitsch, Florian; Buchner, Axel; Kaserer, Christoph (2010) : Risk, return and cash flow characteristics of infrastructure fund investments, EIB Papers, ISSN 0257-7755, European Investment Bank (EIB), Luxembourg, Vol. 15, Iss. 1, pp. 106-136

[33]Alonso, J. A., & Garcimartín, C. (2013). The determinants of institutional quality. More on the debate. *Journal of International Development*, *25*(2), 206-226. C Jones, G., & Potrafke, N. (2014). Human capital and national institutional quality: Are TIMSS, PISA, and national average IQ robust predictors?. *Intelligence*, *46*, 148-155.

[34]Psacharopoulos, George; Patrinos, Harry Anthony Returns to Investment in Education Education Economics26(5) 2018-06-07

[35]GERTLER, P. J., O. SHELEF, C. D. WOLFRAM, AND A. FUCHS (2016): "The Demand for Energy-Using Assets among the World's Rising Middle Classes," American Economic Review, 106(6), 1366–1401

[36]Helene Ahlborg, Linus Hammar, Drivers and barriers to rural electrification in Tanzania and Mozambique – Grid-extension, off-grid, and renewable energy technologies, Renewable Energy, Volume 61, 2014, Pages 117-124,

[37]Lee, T. M., Markowitz, E. M., Howe, P. D., Ko, C. Y., & Leiserowitz, A. A. (2015). Predictors of public climate change awareness and risk perception around the world. *Nature climate change*, *5*(11), 1014-1020. Knight, K. W. (2016). Public awareness and perception of climate change: a quantitative cross-national study. *Environmental Sociology*, *2*(1), 101-113.

[38]Yao, Y., Ivanovski, K., Inekwe, J., & Smyth, R. (2019). Human capital and energy consumption: Evidence from OECD countries. *Energy Economics*, *84*, 104534.

Cross-country evidence also supports the idea that public capital including infrastructure sees higher returns in countries that are rich in human capital.[39] Feng and Yu study the causal relationship between energy use and economic growth using data from 56 countries from 1970 to 2014 and find the growth impact of energy is enhanced by human capital development.[40] Again, Bahia et al. find that the growth impact of extending mobile infrastructure on growth is 30 percent larger in countries with a secondary school enrollment ratio of 60 percent or above compared to countries where secondary school enrollment is below 60 percent. [41]

4 Infrastructure and human capital are complementary

While there appears to be little *long term* impact of blowing up physical capital on economic growth prospects, immediate post-war periods also demonstrate the very high returns to physical capital investment when human capital is already comparatively plentiful. The late 1940s and early 1950s in Europe, for example, saw rapid recovery driven in part by considerable investment in reconstruction (supported by the Marshall Plan).[42] This speaks to the idea of complimentarity.

In the early decades of the Twentieth Century, as electrification spread across America, firms that had more equipment and got more of their power from electricity started hiring more educated workers, who they paid more.[43] It was an early indication that electricity is a 'skill-biased' technology. A lot of the electric power was used in machines that replaced human muscle power but required brains to operate and maintain, which increased demand for smart workers over strong workers. Skill-biased technology change linked with the growing industrial use of electricity has continued and spread worldwide, a factor behind steady or rising wage differentials between more and less educated workers even as the number of educated workers has dramatically climbed.[44]

[39] In a country that is in the top 97.5 percentile in terms of years of education, an increase of 1% in public capital leads to an increase in the share of manufacturing exports of 1.55%. In a country at the 2.5 percentile a 1% increase in public capital leads to a 0.381% increase in the share of manufacturing exports. Rimvie Enoc Kabore. Complementarity between human capital and public infrastructure in industrial comparative advantage. 2021

[40] E Fang, Z., & Yu, J. (2020). The role of human capital in energy-growth nexus: an international evidence. *Empirical Economics*, *58*(3), 1225-1247.

[41] Bahia, Kalvin, Pau Castells, and Xavier Pedrós. "The impact of mobile technology on economic growth: global insights from 2000-2017 developments." In 30th European Regional ITS Conference, Helsinki 2019, no. 205164. International Telecommunications Society (ITS), 2019.

[42] Although recent analysis suggests the plan was simply not large enough to have had much direct effect on output through investment, with an impact through its policy conditionalities Crafts, N. (2011). The Marshall Plan: a reality check. *University of Warwick CAGE Working Paper*, *49*(6). Eichengreen, B. (2010). Lessons from the Marshall Plan.

[43] Goldin, C., & Katz, L. F. (1998). The origins of technology-skill complementarity. *The Quarterly journal of economics*, *113*(3), 693-732.

[44] Berman, E., & Machin, S. (2000). Skill-biased technology transfer around the world. *Oxford review of economic*

The fact that returns to human capital are higher where there is adequate infrastructure and returns to infrastructure are higher where there is adequate human capital helps to explain when and where both are seen as barriers to firm growth. Looking at the 151 countries with enterprise surveys reporting what firms report as the most serious obstacle to their business, it appears that firm concern over electricity is higher in countries where education is not seen as a barrier and vice-verca.[45] Take two measures: first, as an indicator of comparative satisfaction with human capital, the proportion of manufacturing firms in a country that do *not* suggest the quality of workforce education is the biggest barrier and second, as a measure of infrastructure quality, the percentage of electricity *not* self-generated amongst firms with a generator. There are no countries where relative satisfaction with human capital is below 80 percent and electricity quality is also below 80 percent. Countries are divided into three groups: (i) those with reliable electricity and with firms satisfied with education, (ii) those with reliable electricity but where firms are dissatisfied with education (iii) those with unreliable electricity but satisfaction with education. The importance of (and concern over) an educated workforce to firms is higher in countries where there is access to the infrastructure that will help those workers be productive. Without that infrastructure access, concern about education as a potential barrier drops dramatically.

A number of studies find evidence of such a complementarity in terms of investment in physical and human capital, foreign direct investment and human capital, and infrastructure and human capital more specifically.[46] Jalilian and Weiss suggest that the impact of road investments on poverty levels increases by nearly thirty percent as secondary school enrollments in an area increase from 25 to 75 percent. [47] In the Philippines, analysis of rural road rollout suggested that it could in fact significantly *reduce* the welfare of the poor, unless complemented by investments in human capital. But when introduced together, a 1 percent improvement in both roads and schooling provision resulted in a 0.11 percent increase in the mean consumption expenditures of the bottom fifth of the population.[48]

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policy, *16*(3), 12-22.

[45]The median percentage of firms reporting electricity is the greatest barrier is 5.9 percent. The median percentage across countries reporting that an inadequately educated workforce is the biggest barrier is 6.6 percent Taking the proportion of those who do not report education as the greatest barrier, a median of 6.6 percent of remaining firms report electricity as the greatest barrier. Looking at countries who score above that median on each of these measures, 31 are above the median on neither, 28 above the median on both, and 92 on only one. Data from Enterprise Survey accessed 3/25.

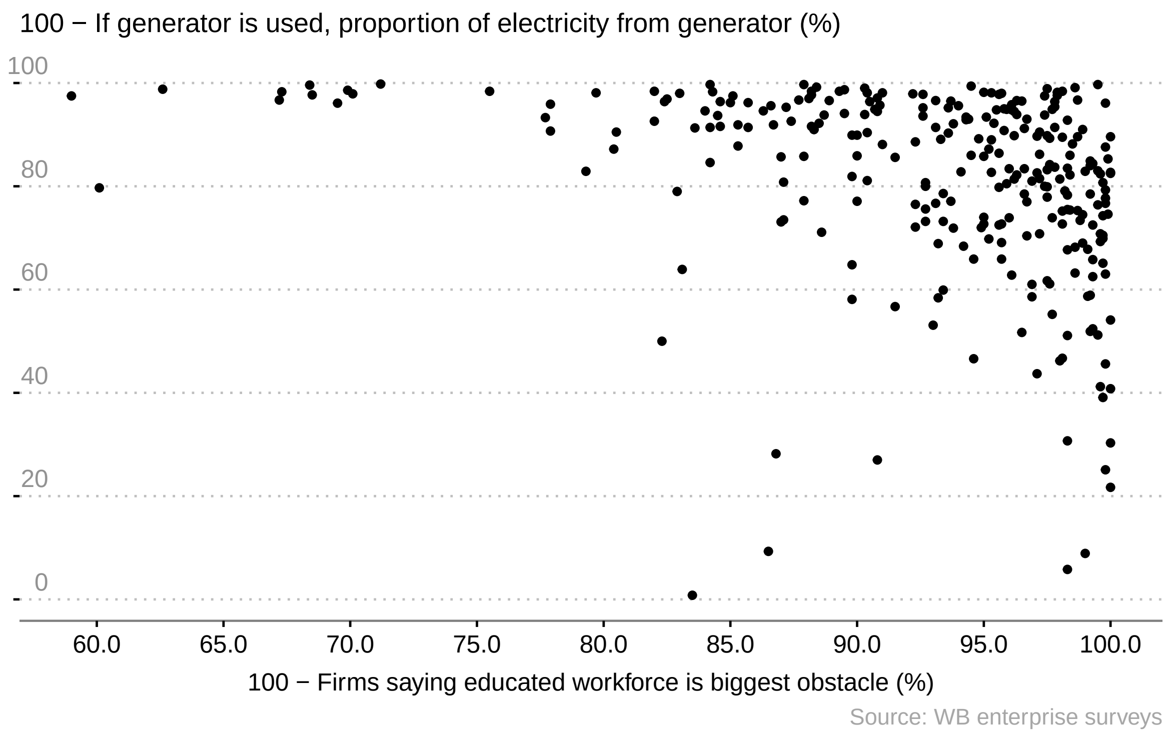
[46]E Amir-ud-Din, R., Usman, M., Abbas, F., & Javed, S. A. (2019). Human versus physical capital: issues of accumulation, interaction and endogeneity. *Economic Change and Restructuring*, *52*(4), 351-382 Toulaboe, D., Terry, R., Johansen, T. (2009). Foreign direct investment and economic growth in developing countries. Southwestern Economic Review, 36, 155-169.

[47]Jalilian, H., & Weiss, J. (2004, December). Infrastructure, growth and poverty: some cross-country evidence. In *ADB Institute annual conference on infrastructure and development: poverty, regulation and private sector investment, Tokyo, Japan* (Vol. 6).)

[48]"Balisacan and Pernia (2002) (Balisacan, A., & Pernia, E. (2002). What else besides growth matters to poverty

Because of this complementarity, greater human capital stocks attract more physical capital investment and vice-versa: people react to the higher potential returns from education provided by more infrastructure by going to school, firms respond to the greater potential for capital to make returns because of a more educated workforce by buying more equipment. [49]

Figure 4: Education Satisfaction vs. Infrastructure Quality



Canning and Bennathan find cross-country evidence that electricity generating capacity and road infrastructure are complementary to both physical capital in general as well as human capital overall. But they also find a number of countries where increased paved roads or electricity generating capacity at the expense of other investments appeared to lead to declining returns.

reduction? Philippines.) Similarly, Leipziger et al find the health outcomes in sample of developing countries show that health returns on infrastructure are conditional on education levels. They also demonstrate a complementarity between investment in health infrastructure and energy, telecoms and water and sanitation infrastructure. Where "Health" is a principal component index of birth attended by a health professional, measles vaccination and antenatal care, and "Infra" is a principal component index of household access to electricity, telephone, water and sanitation, and paved roads per capita, moving from a below median value of both variables to an above median value of infrastructure reduces infant mortality by 20 percent. Moving from low values of both variables to a high value of health care reduces infant mortality by 6 percent. Moving from low to high on both variables is associated with a mortality reduction of 39 percent -a 13 percent greater impact than suggested by the individual improvement of infrastructure and health variables. Leipziger, D., Fay, M., Wodon, Q. T., & Yepes, T. (2003). Achieving the millennium development goals: the role of infrastructure. *Available at SSRN 636582.*

[49] Grier, Robin. "The Interaction of Human and Physical Capital Accumulation: Evidence from Sub-Saharan Africa." *Kyklos* 58.2 (2005): 195-211. Grier, Robin M. (2002). On the Interaction of Human and Physical Capital in Latin America, Economic Development and Cultural Change. 50: 891–913

This does not imply that adding to the stock of these types of infrastructure reduces output, they note, but it does suggest declining returns compared to spending on other types of capital. At the time of their study, for example, the rate of return to electricity generation in Ghana was estimated at 25 percent compared to 18 percent for capital overall, but in Senegal it was 6 percent compared to 24 percent for capital overall. They also report that infrastructure returns vary more in poorer countries, reflecting greater 'capital imbalance' –countries further away from a balanced capital stock between infrastructure, other physical, and human capital.[50] Duczynski finds some evidence that broader measures of human and physical capital demonstrate similarly higher returns when they are 'balanced.'[51]

That infrastructure investments are more economically successful in environments rich in human capital suggests the risk of investing in infrastructure where human capital stocks lag: such projects are more likely to suffer from a lack of skilled construction, operation and maintenance staff, weaker regulatory capacity, and lack of demand, all of which create payment and renegotiation risks. Below, we further analyze the links between infrastructure returns and education.

5 Data

In order to further explore the links between broad-based development, infrastructure and human capital, we create a cross-country panel dataset from sources including the World Bank (World Development Indicators, the Wealth of Nations project, Enterprise Surveys, Worldwide Governance Indicators, and the Independent Evaluation Group), IMF, Barro-Lee (2021), the Public-Private Infrastructure database as manipulated by Kenny and Yang (2020), and Estache and Goioechea (2004).

Our infrastructure variables include electric power consumption and electricity production from renewable sources in kWh/capita from the World Bank; Independent Evaluation Group measures of World Bank infrastructure project performance ratings that include sector, ERR at Appraisal (AERR) ERR at Completion (CERR); [52] public-private infrastructure investment and PPI invest-

[50]E Canning, D., & Bennathan, E. (2000). The social rate of return on infrastructure investments. *World Bank PRWP* 2390. See also Tsaurai, Kunofiwa, and Adam Ndou. "Infrastructure, human capital development and economic growth in transitional countries." (2019)..

[51]E Duczynski, P. (2003). On the empirics of the imbalance effect. *International Journal of Business and Economics*, *2*(2), 121. Note our attempts to interact measures of physical capital and infrastructure stocks with humman capital in a growth regression suggests countries with 'balanced' capital as measured by the product of the residuals from a regression of human capital aganst GDP per capita and physical capital against GDP per capita actually found a negative relationship (see Table 7.15)

[52]Note Bank projects are selected on the grounds of being likely to have high economic returns, and economic

ment in electricity production from the World Bank's PPI database; country average percentage of firms owning a generator and power outages in firms in a typical month from World Bank Enterprise Surveys; measures infrastructure regulatory quality from the Worldwide Governance Indicators regulatory score; and data on the presence of an independent regulator and experience of private participation in electricity generation from Estache and Goioechea (2004).

For human capital we use the World Bank Wealth of Nations measure of Human Capital (based on forecast, discounted labor incomes); World Bank enterprise survey data on the percentage of firms that rank education as the greatest barrier they face; the Barro-Lee dataset measures of average total years of education in the adult population;[53] and World Bank measures of under-five mortality.

rates of return include (some) social externalities, not just financial rate of return. Pohl, G., & Mihaljek, D. (1992). Project evaluation and uncertainty in practice: A statistical analysis of rate-of-return divergences of 1,015 World Bank projects. *The World Bank Economic Review*, 6(2), 255-277.

[53] As this is a five-yearly dataset we fill in missing values using linear interpolation

Table 5.1: Summary Statistics for Numeric Variables

Variable	Label	Year Start	Year End	Mean	Median	Standard Deviation	N	Number of Countries	World Bank Code
Barro Lee									
yr_sch	Average Years of Schooling Attained in Adults (15-64)	1950	2015	6.16	6.07	3.28	8 958	146	
DHS									
ad_women_read_sent	Adult women who can read a sentence (15-49)	2000	2020	24.7	19.9	19.6	191	63	
Estache and Goioechea									
priv_dist	Private distribution in country	2004	2004	0.351	0	0.477	7 840	119	
elect_reg	Electricity regulator in country	2004	2004	0.503	1	0.5	7 787	118	
priv_gen	Private generation in country	2004	2004	0.477	0	0.499	7 566	115	
IEG World Bank Dataset									
err_at_appraisal	ERR at project appraisal	1956	2011	25.2	20.5	20.6	3 728	153	
err_at_completion	ERR at project completion	1956	2012	21.9	17	29.6	3 249	152	
IMF Investment and Capital Stock Dataset									
kgov_rppp_pc	General government capital stock per capita, 2017 international USD	1960	2019	10 400	3 870	27 700	10 440	176	
kpriv_rppp_pc	Private capital stock per capita, 2017 dollars	1960	2019	22 000	8 920	36 600	10 440	176	
ktot_rppp_pc	Total capital stock (sum of general govt, private, public-private) per capita, 2017 international USD	1960	2019	32 300	13 100	59 600	10 440	176	
kppp_rppp_pc	Public-private partnership (PPP) capital stock per capita, 2017 international USD	1985	2019	149	2.68	380	4 804	140	
Kenny Yang IFC									
cu_period_totalinvestment	Sum of Total Per-Capita Private Investment in Period	2002	2018	11.7	0	55.3	2 025	135	
PWT									
gdppc	GDP per capita, PPP (K of 2017 international $)	1960	2019	14.7	7.73	19.3	9 551	180	
Sandefur Patel Rosetta Stone									
mean_ed_score	Average of Median Math and Reading Score (TIMSS Scale, 4th Grade)	2011	2014	462	462	77.8	5 239	77	
WB enterprise surveys									
outage_pct_firms	Firms experiencing electrical outages (% of firms)	2006	2020	56.2	54.8	26.4	299	150	IC.ELC.OUTG.ZS

Table 5.1: Summary Statistics for Numeric Variables *(continued)*

Variable	Label	Year Start	Year End	Mean	Median	Standard Deviation	N	Number of Countries	World Bank Code
ed_satisf	100 - Firms saying educated workforce is biggest obstacle (%)	2006	2020	92.4	95	7.76	294	146	IC.FRM.OBS.OBST9
elect_satisf	100 - firms choosing electricity as their biggest obstacle (%)	2006	2020	89.3	94	12.8	294	146	IC.FRM.OBS.OBST8
obs_ed_pct	Percent of firms choosing inadequately educated workforce as their biggest obstacle (%)	2006	2020	7.63	5	7.76	294	146	IC.FRM.OBS.OBST9
obs_elect_pct	Percent of firms choosing electricity as their biggest obstacle (%)	2006	2020	10.7	5.95	12.8	294	146	IC.FRM.OBS.OBST8
outage_num_pm	Number of electrical outages in a typical month	2006	2020	5.84	1.6	11.7	293	145	IC.FRM.INFRA.IN2
elec_qual	100 - Firms owning or sharing a generator (%)	2006	2020	69.6	76.2	22.5	292	145	IC.FRM.INFRA.IN9
own_share_gen_pct	Percent of firms owning or sharing a generator (%)	2006	2020	30.4	23.8	22.5	292	145	IC.FRM.INFRA.IN9
elec_gen_pct	If a generator is used, average proportion of electricity from a generator (%)	2006	2020	19.3	14.4	18.5	282	142	IC.FRM.INFRA.IN10_C
elec_qual_cond	100 - If generator is used, proportion of electricity from generator (%)	2006	2020	80.7	85.6	18.5	282	142	IC.FRM.INFRA.IN10_C
WB wealth accounts									
hc	Human capital (B 2014 USD)	1995	2018	3 630	214	16 500	3 504	146	NW.HCA.TO
hc_pct	Human capital (% total)	1995	2018	0.515	0.552	0.155	3 504	146	NW.HCA.TO
nc	Natural capital (B 2014 USD)	1995	2018	397	67.9	1 150	3 504	146	NW.NCA.TO
nc_pct	Natural capital (% total)	1995	2018	0.21	0.156	0.178	3 504	146	NW.NCA.TO
nfa	Net foreign assets (B 2014 USD)	1995	2018	-23.8	-7.75	499	3 504	146	NW.NFA.TO
nfa_pct	Net foreign assets (% total)	1995	2018	-0.026	-0.024	0.071	3 504	146	NW.NFA.TO
pc	Produced capital (B 2014 USD)	1995	2018	1 840	120	7 050	3 504	146	NW.PCA.TO
pc_pct	Produced capital (% total)	1995	2018	0.3	0.287	0.142	3 504	146	NW.PCA.TO
tc	Total capital (B 2014 USD)	1995	2018	5 840	409	23 900	3 504	146	NW.HCA.TO; NW.NCA.TO; NW.NFA.TO; NW.PCA.TO
WDI									
pop_tot	Total population	1960	2020	24.5	4.19	103	13 134	216	SP.POP.TOTL
le	Life expectancy at birth, total (years)	1960	2020	64.4	67.5	11.4	11 869	206	SP.DYN.LE00.IN

Table 5.1: Summary Statistics for Numeric Variables *(continued)*

Variable	Label	Year Start	Year End	Mean	Median	Standard Deviation	N	Number of Countries	World Bank Code
mort_child	Under-five mortality	1960	2020	75.8	45.5	77.7	10 761	193	SH.DYN.MORT
power_prod_renew	Electricity production from renewable sources, excluding hydroelectric (gWh)	1960	2015	2 180	0	13 100	6 014	142	EG.ELC.RNWX.KH
power_prod_renew_pc	Electricity production from renewable sources, excluding hydroelectric (kWh) per capita	1960	2015	102	0	647	6 007	142	EG.ELC.RNWX.KH
power_cons_pc	Electric power consumption kWh/capita	1960	2019	3 180	1 580	4 450	5 900	142	EG.USE.ELEC.KH.PC
tdl	Electric power transmission and distribution losses (% of output)	1960	2014	12.8	10.6	9.12	5 834	142	EG.ELC.LOSS.ZS
renew_pct	Renewable electricity output (% of total electricity output)	1990	2019	28.7	12.2	33.8	5 620	216	EG.ELC.RNEW.ZS
nse	Net secondary enrollment (%)	1970	2019	65.7	75.3	26.8	2 778	188	SE.SEC.NENR
World Economic Forum Global Competitiveness Index									
elec_sup_qual	Quality of Electricity Supply (1-7)	2007	2017	4.55	4.8	1.54	1 506	152	
World Governance Indicators									
rqe	Regulatory quality estimate	1996	2020	0	-0.116	0.998	4 516	212	

Note:

Patel & Sandefur are aggregating data across multiple years from different international tests, and Estache & Goioechea data are from a single year.

6 Analysis

Looking at the relationship between infrastructure and human capital, we have seen the close relationship between the two in Figure 1. Figure 5 also suggests a strong relationship between lower under five mortality and higher electric power consumption. More broadly, Figures 6 and 7 show that overall capital stocks as well as private capital stocks are higher in countries with higher human capital as measured by average years of education in the adult population. This is hardly surprising given that all four of education, mortality, electricity consumption and physical capital stocks and are also strongly correlated with income levels, as we saw in Figure 2 for electricity consumption.

That said, Table 7.1 examines the link between capital stocks and education allowing for income per capita using a panel of decade country observations. Allowing for income, total capital stocks are higher in countries with greater education. Adding a year of education to average years of schooling is associated with a six percent higher capital stock at a given GDP per capita. It is notable that the relationship is driven by the relationship with private investment, where adding a year of schooling is associated with a 9 percent higher capital stock (though note the relationship is insignificant looking at government and PPI capital stocks).

Table 7.2 examines the link between electricity consumption and human capital, controlling for private investment in electricity, income, population, and measures of regulation. The regression is based on four year time periods between 1998 to 2018, inclusive (further details of the model in Kenny and Yang, 2020). A more highly educated population is associated with greater electricity consumption. An extra year of average education in the adult population at a given income is associated with an increase in electricity consumption equal to 14 percent of median consumption. (Adding under five mortality suggests a positive relationship between health and electricity consumption, although the causality could well be reversed). It should be noted these results do not survive the inclusion of country fixed effects, but remain in cross-section results (Table 7.3).

Turning to the quality of infrastructure and human capital, Table 7.4 suggests that at a given level of income, private power investment and population, higher levels of human capital are associated with lower transmission and distribution losses, with one additional year of schooling associated with a drop of 0.8 percentage points in the proportion of output lost in transmission and distribution. Note this result is not robust to country fixed effects but it is significant in the cross section until the inclusion of regulatory variables.

Table 7.6 examines the relationship between firms experiencing electrical outages and human capital at a given income, population, and private investment level. In the panel results, a higher level of schooling is consistently linked to a lower level of reported outages: a one year increase in average years of education in the adult population is associated with a decline of between three and five percentage points in the proportion of firms who report electricity outages. While these results are not robust to country fixed effects, they do reappear in the cross section—at least until the addition of regulatory variables (Table 7.7). In that regard, Table 7.8 suggests that the quality of regulatory institutions is higher in countries with more education at a given income.

We have seen that human capital may be particularly associated with the adoption of renewable energy. Figure 8 presents the relationship between renewable power production (excluding hydropower) and education, while Table 7.9 suggests that, controlling for income, private participation, and population, an extra year of education in the adult population is associated with a 2 to 3 percentage point larger share of renewables in electricity production. This result survives country fixed effects although it is not significant in the cross section (Table 7.10).

Next, we look at the economic returns generated by World Bank projects in Table 7.11. Looking across the full sample of World Bank projects, rates of return were 1.9 percentage points higher in countries with one more year in average years of education in the adult population (this allowing for income and an interaction term for income and education). Adding country and sector fixed effects this impact rises to 6.4 percentage points. Notably, Table 7.12 suggests that most of the higher return was unanticipated at appraisal: countries with more educated populations outperformed expectations in terms of returns (1.6 percentage points rising to 6.6 percentage points with country and sector fixed effects). Table 7.13 restricts the analysis to infrastructure projects where the effect is similar. Table 7.14 suggests this effect was again unanticipated at project appraisal.

7 Conclusion

Infrastructure and human capital are both fundamental to economic prosperity, but they are not substitutes. In order to generate high returns to investment both need to be present, implying that education or infrastructure investments themselves will both see lower returns without the presence of the other. In turn that implies those seeking investment opportunities in developing country infrastructure projects should be concerned about human capital: without a skilled and educated workforce, they will have greater difficulty building and operating infrastructure, the quality of regulation will be worse, demand will be lower and returns will be depressed. This appears particularly true for renewable energy infrastructure.

Table 7.1: Capital stocks and education

	Log Total capital stock	Log Private capital stock	Log General government capital stock	Log Public-private partnership capital stock
(Intercept)	7.065****	6.401****	6.177****	3.443****
Log GDP per capita, PPP (K 2017 international $)	1.017****	1.037****	1.014****	1.078****
Average Years of Schooling Attained in Adults (15-64)	0.061****	0.089****	0.016	-0.134
year2000	0.073	0.067	0.039	-0.799***
year1990	0.077	0.067	0.018	
year1980	0.074	0.083	-0.018	
year1970	0.130*	0.184**	-0.043	
year1960	0.386****	0.509****	0.099	
Num.Obs.	736	736	736	171
R2	0.880	0.848	0.758	0.273
R2 Adj.	0.879	0.846	0.756	0.260

Table 7.2: Electric power consumption kWh/capita

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
(Intercept)	-3118.829****	-619.322	-3794.660****	-3650.147****			
Sum of Total Per-Capita Private Investment in Period	0.272	0.220	0.472	0.395	-0.102	-0.084	-0.087
GDP per capita, PPP (K of 2017 international $)	113.387****	163.201****	121.365****	124.768****	139.599****	138.186****	141.158****
Log(Population)	106.456****	48.423**	115.769****	124.647****	285.586	383.046	495.665
Average Years of Schooling Attained in Adults (15-64)	231.127****		262.903****	244.763****	-28.249		-28.017
Under-five mortality		-3.406**	4.468***	3.291**		2.073	2.069
Electricity regulator in country				112.135			
Private generation in country				-358.106****			
Num.Obs.	516	516	516	516	516	516	516
R2	0.677	0.595	0.683	0.696	0.984	0.984	0.984
R2 Adj.	0.674	0.592	0.679	0.692	0.981	0.982	0.982
R2 Within					0.632	0.636	0.636
Std.Errors	HC3	HC3	HC3	HC3	by: Country	by: Country	by: Country
FE: Country					X	X	X

Note:
OLS of Electric power consumption kWh/capita on total infrastructure investment, measures of population, GDP per capita, and presence of electricity regulator or private generation. Regressions are panel regressions. Observations are country-years. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.3: Electric power consumption kWh/capita

	Model 1	Model 2	Model 3	Model 4
(Intercept)	-4178.139****	-942.074	-4323.769****	-4206.842****
Sum of Total Per-Capita Private Investment in Period	-0.336	-0.508	-0.307	-0.498
GDP per capita, PPP (K of 2017 international $)	122.841****	154.783****	124.347****	130.847****
Log(Population)	150.698***	78.208	152.645***	168.820****
Average Years of Schooling Attained in Adults (15-64)	241.594****		248.227****	221.848****
Under-five mortality		-8.800**	1.191	-0.306
Electricity regulator in country				118.386
Private generation in country				-453.676**
Num.Obs.	124	124	124	124
R2	0.724	0.671	0.724	0.743
R2 Adj.	0.715	0.660	0.713	0.727
Std.Errors	HC3	HC3	HC3	HC3

Note:
OLS of Electric power consumption kWh/capita on total infrastructure investment, measures of population, GDP per capita, and presence of electricity regulator or private generation. Regressions are cross_section regressions. Observations are country-years.
**** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.4: If a generator is used, average proportion of electricity from a generator (%)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
(Intercept)	18.401	28.044	17.753	18.820			
Sum of Total Per-Capita Private Investment in Period	0.053	0.041	0.054	0.061	0.009	0.125	-0.012
GDP per capita, PPP (K of 2017 international $)	-1.009**	-0.721**	-1.004**	-1.046**	-0.002	1.632	0.216
Log(Population)	0.112	0.213	0.111	0.154	-117.706***	208.965	-240.869**
Average Years of Schooling Attained in Adults (15-64)	1.585		1.636	1.759	37.988***		42.011***
Under-five mortality		-0.050	0.006	-0.006		1.668	-0.890
Electricity regulator in country				-0.699			
Private generation in country				-1.986			
Num.Obs.	78	78	78	78	78	78	78
R2	0.060	0.043	0.060	0.064	0.870	0.669	0.877
R2 Adj.	0.008	-0.010	-0.005	-0.030	0.772	0.421	0.780
R2 Within					0.656	0.125	0.675
Std.Errors	HC3	HC3	HC3	HC3	by: Country	by: Country	by: Country
FE: Country					X	X	X

Note:
OLS of If a generator is used, average proportion of electricity from a generator (%) on total infrastructure investment, measures of population, GDP per capita, and presence of electricity regulator or private generation. Regressions are panel regressions. Observations are country-years. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.5: If a generator is used, average proportion of electricity from a generator (%)

	Model 1	Model 2	Model 3	Model 4
(Intercept)	12.804	19.736	13.267	15.613
Sum of Total Per-Capita Private Investment in Period	-0.074	-0.086	-0.075	-0.049
GDP per capita, PPP (K of 2017 international $)	-0.769	-0.570	-0.772	-0.780
Log(Population)	0.563	0.680	0.563	0.499
Average Years of Schooling Attained in Adults (15-64)	1.187		1.150	1.336
Under-five mortality		-0.045	-0.004	-0.007
Electricity regulator in country				-2.772
Private generation in country				-0.499
Num.Obs.	53	53	53	53
R2	0.042	0.035	0.042	0.047
R2 Adj.	-0.038	-0.045	-0.060	-0.101
Std.Errors	HC3	HC3	HC3	HC3

Note:
OLS of If a generator is used, average proportion of electricity from a generator (%) on total infrastructure investment, measures of population, GDP per capita, and presence of electricity regulator or private generation. Regressions are cross_section regressions. Observations are country-years. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.6: Firms experiencing electrical outages (% of firms)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
(Intercept)	122.724****	79.905***	102.832****	122.536****			
Sum of Total Per-Capita Private Investment in Period	-0.152	-0.076	-0.110	-0.041	-0.011	0.043	0.016
GDP per capita, PPP (K of 2017 international $)	0.259	-0.231	0.346	0.376	5.461***	5.503***	5.255***
Log(Population)	-1.464	-1.734	-1.476	-1.863	-18.561	228.191**	135.294
Average Years of Schooling Attained in Adults (15-64)	-5.218***		-3.597*	-3.315*	13.771*		8.298
Under-five mortality		0.295***	0.164	0.106		1.645**	1.112
Electricity regulator in country				-17.720**			
Private generation in country				2.277			
Num.Obs.	80	80	80	80	80	80	80
R2	0.305	0.286	0.331	0.400	0.928	0.930	0.934
R2 Adj.	0.268	0.247	0.285	0.342	0.877	0.880	0.885
R2 Within					0.398	0.412	0.449
Std.Errors	HC3	HC3	HC3	HC3	by: Country	by: Country	by: Country
FE: Country					X	X	X

Note:
OLS of Firms experiencing electrical outages (% of firms) on total infrastructure investment, measures of population, GDP per capita, and presence of electricity regulator or private generation. Regressions are panel regressions. Observations are country-years. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.7: Firms experiencing electrical outages (% of firms)

	Model 1	Model 2	Model 3	Model 4
(Intercept)	112.496****	84.934***	99.678****	112.617****
Sum of Total Per-Capita Private Investment in Period	-0.297	-0.256	-0.282	-0.217
GDP per capita, PPP (K of 2017 international $)	0.149	-0.228	0.234	0.344
Log(Population)	-1.099	-1.376	-1.109	-1.520
Average Years of Schooling Attained in Adults (15-64)	-3.644*		-2.621	-1.855
Under-five mortality		0.199*	0.105	0.107
Electricity regulator in country				-19.769***
Private generation in country				4.867
Num.Obs.	53	53	53	53
R2	0.270	0.255	0.283	0.408
R2 Adj.	0.210	0.193	0.206	0.316
Std.Errors	HC3	HC3	HC3	HC3

Note:
OLS of Firms experiencing electrical outages (% of firms) on total infrastructure investment, measures of population, GDP per capita, and presence of electricity regulator or private generation. Regressions are cross_section regressions. Observations are country-years. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.8: Regulatory quality and education

	Regulatory quality estimate
(Intercept)	-1.796****
Log GDP per capita, PPP (K 2017 international $)	0.527****
Average Years of Schooling Attained in Adults (15-64)	0.068**
Num.Obs.	139
R2	0.655
R2 Adj.	0.650
Std.Errors	HC3

Note:
OLS of World Governance Indicators regulatory quality vs. GDP per capita and years of schooling. Regression is a cross-section of the latest available data per country. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.9: Renewable electricity output (% of total electricity output)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
(Intercept)	73.183****	84.779****	52.718***	53.757***			
Sum of Total Per-Capita Private Investment in Period	0.043	0.047	0.048*	0.044	-0.001	-0.002	-0.001
GDP per capita, PPP (K of 2017 international $)	-2.551****	-1.812****	-2.321****	-2.322****	-0.545	-0.241	-0.537
Log(Population)	-1.846**	-1.930**	-1.504*	-1.524*	-17.503*	-5.306	-16.034
Average Years of Schooling Attained in Adults (15-64)	2.309***		3.247****	2.699***	2.735*		2.730*
Under-five mortality		0.016	0.114**	0.099*		0.013	0.012
Electricity regulator in country				9.030***			
Private generation in country				-3.044			
Num.Obs.	596	596	596	596	596	596	596
R2	0.135	0.120	0.143	0.156	0.950	0.949	0.950
R2 Adj.	0.130	0.114	0.136	0.146	0.942	0.941	0.941
R2 Within					0.023	0.011	0.023
Std.Errors	HC3	HC3	HC3	HC3	by: Country	by: Country	by: Country
FE: Country					X	X	X

Note:
OLS of Renewable electricity output (% of total electricity output) on total infrastructure investment, measures of population, GDP per capita, and presence of electricity regulator or private generation. Regressions are panel regressions. Observations are country-years. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.10: Renewable electricity output (% of total electricity output)

	Model 1	Model 2	Model 3	Model 4
(Intercept)	89.872***	93.639***	75.544*	73.749*
Sum of Total Per-Capita Private Investment in Period	0.078**	0.081**	0.081**	0.069*
GDP per capita, PPP (K of 2017 international $)	-2.053****	-1.720****	-1.928****	-1.857****
Log(Population)	-2.338	-2.395	-2.096	-2.034
Average Years of Schooling Attained in Adults (15-64)	0.930		1.578	0.916
Under-five mortality		0.035	0.097	0.089
Electricity regulator in country				13.278**
Private generation in country				-5.458
Num.Obs.	141	141	141	141
R2	0.160	0.158	0.163	0.190
R2 Adj.	0.135	0.134	0.132	0.148
Std.Errors	HC3	HC3	HC3	HC3

Note:
OLS of Renewable electricity output (% of total electricity output) on total infrastructure investment, measures of population, GDP per capita, and presence of electricity regulator or private generation. Regressions are cross_section regressions. Observations are country-years. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.11: World Bank Project Rate of Return at Completion and Education

	Model 1	Model 2	Model 3
(Intercept)	15.982****		
Average Years of Schooling Attained in Adults (15-64)	1.909***	1.740****	6.429****
Log GDP per capita, PPP (K 2017 international $)	-3.489***	-3.059**	-5.872***
Avg. Years of Schooling in Adults (15-64) X Log GDP per capita, PPP (K 2017 international $)	0.120	0.049	-0.874**
Num.Obs.	2672	2672	2672
R2	0.024	0.135	0.277
R2 Adj.	0.023	0.130	0.240
R2 Within		0.019	0.032
Std.Errors	by: Country	by: Country	by: Country
FE: Sector		X	X
FE: Country			X

Note:
OLS of World Bank IEG ERR rates at completion vs. GDP per capita and measures of education. Regressions are panel regressions. Observations are project-years. This table indicates that the World Bank project economic rate of return is highly correllated with the average years of schooling and wealth of the project country. In fact, in every specification, world bank projects located in wealthier countries had lower economic rates of return. Moreover, those projects where countries had higher years of schooling also had higher economic rate of return, while controling for wealth. Years of schooling is associated with a higher economic rate of return. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.12: World Bank Project Change in Rate of Return and Education

	Model 1	Model 2	Model 3
(Intercept)	-8.858****		
Average Years of Schooling Attained in Adults (15-64)	1.573***	1.401***	3.466****
Log GDP per capita, PPP (K 2017 international $)	-0.080	-0.176	1.106
Avg. Years of Schooling in Adults (15-64) X Log GDP per capita, PPP (K 2017 international $)	-0.258	-0.265	-0.956***
Num.Obs.	2672	2672	2672
R2	0.011	0.069	0.201
R2 Adj.	0.009	0.063	0.161
R2 Within		0.007	0.008
Std.Errors	by: Country	by: Country	by: Country
FE: Sector		X	X
FE: Country			X

Note:
OLS of World Bank IEG (ERR at Completion - ERR at Appraisal) vs. GDP per capita, measures of education, and an interaction between the two. Regressions are panel regressions. Observations are project-years. This table has as its dependent variable the World Bank project economic rate of return at completion minus the economic rate of return at appraisal. Thus, this describes whether the World Bank adjusted its expectations for the economic rate of return once the project was finally completed. Here, the model shows that on average, the World Bank IEG lowered its estimates of economic rate of return. However, it lowered its estimate to a lesser degree in countries that had higher average years of schooling. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.13: World Bank Project Rate of Return at Completion and Education : Transport, Energy and Mining, Water, and Urban Development Sectors

	Model 1	Model 2	Model 3
(Intercept)	19.507****		
Average Years of Schooling Attained in Adults (15-64)	1.650*	1.851***	6.569***
Log GDP per capita, PPP (K 2017 international $)	-5.871***	-4.952**	-7.749***
Avg. Years of Schooling in Adults (15-64) X Log GDP per capita, PPP (K 2017 international $)	0.448	0.323	-0.673
Num.Obs.	1537	1537	1537
R2	0.030	0.065	0.269
R2 Adj.	0.028	0.061	0.211
R2 Within		0.031	0.034
Std.Errors	by: Country	by: Country	by: Country
FE: Sector		X	X
FE: Country			X

Note:
OLS of World Bank IEG ERR rates at completion vs. GDP per capita and measures of education. Regressions are panel regressions. Observations are project-years. This table indicates that the World Bank project economic rate of return is highly correllated with the average years of schooling and wealth of the project country. In fact, in every specification, world bank projects located in wealthier countries had lower economic rates of return. Moreover, those projects where countries had higher years of schooling also had higher economic rate of return, while controling for wealth. Years of schooling is associated with a higher economic rate of return. **** $p<0.001$, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 7.14: World Bank Project Change in Rate of Return and Education : Transport, Energy and Mining, Water, and Urban Development Sectors

	Model 1	Model 2	Model 3
(Intercept)	-4.351*		
Average Years of Schooling Attained in Adults (15-64)	1.310*	1.327	2.058**
Log GDP per capita, PPP (K 2017 international $)	-2.948**	-2.857***	-1.459
Avg. Years of Schooling in Adults (15-64) X Log GDP per capita, PPP (K 2017 international $)	0.041	0.029	-0.466
Num.Obs.	1537	1537	1537
R2	0.013	0.013	0.227
R2 Adj.	0.011	0.009	0.165
R2 Within		0.012	0.003
Std.Errors	by: Country	by: Country	by: Country
FE: Sector		X	X
FE: Country			X

Note:
OLS of World Bank IEG (ERR at Completion - ERR at Appraisal) vs. GDP per capita, measures of education, and an interaction between the two. Regressions are panel regressions. Observations are project-years. This table has as its dependent variable the World Bank project economic rate of return at completion minus the economic rate of return at appraisal. Thus, this describes whether the World Bank adjusted its expectations for the economic rate of return once the project was finally completed. Here, the model shows that on average, the World Bank IEG lowered its estimates of economic rate of return. However, it lowered its estimate to a lesser degree in countries that had higher average years of schooling. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Table 7.15: Log GDP per capita_t+10

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
(Intercept)	-0.411***		-0.470***		-0.760****		0.082*		0.212****	
Log GDP per capita, PPP (K 2017 international $)	0.881****	0.549****	0.871****	0.479****	0.840****	0.483****	0.927****	0.348****	0.932****	0.413****
Log General government capital stock per capita, 2017 international USD	0.083****	0.186***								
Average Years of Schooling Attained in Adults (15-64)	0.080****	0.076*	0.072***	0.083**	0.078***	0.090*	0.037****	0.121****	0.013	0.063***
Log gen govt capital stock per capita, 2017 USD X Average Years of Schooling in Adults (15-64)	-0.007***	-0.006								
Log Private capital stock per capita, 2017 dollars			0.086****	0.290****						
Log private capital stock per capita, 2017 USD X Average Years of Schooling in Adults (15-64)			-0.005**	-0.006						
Log Total capital stock (sum of general govt, private, public-private) per capita, 2017 international USD					0.119****	0.301****				
Log total capital stock per capita, 2017 USD X Average Years of Schooling in Adults (15-64)					-0.006**	-0.007				
Electric power consumption kWh/capita							0.000	0.000		
Electric power consumption kWh/capita X Average Years of Schooling in Adults (15-64)							0.000	0.000		
Electric power transmission and distribution losses (% of output)									-0.008**	-0.022****
Electric power T&D losses (% of output) X Average Years of Schooling in Adults (15-64)									0.001**	0.004****
Num.Obs.	603	603	603	603	603	603	386	386	384	384
R2	0.954	0.975	0.954	0.976	0.955	0.976	0.946	0.982	0.945	0.983
R2 Adj.	0.954	0.968	0.954	0.969	0.954	0.969	0.945	0.973	0.945	0.976
R2 Within		0.669		0.681		0.680		0.649		0.688
Std.Errors	HC3	by: Country	HC3	by: Country	HC3	by: Country	HC3	by: Country	HC3	by: Country
FE: Country		X		X		X		X		X

Note:
OLS of log GDP per capita lead 10 vs. log GDP per capita + years of schooling + log capital stocks per capita + interaction between years of schooling and log capital stocks per capita on a decade panel. **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1.

Figure 5: Child Mortality vs. Power Consumption

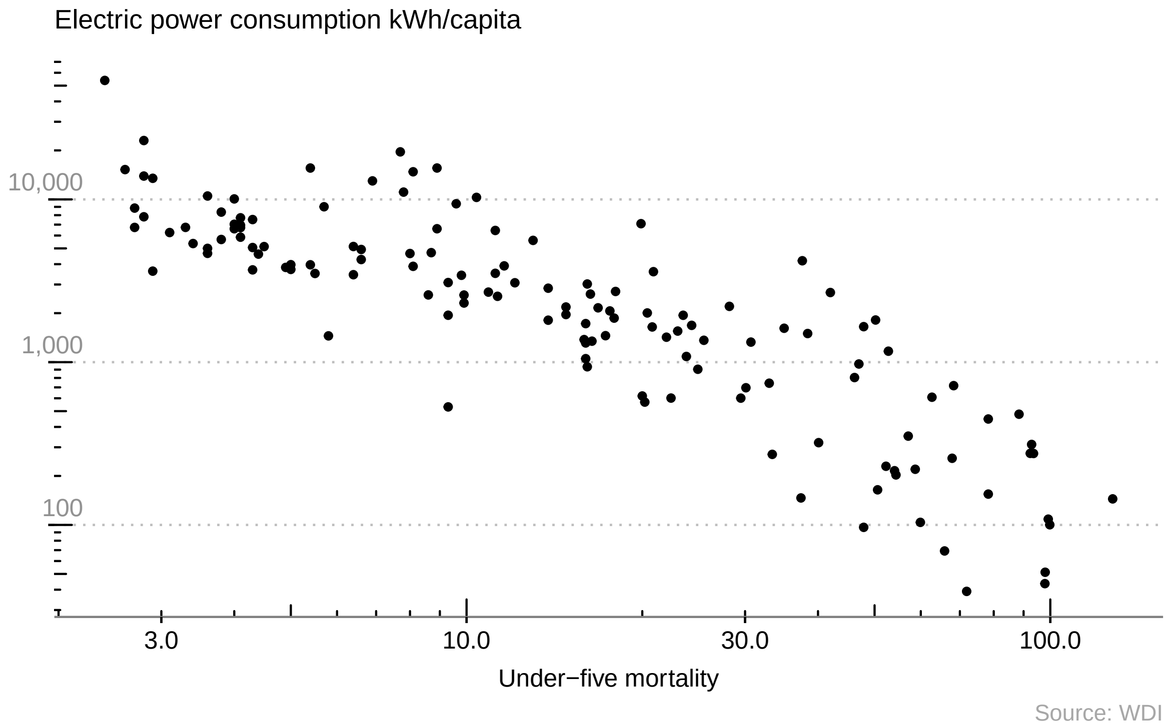


Figure 6: General Government Capital vs. Years of Schooling

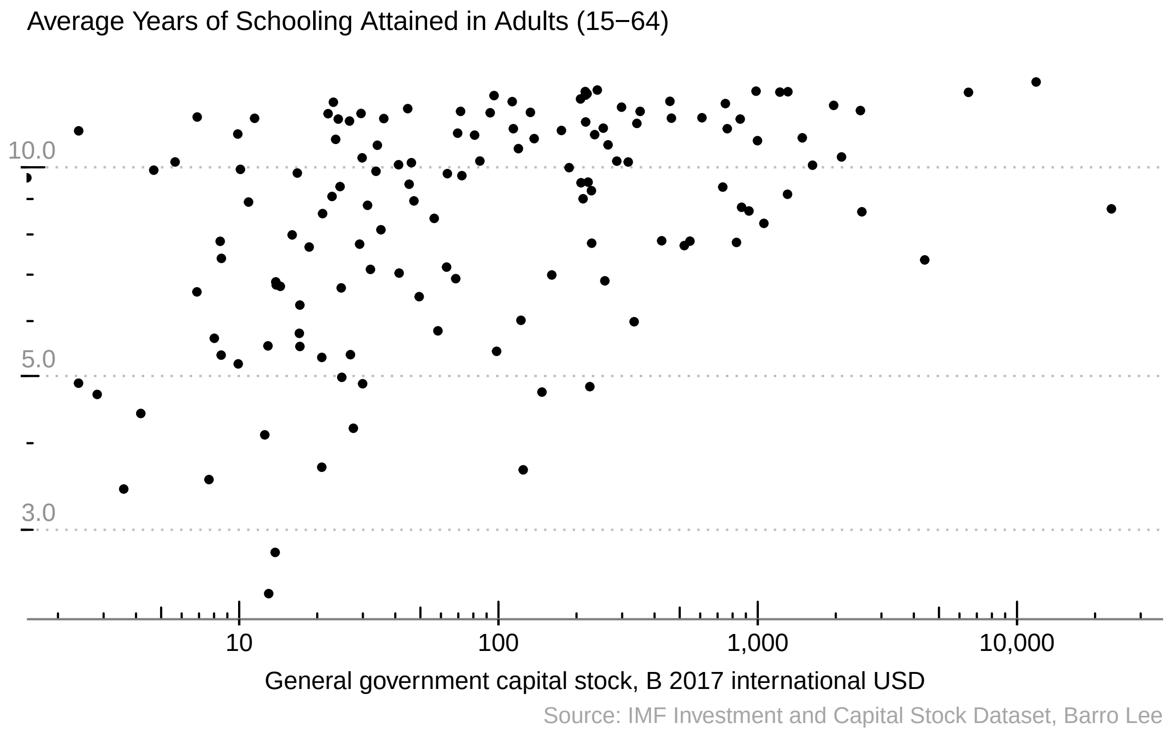


Figure 7: Private Capital vs. Years of Schooling

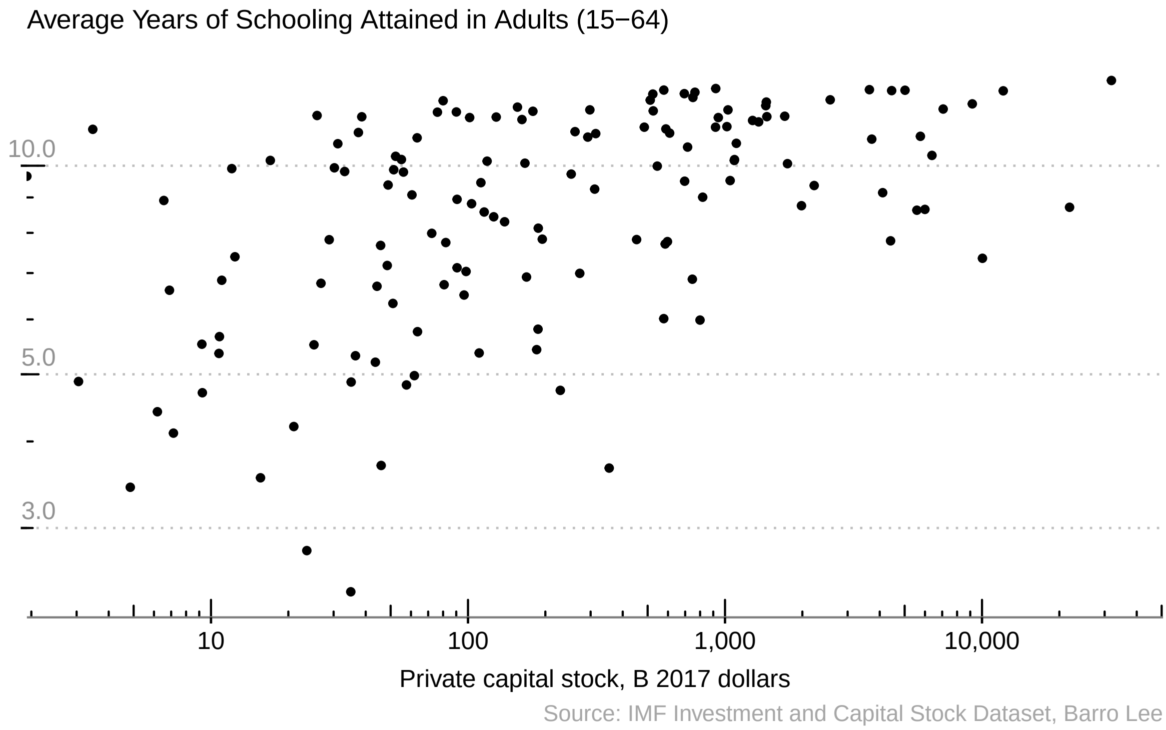


Figure 8: Electricity Production from Renewables vs. Years of Schooling