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Power outages and economic growth in Africa

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ABSTRACT

This paper estimates the total effect of power outages on economic growth in Sub-Saharan Africa over the period 1995–2007. We pay close attention both to potential errors of measurement of African economic growth and to the endogeneity of outages. As suggested by Henderson et al. (*American Economic Review* 102(2): 994–1028, 2012), we combine Penn World Tables GDP data with satellite-based data on nightlights to arrive at a more accurate measure of economic growth. Following Andersen et al. (*Review of Economics and Statistics* 94(4): 903–924, 2012), we also employ lightning density as an instrument for power outages. Our results suggest a substantial growth drag of a weak power infrastructure in Sub-Saharan Africa.

1. Introduction

Since the mid-1990s Sub-Saharan Africa has, for the first time in three decades, started growing at about the same rate as the rest of the world (World Bank, 2008). There is even econometric evidence that finds that a structural break in the rate of African GDP per capita growth occurred in 1995 (Arbache and Page, 2009). Average growth in per capita GDP, from 1995 until the outbreak of the crisis, was about 3% per year (Penn World Tables, 7.0). Yet the observed variation in growth performance is equally astonishing; across Sub-Saharan Africa the standard deviation in growth is about 5%. What accounts for this variation?

Power problems could be a culprit, as it is widely acknowledged that Sub-Saharan Africa is in the midst of a power crisis (Eberhard et al., 2008; UN 2007).[2] Outages are not just frequent and long but also erratic. According to the World Bank's Enterprise Surveys, pertaining to the years 2006–2010, the average number of power outages during a typical month is 10.5, while the average length of an outage is 6.6 h. Unsurprisingly, more than 50% of African businesses surveyed cite inadequate power supply as a major business constraint.[3] Overall, there is no doubt that a deficient power infrastructure dampens economic growth (Eberhard et al., 2008; International Monetary Fund, 2008, Chapter IV; Jones, 2011). But how large is the effect? This paper provides an estimate.

Our paper is related to a large literature investigating the importance of infrastructure for growth and development. In a recent contribution, Dinkelman (2011) estimates the impact of household electrification on employment growth in rural communities by analyzing rural electrification roll-out in post-apartheid South Africa. While Dinkelman contributes to what we know about the *microeconomic effects* of the *quantity* of physical infrastructure in developing countries, we focus on the *macroeconomic effects* of the *quality* of physical infrastructure.[4] The 1994 version of the World Development Report, which was devoted to "Infrastructure for Development", also made the distinction between the quantity and the quality of infrastructure services. The tradition in the macroeconomics literature has been to estimate quantity effects of public infrastructure on total factor productivity using time-series data, with Aschauer (1989) being a classic reference. The Jimenez (1995) and World Bank (2008) provide overviews relevant for developing countries.

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[2] See "Toiling in the Dark: Africa's Power Crisis" by Michael Vines in the New York Times (July 29, 2007) for a vivid description of Africa's ongoing power crisis.
[3] http://enterprisesurveys.org/Data/ExploreTopics/infrastructure#–7.
[4] For a general survey of the relationship between energy use and economic growth, see Ozturk (2010) and Payne (2008).

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This paper departs from the macroeconomic tradition in three ways. First we focus exclusively on the quality of infrastructure. Secondly, we estimate the total effect of infrastructure as opposed to a partial effect. Thirdly, using IV estimation and adjusted data, we pay more attention to the intricacies of obtaining identification.

The remainder of this paper is organized as follows. The next section discusses the empirical specification, identification and data. Section 3 presents and discusses the main results, while Section 4 concludes.

2. Empirical strategy

2.1. Specification

Consider the following parsimonious regression model:

$$g_i = \alpha_0 + \alpha_1 \log(\text{OUTAGES}_i) + \varepsilon_i, \quad (1)$$

where g is the average annual growth rate of real income per capita over the period 1995–2007; the pre-crisis period in which Sub-Saharan Africa evidently witnessed something of a growth revival. Interest centers on retrieving a consistent estimate of α_1, i.e., the impact of power outages on economic growth.

In order to appreciate this parsimonious specification, note that power supply is a *general-purpose technology*, which affects the economy directly and/or indirectly through multiple channels. This has important implications for identification. To see this, assume that power outages only have indirect effects on economic growth; i.e., assume the following causal structure: OUTAGES → PROXIMATE FACTORS → GROWTH. If we include all proximate factors, $\mathbf{X}$, assumed to be a vector valued function of power outages, $\mathbf{X} = \mathbf{f}(\text{OUTAGES})$, and estimate (2):

$$g_i = \tilde{\alpha}_0 + \tilde{\alpha}_1 \log(\text{OUTAGES}_i) + \mathbf{X}'_i \tilde{\alpha}_2 + \upsilon_i, \quad (2)$$

then plim $\tilde{\alpha}_1 = 0$ (Achen, 2005). Adding all proximate factors thus leads to a vanishing estimate. More generally, since the potential proximate factors are too numerous to account for, and since the *total effect* (= direct + indirect) is what should really interest us when dealing with a general-purpose technology, the parsimonious specification (1) is appropriate. Consequently, α_1 in Eq. (1) is the *total effect of power outages on economic growth*, which we attempt to identify below.

2.2. Identification

The outages variable is endogenous in Eq. (1). It is both correlated with a number of economic growth determinants, subject to reverse causal influence, and measured with error. An appropriate identification strategy is thus called for.

We adopt the strategy proposed by Andersen et al. (2011, 2012), which entails using lightning density as an exogenous determinant of power disturbances. Lightning damage accounts for about 65% of all over-voltage damage to electrical distribution networks in South Africa; over-voltage damage in turn is thought to account for one-third of all outages.[5] In Swaziland more than 50% of power outages on transmission lines are attributed to lightning (Mswane and Gaunt, 2005). These numbers are roughly in line with (though somewhat bigger than) measurements reported for the U.S. (Chisholm and Cummins, 2006; McGragnaghan et al., 2002). For instance, Chisholm and Cummins argue that lightning is the direct cause of one third of all U.S. power quality disturbances.[6] In areas with greater lightning density (strikes/km^2/year) we should therefore expect to see more power outages, ceteris paribus.

Is lightning density a valid instrument? It is certainly external in the sense of Deaton (2010). However, this does not imply that it fulfills the exclusion restriction required for instrument validity: Cov(lightning,ε) = 0. In particular, it could correlate with geographical factors, say, which themselves exert an effect on economic growth. In an African context, the most obvious factor is natural resources. We therefore check the robustness of our results with respect to this particular concern. We also check the robustness of our results to the inclusion of initial (or predetermined) income per capita, a coastal dummy, tropical disease, precipitation, temperature, and absolute latitude.

2.3. Data sources

Since GDP is likely to be particularly plagued by non-random measurement error in Africa, we follow Henderson et al. (2012) in producing "adjusted" real GDP per capita growth rates by employing satellite data on nightlights. Briefly, the growth observations used below are a convex combination (weight: 0.5) of observed real (chained PPP) GDP per capita growth (from Penn World Tables 7.0) and the fitted values from a regression of this variable on growth in nightlights 1995–2007.[7] Our results are qualitatively the same if we employ the "raw" GDP per capita numbers; *quantitatively*, however, our estimates are (numerically) smaller using adjusted data. Accordingly, using adjusted growth rates provides more conservative estimates.

The OUTAGES variable refers to the (log) number of outages in a typical month and derives from World Bank's Enterprise Surveys 2011.

As with nightlights, the lightning data also derives from satellites. The National Aeronautics and Space Administration (NASA) provides the raw data (strikes/km^2/year). More specifically, we rely on the data from the so-called Optical Transient Detector (OTD), a space-based sensor launched on April 3, 1995. For a period of roughly 5 years the satellite orbited Earth once every 100 min at an altitude of 740 km. At any given instant it viewed a 1300 km × 1300 km region of Earth. Lightning is determined by comparing the luminance of adjoining frames of OTD optical data. When the difference was larger than a specified threshold value, an event was recorded.[8] These satellite-based data are archived and cataloged by the Global Hydrology and Climate Center, where they are also made publicly available.[9] We apply the data from a high-resolution (0.5° latitude × 0.5° longitude) grid of total lightning bulk production, expressed as a flash density, from the completed 5-year OTD mission.[10] We then construct average flash densities for each country by first mapping the corresponding geographic areas into the lightning data grid and then taking the average of flash densities within each of these areas. The coordinates describing the areas are taken from the GEOnet Names Server (GNS) at the U.S. National Geospatial-Intelligence Agency's (NGA),[11] and the U.S. Board on Geographic Names' (U.S. BGN) database of foreign geographic names and features.[12] We used the GNS database released on October 7, 2008.[13] For further information on the data and its construction, see Andersen et al. (2011).

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5 http://www.liveline.co.za/lightning-stats.php.

6 In 1997, the Tennessee Valley Authority (TVA) implemented a system at TVA's Chattanooga facility that integrated lightning strike data with power quality data. TVA has about 17,000 miles of transmission lines spread across 7 U.S. states, and lightning was found to be responsible for about 45% of all power quality disturbances (McGragnaghan et al., 2002).

7 Even if changes in light from space are subject measurement error, it is well known that several error-prone measures are better than one, especially if there is no reason to think that the measurement errors are correlated (Henderson et al., 2012).

8 Basically, these optical sensors use high-speed cameras designed to look for changes in the tops of clouds. By analyzing a narrow wavelength band (near-infrared region of the spectrum) they can spot brief lightning flashes even under daytime conditions.

9 http://thunder.msfc.nasa.gov/data/#OTD_DATA.

10 ftp://microwave.nsstc.nasa.gov/pub/data/lightning-satellite/lis-otd-climatology/HRFC/LISOTD_HRFC_V2.2.hdf.

11 http://earth-info.nga.mil/gns/html/namefiles.htm.

12 http://geonames.usgs.gov/domestic/download_data.htm.

13 ftp://ftp.nga.mil/pub2/gns_data/geonames_dd_dms_date_20081007.zip.