How Much Should We Trust the Dictator's GDP Growth Estimates?

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Abstract

I study the manipulation of GDP growth statistics in non-democracies by comparing the self-reported GDP figures to the nighttime lights recorded by satellites from outer space. I show that the night-lights elasticity of GDP is systematically larger in more authoritarian regimes. This autocracy gradient in the elasticity is not explained by potential differences in a large set of country characteristics, including economic structure, urbanization, corruption, state capacity or levels of development. The gradient is larger when countries have a stronger incentive to exaggerate economic performance or when the institutions that constrain the manipulation of official statistics are weaker. I estimate that the most authoritarian regimes inflate yearly GDP growth rates by a factor of 1.15-1.3 on average. I show that correcting for data manipulation provides a more nuanced view on the economic success of non-democracies in recent years and affects our understanding of the effect of foreign aid on growth.

Keywords: GDP, nighttime lights, economic growth, democracy, data manipulation

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1 Introduction

The importance of economic performance for political survival is well known. The economy is a frequent object of political debate -"It's the economy, stupid" - and a major determinant of government turnover in both democracies and autocracies (Burke and Leigh, 2010; Brückner and Ciccone, 2011). However, people lack perfect information about the state of the economy and must often rely on imperfect estimates, such as Gross Domestic Product (GDP), to assess government performance (Leigh, 2009). Governments themselves usually produce these estimates, which gives rise to a moral hazard problem, as they are constantly tempted to exaggerate just how well the economy is doing. In this regard, GDP stands out as perhaps the most widely used measure of economic activity (Lepenies, 2016). As such, it is probably the most profitable for governments to manipulate .

Although the incentive to exaggerate economic growth is shared by governments of all kinds, a well-functioning democracy should be able to rein in, at least to some extent, the executive's impulse to manipulate official statistics. In the words of George Orwell, "If liberty means anything at all it means the right to tell people what they do not want to hear." A strong democracy guarantees that opposition parties, the media, and the public at large can freely scrutinize government figures. It also provides for an independent judiciary to investigate and prosecute those that fiddle with the numbers. Such checks and balances are largely absent in more autocratic regimes. The execution of the civil servants in charge of the 1937 population census of the USSR following its unsatisfactory findings serves as an extreme example (Merridale, 1996). A more recent example concerns Chinese premier Li Keqiang's alleged acceptance of the unreliability of the country's official GDP estimates (Clark et al., 2017). But despite the large controversy surrounding Chinese GDP statistics over the past several decades, systematic evidence establishing whether manipulation of growth figures is a generic trait of modern authoritarian regimes, as well as estimates of the magnitude of this phenomenon, are almost non-existent.

This paper uses nighttime luminosity to detect and measure the manipulation of GDP growth statistics in non-democracies. GDP and nighttime lights provide complementary measures of real economic activity, but while GDP is self-reported by governments and prone to manipulation, night lights are recorded by satellites from outer space and are much less vulnerable. Using panel data for 179 countries between 1992 and 2008, I study the relationship between reported GDP figures and nighttime lights across political regimes. In particular, I examine whether the same amount of growth in lights translates into systematically larger amounts of GDP growth in autocracies than in democracies.

The basic specification I use regresses ln(GDP) on ln(lights), a measure of autocracy and

their interaction. The regression includes country and year fixed effects and uses the data sources and coding of variables from the seminal paper on nighttime luminosity as a measure of economic activity by Henderson et al. (2012). The interaction of lights and autocracy is my main object of interest, as it captures the heterogeneity in the mapping from changes in lights to changes in GDP across political regimes. I derive this specification from a simple econometric model that shows how the regression estimates can then be used to back out the rate at which GDP growth is artificially inflated in authoritarian regimes. The identifying assumption is that, in the absence of manipulation, the mapping from lights to GDP should not be systematically affected by how democratic a country is.

The main result of the paper is that the night-lights elasticity of GDP is significantly larger in more autocratic regimes. In other words, I find that a same amount of growth in lights translates into higher reported GDP growth in autocracies than in democracies. This result is visible in simple comparisons of average growth rates, in non-parametric estimations or in the more rigorous panel regressions. It is also visible in subnational estimates for Chinese provinces and US states. It is robust as well to the use of multi-valued or binary regime classifications from different sources (e.g., Freedom House, Polity IV).

The initial assumption of a homogeneous night-lights elasticity of GDP across countries is quite strong. In a series of robustness tests I relax this assumption and allow the elasticity to vary according to more than 50 different fixed and time-varying characteristics. The autocracy gradient is unaffected by any of these potential sources of heterogeneity in the night-lights elasticity of GDP. These tests also allow me to rule out alternative explanations based on differences in state or statistical capacity across regimes (e.g., Jerven, 2013) or based on differences in the efficiency of government spending. The results are equally unaffected if I allow each of 22 subregions of the world to have its own baseline elasticity and they remain qualitatively similar if I allow the elasticity to be country-specific.

Several additional pieces of evidence point to increased manipulation of GDP statistics in authoritarian regimes as the underlying mechanism. First, the mapping from night lights to GDP sub-components is only heterogeneous across regimes for investment and government spending. These are the two components that are most reliant on government-provided information and that lack some form of third-party verification. Secondly, even within broadly-defined political regimes, the autocracy gradient in the night-lights elasticity of GDP is larger in the absence of key independent political, legal and economic institutions. These include an elected legislature, an autonomous central bank and a national constitutional court. Consistent with the earlier motivating examples, the autocracy gradient is also larger among countries that have had a communist regime. Within democracies, the night-lights elasticity of GDP is larger in the weaker presidential democracies than in the

more established parliamentarian ones. Within autocracies, the elasticity is larger in civilian dictatorships than in royal or military ones, which have access to other tools, such as patronage or repression, to ensure political stability. Thirdly, the autocracy gradient is larger in instances when the incentive to exaggerate economic performance is greater. These include years in which the national economy is growing below the world average, the year before a national election, and the years after a country loses eligibility for foreign aid. Fourthly, the autocracy gradient is not present among countries that subscribe to a set of IMF guidelines for the transparent production of official economic statistics.

The observed magnitude of the variation in the night-lights elasticity of GDP across regimes is substantial. The results indicate that the most authoritarian governments inflate yearly GDP growth by a factor of 1.15-1.3 on average. I use these estimates to adjust the yearly and long-run growth rates for data manipulation in autocracies. The adjustment of long-run growth rates provides a more nuanced view on the apparent economic success of non-democracies in recent years. According to the raw GDP data, more than half of the 20 countries that experienced the highest aggregate growth between 1992 and 2006 were classified as 'not free'. Once corrected for manipulation, the top-20 includes a more balanced composition of political regimes. At the very top of the ranking, adjusted aggregate GDP growth for China and Myanmar drops from above 1.2 log points to slightly less than 0.9. Further down the ranking the adjustment is even more substantial. On average, free countries jump 9.6 positions in the ranking, while not-free ones lose 13.3 spots. Using yearly data, I provide an application showing that the magnitude and precision of estimates of the effect of foreign aid on economic growth crucially depends on correcting for the bias in the growth rates of autocracies.

This paper contributes to several strands of the academic literature. Its most immediate contribution is to the literature on the manipulation of government statistics. In their seminal study, Henderson et al. (2012) report much higher growth in GDP than in lights in Myanmar and interpret this finding as potentially driven by "a governing regime that would not be averse to exaggerating GDP growth" (p.1021), but they do not pursue this point further. Only Magee and Doces (2015) have explicitly studied this topic, reporting a positive effect of autocracy on GDP growth after controlling for growth in nighttime lights.[1]

[1]Wallace (2016) provides a similar result using electricity consumption. Relatedly, Hollyer et al. (2011) show a positive correlation between democracy and the availability of economic data in the World Development Indicators. Other related research has studied manipulation of government statistics without a focus on political institutions. Sandefur and Glassman (2015) study how governments in the developing world are themselves misled by public employees in charge of service provision. Kerner et al. (2017) provide evidence of manipulation of GNI around the IDA cut-off in countries that are highly dependent on foreign aid. Another strand of literature has studied the use of creative accounting by European countries trying to bypass EU budget rules (von Hagen and Wolff, 2006; Alt et al., 2014). Michalski and Stoltz (2013) find, more generally,

As suggestive as this finding is, the econometric model I develop illustrates how it may be confounded by differences in the sources of economic growth across political regimes that are not perfectly captured by either GDP or nighttime lights. For instance, autocracy may affect GDP growth, even after controlling for growth in lights, due to differential rates of electrification conditional on income (Min, 2015). My empirical strategy allows for such a possibility and provides improved identification of the manipulation bias present in the GDP growth figures of non-democracies. The additional findings regarding the factors that affect the autocracy gradient in the night-lights elasticity of GDP provide new evidence that strongly supports data manipulation as the underlying mechanism.

The paper is also related to the broader literature on the manipulation of information in authoritarian regimes. Guriev and Treisman (2018) have recently argued that this is the defining feature of modern autocrats. Several theoretical papers have studied the incentives that autocrats have to manipulate information or control the media (Egorov et al., 2009; Edmond, 2013; Gehlbach and Sonin, 2014; Lorentzen, 2014; Gehlbach et al., 2016). Empirically, King et al. (2013, 2017) document both censorship and fabrication of social media content by the communist government in China. Other work has studied the effects of media bias and ideological indoctrination on electoral outcomes and political preferences in autocracies (Enikolopov et al., 2011; Cantoni et al., 2017).[2] I contribute to this literature by uncovering a specific channel through which the manipulation of information takes place in autocracies, namely the systematic manipulation of official economic statistics.

One country whose official statistics have received substantial attention is China. Some studies argue that Chinese GDP growth has been systematically exaggerated in the national accounts (Young, 2003; Madisson, 2006; Chen et al., 2019). Others claim that there is no evidence of manipulation or that growth may actually be understated (Holz, 2006; Mehrotra and Pääkkönen, 2011; Nakamura et al., 2016; Clark et al., 2017). The evidence I provide indicates that China, being a civilian-led, communist dictatorship, is one of the countries with the largest predicted exaggeration of GDP growth. In consequence, China experiences one of the most substantial reductions in economic growth after the data is adjusted for manipulation. The comparison of GDP and night lights growth rates between Chinese provinces and US states provides further proof of data manipulation in the former.

This paper also complements a strand of literature that has used data from various other sources to assess and complement the information on living standards contained in the

that balance of payments data fails to satisfy Benford's law.

[2] A separate literature has looked at the effects of exposure to uncensored media on residents of authoritarian regimes (Kern and Hainmueller, 2009; Bursztyn and Cantoni, 2016). Qian and Yanagizawa-Drott (2017) provide empirical evidence on the manipulation of information in democracies, while Allcott and Gentzkow (2017) study the role of fake news in democratic elections.

national accounts (Deaton, 2005; Chen and Nordhaus, 2011; Henderson et al., 2012; Young, 2012; Pinkovskiy and Sala-i Martin, 2014, 2016a,b; Duede and Zhorin, 2016). Previous work has not considered data manipulation or political economy factors as a source of discrepancy between these sources. I add to this literature by documenting how politically-motivated data manipulation leads to systematic bias in GDP as a measure of economic activity.

Finally, this paper also belongs to the burgeoning literature in forensic economics (Zitzewitz, 2012). In particular, it is related to other studies that compare measurements from different sources, mostly self-reported and non-self-reported, to uncover hidden behavior (Fisman and Wei, 2004, 2009; Olken, 2007; Zinman and Zitzewitz, 2016). The most closely related paper in this vein is Cavallo (2013), which uses price data from online retailers to unmask manipulation of official inflation statistics in Argentina.

The rest of the paper is structured as follows. Section 2 provides some background information on the production of the national accounts and a theoretical framework on the political incentives and constraints that shape the manipulation of official statistics. Section 3 introduces the data and the econometric model. Section 4 presents the main results and documents the autocracy gradient in the night-lights elasticity of GDP. Section 5 presents results from additional exercises supporting increased exaggeration of GDP growth in autocracies as the underlying mechanism. Section 6 shows the implications of the resulting bias in GDP figures. Section 7 concludes.

2 Background Information and Theoretical Framework

Systematic measurement of national income only begun in the 1930s and became increasingly sophisticated in response to the need for detailed economic information during the second world war (Coyle, 2014). Accordingly, the first estimate of Gross National Product (GNP) for the United States dates back to 1942. The publication of the United Nation's System of National Accounts (SNA) in 1951 was a landmark event in the history of official statistics and reflected increased interest in the homogeneous estimation of economic activity across countries. The cold war stood in the way of this goal for some time, with the Soviet Union and other communist countries employing the Material Product System (MPS) instead. However, many of these countries begun transitioning from the MPS to the SNA even before the fall of the Berlin wall. For example, China's transition started in 1985 and finished in 1992 (Xu, 2009), the first year in my sample period. Nowadays, most countries follow the SNA or some variation of it (e.g. the European System of Accounts). The SNA was updated in 1968, 1993 and most recently in 2008.

A country's GDP estimates are usually produced by its national statistical agency. Pre-

liminary estimates are produced on a quarterly basis and are revised when more information becomes available. GDP can be calculated as the sum of expenditures, or incomes, or value-added across the economy. National statistical agencies collect information from multiple sources to produce such estimates. These sources include banks, public utilities, transportation companies and various levels of government, as well as surveys of households and firms.

The starting point for the present inquiry is the idea that governments of all types have an incentive to exaggerate how well the economy is doing. This incentive results from the fact that citizens usually decide whether to remove the incumbent from office based on observable measures of competence, including those pertaining to economic performance (Ashworth, 2012). In this regard, GDP stands out as a very salient indicator of the state of the economy. In a democracy, low GDP growth may lead voters to support the opposition party at the polls. In the case of autocracies, these official statistics may act as coordination devices, triggering political action against the ruling regime when economic performance is poor (Edmond, 2013; Hollyer et al., 2015). Low growth in an autocracy may also undermine the support that the incumbent receives from some key constituency, such as the military (Bueno de Mesquita et al., 2004). Available empirical evidence indicates that economic conditions are indeed an important determinant of political turnover in both democracies and autocracies (Burke and Leigh, 2010; Brückner and Ciccone, 2011).

Hence, governments of all kinds have an incentive to inflate the GDP growth rates that they report. Their ability to do so is enhanced by the fact that the statistical agency producing these figures is usually under their control. The question that this paper asks, then, is whether the institutional constraints provided by democratic forms of government are able to rein in, to some extent, the impulse to exaggerate GDP growth. Underlying this question is the idea that a healthy democracy is characterized by a system of checks and balances that limit the incumbent's ability to fiddle with the numbers. These checks and balances include formal political institutions, such as regular elections and the separation of powers. They also include the upholding of civil liberties that allow the public and the press to scrutinize the official figures and hold the government accountable.

Such checks and balances are largely absent in authoritarian regimes. Many of them do not hold elections, although there has been an increase in the number of hybrid regimes, or electoral autocracies, that do so in the last decades (Levitsky and Way, 2010). Still, elections in such hybrid regimes are not usually useful tools for political accountability, as they are easily manipulated through state-controlled media or outright fraud (Enikolopov et al., 2011, 2013). Perhaps more importantly, authoritarian regimes are characterized by a high concentration of power in the hands of the executive and by strong limitations on civil liberties: intimidation of political opponents, limited access to government information,

media censorship, etc. As a result, the possibilities for manipulation of official statistics would appear to be greater in non-democracies. While it is true that authoritarian regimes can also resort to repression and violence in order to secure their hold on power, contemporary autocrats appear to be much more reliant on the manipulation of information and their projected competence than their counterparts from previous decades (Guriev and Treisman, 2018). In line with this argument, I show below that manipulation of GDP statistics is more common in civilian dictatorships than in military ones, which are more prone to engage in human rights violations (Geddes et al., 2014).

Naturally, the Lucas critique applies in this setting and blatant misreporting of economic indicators will be eventually incorporated in the expectations of the consumers of this information, rendering it useless.[3] Hence, the manipulation of GDP statistics must be sporadic and subtle in order to be effective.[4] In this regard, proportional exaggeration of GDP growth (i.e. inflating more when the real growth rate is higher) would appear to be more feasible than the fixed addition of one or two points of growth independent of real economic conditions. Furthermore, reserving this practice for times of real need, such as years of relatively poor growth or right before elections, also seems sensible.

Establishing how exactly the manipulation of GDP figures takes place is to some extent beyond the scope of this paper. However, the disaggregate analysis of GDP components below provides some clues as to whether the manipulation occurs in the production of the inputs that go into the estimation of GDP or in the reporting of the aggregate figure. Existing evidence from China indicates that the career incentives faced by provincial public officials make them exaggerate the GDP growth they report to the national government (Wallace, 2016), but this 'bottom-up' reporting system seems somewhat unique to the Chinese context.

3 Research Design

3.1 Data

The data on GDP and nighttime lights that I use comes from the replication files of Henderson et al. (2012).[5] I intentionally use this replication data to ensure that the results below are not driven by ad-hoc choices regarding data sources and definitions of variables. Henderson

[3] Cavallo et al. (2016) provide evidence that Argentinian households interpret potentially biased inflation statistics in a sophisticated manner.

[4] Gehlbach et al. (2016, p.578) provide a sketch of a model of accountability with government control of the media that can be used to formalize this argument. In equilibrium, citizens will always update somewhat positively on the incumbent upon receiving good news, as long as manipulation is not permanent (i.e. positive probability of truth-telling).

[5] Available at `https://www.aeaweb.org/articles?id=10.1257/aer.102.2.994`

et al. (2012) use GDP data from the January 2010 vintage of the World Bank's World Development Indicators (WDI). The World Bank collects GDP data directly from national statistical offices for most countries. To study the effects of GDP data revisions, I also use the publicly-available WDI vintages from 2005-2017. The source of information on various other topics, including GDP sub-components, sectoral composition of the economy, and rates of urbanization and electrification is also the World Bank.

Henderson et al. (2012) use pre-processed data on nighttime luminosity from the National Oceanic and Atmospheric Administration (NOAA). The original source of the data is the United States Air Force Defense Meteorological Satellite Program (DMSP), which uses the Operational Linescan System (OLS) instruments on their satellites to record nightime luminosity coming from Earth. NOAA provides data on nighttime lights at the pixel-year level (roughly 0.86 square kilometers at the equator) starting in 1992. For each pixel, 30 different satellites provide a lights digital number (DN) ranging from 0 (unlit) to 63 (top-coded). Henderson et al. (2012) calculate simple averages for each pixel-year across satellites and construct an area-weighted average of DN for each country-year. This is standard practice in the literature (e.g., Pinkovskiy and Sala-i Martin, 2016a).

Data on political regimes is available from several sources. For most of the analyses in the paper, I use the Freedom in the World (FiW) index that is published annually by Freedom House. This index is based on a fixed questionnaire that is answered yearly for each country by a team of analysts and country specialists. The final index is the average of two sub-indices for 'civil liberties' and 'political rights', each of which ranges from 0 to 6, with lower numbers corresponding to a greater enjoyment of rights and liberties.[6] The 'civil liberties' index is based on the answers to questions regarding freedom of expression and belief, rights of association and organization, rule of law and personal autonomy. The 'political rights' index is based on answers to questions related to the electoral process, political pluralism and participation, and the functioning of government. Freedom House classifies countries as 'free' if FiW<2, 'partially free' if $2 \leq$FiW≤ 4, and 'not free' if FiW>4. It also provides a binary indicator for 'electoral democracies'.

Democracy is not an easily quantified concept and all measures are subject to criticism.[7] As part of the robustness checks, I examine the sensitivity of the results to different regime classifications. For this purpose, I consider three additional sources: the Polity IV project, the Democracy-Dictatorship (DD) dataset by Cheibub et al. (2010), and the democratization data produced by Papaioannou and Siourounis (2008). Polity IV provides continuous

[6]The original indices range from one to seven. I subtract one from both, so that the lowest scores are normalized at zero. All references to the FiW in the text correspond to this adjusted version.

[7]The Freedom House indicators have been charged in the past with being disproportionately favourable to countries with close ties to the United States (Giannone, 2010; Steiner, 2016; Bush, 2017).

measures of democracy and autocracy, while the latter two sources provide binary indicators. Cheibub et al. (2010) update a democracy measure originally proposed by Przeworski et al. (2000) and also classify regimes into subcategories of democracy and dictatorship. I use this information to examine further heterogeneity across these groups. I also consider a hybrid measure of democracy proposed by Acemoglu et al. (2016), which combines information from Freedom House, Polity IV and DD.

I use the FiW index as the baseline measure of autocracy for several reasons. Relative to other sources of information, Freedom House has data for a larger number of countries (15% increase over Polity IV). FiW is also, by construction, more responsive to the *de facto* enjoyment of political rights and civil liberties than other measures focusing predominantly on formal electoral rules and political institutions (Freedom House, 2017). This feature is desirable for the analysis insofar as we expect democracy to constrain the incumbent's ability to manipulate information only to the extent that the ensuing system of checks and balances is actually operative and not a mere formality. Furthermore, the period under study is characterized by an increasing number of hybrid regimes that may resemble a democracy on paper (Levitsky and Way, 2010). The FiW index is arguably the best-suited indicator to capture the nuances of such regimes.

After combining the Henderson et al. (2012) data on GDP and lights with the FiW index, I am left with 2,914 observations for 179 countries between 1992 and 2008. Figure A1 in the appendix shows the average value of FiW for each country, as well as the change that each experienced during the sample period. Cross-sectionally, the strongest democracies are concentrated in the Americas and western Europe, while most autocracies are in Africa and Asia. The within-region variation in the change of the FiW over time is much greater, especially in Africa and South America. Table A1 in the Appendix shows summary statistics for the main variables in the paper, as well as for all measures of democracy. All sources suggest that the world was relatively democratic over the sample period. The average country-year in the sample was partially free, with an FiW of 2.41. According to the binary indicators, between 34 and 42% of the country-years correspond to authoritarian regimes.

To further understand the FiW as a measure of autocracy, I examine its correlation with a large set of observable political characteristics. For this purpose, I employ the IAEP dataset produced by Wig et al. (2015). This dataset documents both institutional arrangements (e.g. existence of a national constitutional court) and political outcomes (e.g. voter turnout in the last legislative election) for a large number of countries and years. Panel A in Table A2 in the appendix shows results of bivariate cross-sectional regressions of countries' average FiW on various political characteristics. The index captures several features that are commonly associated with authoritarian regimes. In particular, countries with higher average FiW are

more likely to have an official state party or to have banned parties. They are less likely to have an elected legislature (which is more likely to be unicameral if it exists). They also hold elections less frequently and are less likely to require voter registration. These countries are more likely to have one party in control of more than 90% of the legislature. They are less likely to have a constitutional court and more likely to have a new constitution enacted during the sample period. Panel B shows results from panel regressions that seek to identify correlates of within-country changes in FiW. Having an elected legislature or executive is strongly and negatively correlated with the index (i.e. improved democracy), while the occurrence of electoral protests or violence has a positive correlation.

3.2 Empirical Strategy

In this section I present the econometric model that guides the empirical analysis. The model illustrates how we can use the heterogeneity in the mapping from nighttime lights to GDP across political regimes to detect and measure the increased manipulation of government-produced statistics in autocracies. I use the model to derive the regression specification that I take to the data.

I assume that the true growth rate of economic activity (true income growth) in country i during year t is given by the unobserved variable $\tilde{y}_{i,t}$. I allow for the possibility that true income growth differs between democracies and autocracies by decomposing it into a baseline growth rate for democracies ($y^d_{i,t}$) and an adjustment factor α for autocracies ($\text{autocracy}_{i,t} = 1$):

$$\tilde{y}_{i,t} = y^d_{i,t} + \alpha \text{ autocracy}_{i,t} \tag{1}$$

We can think of the reduced-form effect of autocracy on growth, α, as a composite of differences in growth from different sources. It is plausible that regime type correlates with differences in the spatial distribution of production (urban v.s. rural), in the sectoral composition of output (agriculture v.s. manufacturing) or in the way that output is allocated (private v.s. public).[8] Thus, even a small value of α may actually hide substantial differences in economic structure and in the nature of economic growth across countries with different political regimes.

Each country's government constructs an estimate of economic growth using the concept of Gross Domestic Product (GDP). I assume that the estimated GDP growth rate, $\text{gdp}_{i,t}$, is a linear function of true income growth and an error term $\epsilon_{i,t}$, as shown in equation

[8] We can think of y^d as the share-weighted sum of growths in a partition of output in democracies (by sector, location, etc.): $y^d = \sum_{k=1}^{n} share_k^{dem} \times growth_k^{dem}$. The parameter α is then equal to the sum of adjustments for autocracies: $\alpha = \sum_{k=1}^{n} share_k^{aut} \times growth_k^{aut} - share_k^{dem} \times growth_k^{dem}$.

(2). However, this estimate does not necessarily match the reported GDP growth rate, $\widehat{\text{gdp}}_{i,t}$, which is subject to manipulation in autocracies. In equation (3), I first consider the possibility that authoritarian regimes exaggerate GDP growth by a constant amount $\theta > 0$:

$$\text{gdp}_{i,t} = \beta \tilde{y}_{i,t} + \epsilon_{i,t} \tag{2}$$

$$\widehat{\text{gdp}}_{i,t} = \text{gdp}_{i,t} + \theta \text{ autocracy}_{i,t} \tag{3}$$

Several studies have documented a positive and robust correlation between the nighttime lights recorded by satellites from outer space and local levels of economic activity (Doll et al., 2006; Chen and Nordhaus, 2011; Henderson et al., 2012; Donaldson and Storeygard, 2016; Michalopoulos and Papaioannou, 2017). Hence, I further assume that the growth rate of night lights ($\text{lights}_{i,t}$) is also a linear function of true income growth and a separate error term $u_{i,t}$. But there are two features that set lights and GDP apart as measures of economic activity. First, growth in lights may not capture to the same extent true income growth in democracies and autocracies ($\gamma^d \neq \gamma^a$ below).[9] This assumption seems reasonable, as autocracies and democracies are likely to generically differ in economic structure or public policies and night lights may vary in their ability to capture different types of economic activity. Second, night light data is independently collected, processed and published, making it immune to manipulation:

$$\text{lights}_{i,t} = \gamma^d y^d_{i,t} + \gamma^a \alpha \text{ autocracy}_{i,t} + u_{i,t} \tag{4}$$

This set-up is very similar to Henderson et al. (2012) and Pinkovskiy and Sala-i Martin (2016a). The two innovations are the explicit distinction between the sources of economic growth in democracies and autocracies and the possibility of manipulation of GDP growth figures in the latter. By combining equations (1)-(4), we can see what happens when we regress reported GDP growth on the growth of night lights and a measure of autocracy:

$$\widehat{\text{gdp}}_{i,t} = \frac{\beta}{\gamma^d} \text{lights}_{i,t} + (\lambda + \theta) \text{ autocracy}_{i,t} + \eta_{i,t} \tag{5}$$

In equation (5), λ is defined as $(1 - \frac{\gamma^a}{\gamma^d})\beta\alpha$ and η is a combination of the error terms ϵ and u. This equation shows that the autocracy coefficient from such a regression is a combination of the fixed reporting bias (θ) with the parameters that map (i) regime type into true income growth and (ii) true income growth into growth in night lights and GDP.

[9] I assume for simplicity, but without loss of generality, that the mapping from true income growth to GDP growth is independent of regime type. See appendix A for further information.

If autocracies and democracies have different sources of true income growth and night lights (or GDP) cannot capture equally well growth from these sources, the autocracy coefficient in equation (5) fails to provide an unbiased estimate of the exaggeration in reported GDP growth that takes place in autocracies.[10] Furthermore, constant inflation of GDP growth should be easily detected and seems unlikely.

I next consider the possibility that the exaggeration of reported GDP growth in autocracies is proportional to the amount of growth that the government observes (perhaps additionally to the fixed exaggeration θ, but this is not necessary). Proportional inflation of GDP growth figures reduces the likelihood of detection when real growth is low and allows for greater exaggeration in absolute terms when growth is high. For instance, an inflation factor of 1.2 means that the government reports a growth rate of 1.2% when the true rate is 1%, but reports a growth rate of 12% when the true rate is 10%. Under this additional assumption, the equation for reported GDP growth becomes

$$\widehat{\text{gdp}}_{i,t} = (1 + \sigma a_{i,t})\text{gdp}_{i,t} + \theta \text{ autocracy}_{i,t} \tag{3'}$$

If we substitute equations (1), (2) and (4) into (3'), we obtain the following:

$$\begin{aligned}\widehat{\text{gdp}}_{i,t} = \frac{\beta}{\gamma^d}\text{lights}_{i,t} + \frac{\beta\sigma}{\gamma^d}\left(\text{lights}_{i,t} \times \text{autocracy}_{i,t}\right) + (\lambda + \theta + \sigma\epsilon_{i,t} - \frac{\sigma\beta}{\gamma^d}u_{i,t})\text{ autocracy}_{i,t} \\ + \sigma\lambda \text{ autocracy}_{i,t}^2 + \nu_{i,t}\end{aligned} \tag{6}$$

Several things stand out from equation (6). First, the coefficient for the interaction of growth in lights and autocracy is increasing in σ, which is the proportional exaggeration of GDP growth that takes place in autocracies. If there is no exaggeration, the estimate for the interaction term should be zero. Second, we can actually back out the value of σ, the rate at which GDP growth is inflated in autocracies, by dividing the point estimate for the interaction by the estimate for lights. Third, we observe again that the autocracy coefficient is not easily interpreted, as it combines a potentially constant bias, differences in economic structure across regimes that are differentially captured by night lights and GDP, and the magnifying effect of relative manipulation on the measurement error in GDP. Fourth, the equation also indicates that the correct specification should include the square of autocracy. This term captures the fact that the heterogeneous growth rate in autocracies, which is

[10]Lenin famously wrote in 1920 that "Communism is Soviet Power plus the electrification of the whole country." The model yields a similar result if we allow night lights and GDP to capture true growth equally well across regimes, but we assume that night lights are also affected by electrification policies that differ across regime types, conditional on income (Min, 2015). See appendix A for further information.

imperfectly captured by lights, is compounded by the proportional exaggeration of GDP under this type of regime.[11]

Following Henderson et al. (2012), I rewrite equation (6) in log-linear form in levels and disaggregate the error term $\nu_{i,t}$ into a country-specific component (μ_i), a year-specific component (δ_t) and an idiosyncratic error term ($\xi_{i,t}$). Using the Freedom in the World (FiW) index to measure autocracy, I obtain the main equation that I take to the data:

$$\ln(\text{GDP})_{i,t} = \mu_i + \delta_t + \phi_0 \ln(\text{lights})_{i,t} + \phi_1 \text{FiW}_{i,t} + \phi_2 \text{FiW}_{i,t}^2 + \phi_3 \left(\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}\right) + \xi_{i,t} \tag{7}$$

In this specification, μ_i is a country fixed effect, δ_t is a year fixed effect and $\epsilon_{i,t}$ is an error term that I cluster by country. $\text{Ln(lights)}_{i,t}$ is the natural log of the area-weighted country average of the night lights Digital Number (DN). This specification is identical to the one in Henderson et al. (2012) (i.e. Table 2, column 1), except for the terms involving FiW. The main coefficient of interest is ϕ_3, which captures the autocracy gradient in the night-lights elasticity of GDP. $\phi_3 > 0$ implies that a same-sized increase in nighttime lights is associated with a larger increase in GDP in more authoritarian regimes. I can use estimates of equation (7) to back out $\hat{\sigma}$ as $\frac{\phi_3}{\phi 0}$, which represents the increase to the rate at which GDP growth is inflated that results from a one-unit increase to the FiW index.

The identifying assumption is that, in the absence of manipulation, the night-lights elasticity of GDP should not vary depending on regime type. Said differently, we must assume that regime type is uncorrelated with the errors in night lights and GDP. Importantly, the model shows that differences in economic structure or public policies across regimes only matter to the extent that they are differentially captured by GDP and nighttime lights. Furthermore, these differences are absorbed by the autocracy variable, FiW, and its square and should not affect the estimate of ϕ_3.

A more subtle form of bias could arise if economic fluctuations are related to differential changes across regimes in characteristics that affect the mapping from night lights to GDP (e.g. larger increase in government consumption in autocracies for the same amount of income growth). I address concerns of this nature in two ways. First, I provide below a large battery of robustness tests that indicate that differential changes in relevant characteristics are not behind the results. Second, I provide several pieces of evidence on the constraints and incentives that affect the coefficient ϕ_3, all of which lend additional support to manipulation of government statistics as the underlying mechanism.

Another source of bias is the error in nighttime lights as a measure of economic activity, $u_{i,t}$. This measurement error generates a correlation between lights and the error term $\nu_{i,t}$ in

[11] Naturally, there is no need to include the quadratic if the regime classification is binary.

equation (6). It is not obvious how this type of measurement error will affect the estimate of ϕ_3. Well-known results indicate that measurement error in one variable will lead to attenuation in its own coefficient and to bias in those of other regressors that are correlated with it. If two variables are independently measured with error, attenuation of their own coefficients is no longer guaranteed (Garber and Klepper, 1980). The problem becomes even more complicated if the errors in measurement are correlated, as is the case here (Day et al., 2004). However, it seems unlikely that the results below are an artifact of measurement error for several reasons. First, initial processing of the nightlights data removes noise caused by auroral activity, forest fires and cloud cover. Second, the country and year fixed effects included in all regressions will absorb all country-specific and time-invariant sources of measurement error, as well as all common shocks. Third, the measurement error arises because the nighttime lights are picking up changes in factors other than real economic activity (Burlig and Preonas, 2016). The large battery of robustness tests carried out below are also useful in this regard, as they take into account some of the most plausible sources of measurement error, including top-coding of the lights digital number, changes in access to electricity or urbanization rates, as well as changes in economic structure or the size of the informal economy.

4 Autocracy and the Night-lights Elasticity of GDP

4.1 Summary statistics and non-parametric estimates

In this section, I present summary statistics and non-parametric estimates of the heterogeneous relation between growth in lights and GDP across political regimes. These exercises anticipate the findings in the following sections, with the advantage of not imposing almost any structure on the data.

The analysis of average growth rates across regime types provides preliminary evidence that the same amount of growth in lights is associated with a systematically higher amount of GDP growth in non-democracies. The top row in Table 1 shows the average yearly growth rates of nighttime lights and GDP in the sample. GDP grew 4% per year on average (across countries and years), while night lights grew at an average rate of 5.2%. The remaining rows in the table disaggregate the average growth rates of GDP and lights for country-years classified as free (3.6% and 5%, respectively), partially free (4.1% and 5.7%) and not free (4.5% and 5%). Free and not-free countries had an identical average growth rate of nighttime lights, but average GDP growth in the latter category exceeded that in the former by almost a full percentage point (corresponding to a 25% increase). This difference is statistically

significant at the 1% level. A comparison of free and partially-free provides similar results, while there are no significant differences between partially-free and not-free.

Panel (a) in Figure 1 shows a binned scatter plot of the yearly growth rates of GDP and nighttime lights, disaggregated between not-free country-years and free or partially free ones (which I have bundled for clarity). There is a robust positive relationship between growth in lights and GDP growth for both categories. But, for all positive rates of growth in lights, the average GDP growth rate in the not-free category is at least as large as that in the free category, and it is usually quite larger. For negative rates of growth in lights, there is no clear pattern. The group-specific lines of best fit indicate that not-free countries tend to report larger amounts of GDP growth for any amount of growth in nighttime lights. This pattern is quite robust and does not appear to be driven by a small number of observations.

In panel (b), I use a local polynomial smoother to plot the non-parametric relationship between growth in GDP and lights for the same categories as in panel (a), as well as the respective 95% confidence intervals. The difference between the two categories in the mapping from growth in lights to growth in GDP is only statistically significant for lights growth rates between 0 and 25%, which is precisely the interval in which panel (a) shows large differences in the averages. This graph also indicates that there is no clear ordering when the growth rate of nighttime lights is negative.

4.2 Baseline estimates

Table 2 shows the main results of the paper. Column 1 replicates the main regression in Henderson et al. (2012) [Table 2, column 1] with the slightly reduced sample for which the FiW index is available. The estimate for the night-lights elasticity of GDP is essentially identical, at 0.283, to the one of 0.277 reported in the original study.

Column 2 shows estimates of the log-linearized version of equation (5), in which ln(GDP) is regressed on ln(lights) and FiW. Conditional on lights, more authoritarian regimes appear to report smaller changes to GDP.[12] Assuming that autocracies would never understate growth ($\theta \geq 0$), the negative point estimate indicates that $\lambda < 0$. This could happen if $\alpha < 0$ (i.e. autocracies indeed grow less than democracies), or if $\gamma^a > \gamma^d$ (i.e. night lights pick up real growth in autocracies better than in democracies).

Column 3 shows the results after introducing the interaction between ln(lights) and FiW. A one-unit increase in the index is associated with a very precisely measured increase of 0.012

[12]This finding contradicts the results in Magee and Doces (2015). The results differ because Magee and Doces (2015) use a first-differenced specification without country fixed effects, while I follow Henderson et al. (2012) in estimating the model in (log) levels with country fixed effects. Table A7 in the Appendix shows that my findings are robust to first-differencing plus fixed effects.

units in the night-lights elasticity of GDP. In this enlarged specification, the point estimate for FiW becomes very small and is not statistically significant at conventional levels. The results are almost identical after I introduce FiW^2 in column 4. This specification corresponds to equation (7) and will be the one I use for most further analyses.

The estimates in column 4 provide evidence of a large heterogeneity in the night-lights elasticity of GDP by regime type. The value of σ implied by these estimates is 0.05 (=0.012/0.238). Hence, a one-unit increase in FiW is associated with an additional 5% inflation of the reported GDP growth rate. Relative to the baseline elasticity of 0.24 for the most democratic countries (FiW=0), the estimated elasticity for the most authoritarian regimes (FiW=6) is 0.31. Hence, annual GDP growth is exaggerated by a factor of around 1.3 in the latter group.

I introduce greater flexibility in the autocracy gradient in column 5 by replacing FiW with dummies for partially-free and not-free countries, as defined by Freedom House (free is the omitted category). The estimates show that the night-lights elasticity of GDP is on average 0.032 units higher in not-free countries than in free ones. The implied σ indicates that not-free countries exaggerate reported GDP growth by a factor of 1.12 on average. Partially-free countries have a larger estimated elasticity than free countries, but a smaller one than those classified as not-free. The estimated elasticity for this intermediate group is statistically different from that for not-free countries (p=0.086), but not from the baseline elasticity for free ones. This result indicates that the autocracy gradient in the night-lights elasticity of GDP is mostly driven by countries at the bottom of the democracy spectrum.

The estimated elasticity for the most authoritarian countries in column 5 is smaller than the one implied by the results with the continuous FiW in column 4. The attenuation results from bundling countries into broader democracy categories. Figure 2 plots results from a regression with separate indicators for each value of the FiW index (rounded to the nearest integer), setting the lowest value (zero) as the omitted category. The estimates (dark round markers) show a clear increase in the night-lights elasticity of GDP as we move from lower to higher values of FiW. The night-lights elasticity of GDP is significantly different (at 5% level) from that of the baseline category for FiW values of three or more. The disaggregate results also point to a sharp increase in the elasticity for the largest value of the FiW index (6), which corresponds to the most authoritarian regimes. Given the baseline elasticity of 0.23 for the most democratic countries, the excess elasticity of 0.09 observed for these countries implies that they inflate GDP growth by a factor of 1.39.

All the previous results are based on yearly fluctuations in GDP. Column 6 in Table 2 examines whether the observed autocracy gradient in the night-lights elasticity of GDP extends to longer periods of time. Even if exaggeration of GDP growth only takes place

occasionally, so as to go unnoticed, the mapping of changes in lights to changes in GDP over several years, or even decades, should display a similar pattern to the one observed for the yearly fluctuations. In fact, we should observe a somewhat larger autocracy gradient as a result of compounding, since future GDP growth will be overstated relative to an already exaggerated estimate for the present.

Column 6 shows estimates of equation (7) for a restricted sample that only includes the average value of each variable for the years 1992/1993 and 2005/2006 (two observations per country). The interaction term remains positive and statistically significant. The value of σ implied by the estimates is 0.068. This larger $\hat{\sigma}$ indicates that aggregate GDP growth over the 13-year period studied is inflated by a factor of 1.4 in the most autocratic regimes. However, the long-run estimate of σ is only 36% larger than the one obtained using the yearly data and is substantially smaller than the one implied by 13 successive years of exaggeration at the estimated average yearly rate. This result indicates that the governments that are able to inflate official figures on economic growth do not engage in this practice indiscriminately over multiple years, a behavior that is to be expected in order for this practice to go unnoticed.

4.3 Robustness checks

In this section I summarize the findings from a battery of robustness tests of the autocracy gradient in the night-lights elasticity of GDP. I examine the sensitivity of this result to changes in the sources and definitions of the main variables, as well as to changes in the sample or the specification. I also examine whether taking into consideration other country characteristics potentially correlated with regime type, both fixed and time-varying, explains away the main result. All the tables and figures are available in the online appendix.

Table A3 shows estimates of equation (7) using different sources to classify countries' political regimes. The results indicate that the autocracy gradient in the night-lights elasticity of GDP is not exclusive to the Freedom House classification. All estimates of the gradient are positive and all are statistically significant at the 5% level except for the binary measure from the DD dataset (p=0.167). This result is consistent with the idea that the 'minimalist' concept of democracy used to classify regimes in DD does not capture the richer set of institutional constraints that is required to curtail the manipulation of government statistics. The results using the continuous Polity2 score and the underlying democracy and autocracy scores indicate that the autocracy gradient is driven by the most authoritarian regimes, which exaggerate yearly GDP growth by a factor of 1.15-1.2. As with the Freedom House categories, using coarser classifications leads to attenuation in the autocracy gradient. Still, the four binary measures considered imply that non-democracies inflate reported GDP

growth by a factor of 1.08-1.15.

Table A4 looks at the possibility that the results are driven by several features of the nighttime lights, including the way they are measured and aggregated. I allow the mapping from lights to GDP to be non-linear (4th-order polynomial), year-specific or to vary depending on the latitude and longitude of each country's capital. I also allow for this mapping to be heterogeneous across the 22 subregions of the world defined in the UN geoscheme. The results are hardly affected. Table A4 also shows that the gradient is not confounded by countries with different area (i.e. more pixels) or more top-coded or unlit cells. The gradient is also not driven by variation in the spatial concentration of lights, as measured by the Gini coefficient. Figure A2 further shows that the autocracy gradient remains quite stable if I allow it to vary by year.

Table A5 replicates the analysis using sources other than Henderson et al. (2012) on nighttime luminosity. For this purpose, I use the replication data from Pinkovskiy and Sala-i Martin (2016a) and Hodler and Raschky (2014). The results are remarkably similar to the baseline estimates. These tests indicate that the results are robust to (i) using an unweighted average of luminosity rather than the area-weighted one; (ii) averaging across level-2 subnational units rather than across pixels; (iii) extending the sample period as far as 2013, the last year for which the DMSP-OLS nighttime lights data is available.

In Table A6 I replicate the main analysis replacing the logs of lights and GDP with the corresponding growth rates, while Table A7 verifies that the results are robust to potential misspecification of the relationship between lights and GDP. These checks include replacing the logs of lights and GDP with their first difference. They also include introducing lags of ln(lights) or ln(GDP) and, in the latter case, estimating the model through system-GMM. I also expand equation (7) by introducing a country-specific time trend. In all cases I find evidence of a positive and significant autocracy gradient in the mapping from changes in nighttime lights to changes in GDP.

Tables A8-A12 consider a wide range of structural economic characteristics and examine whether they help explain the main result. Table A8 shows that the autocracy gradient in the night-lights elasticity of GDP is not driven by changes in the expenditure decomposition of GDP. This indicates, for instance, that the autocracy gradient is not driven by authoritarian regimes allocating a greater share of output to government spending. Table A9 similarly shows that the gradient is unaffected if I allow the mapping from lights to GDP to vary depending on the share of GDP generated by various sectors, including agriculture and the exploitation of natural resources. Population growth, as well as rates of urbanization or access to electricity also fail to explain away the autocracy gradient, as shown in Table A10. Table A11 considers the possibility that different initial levels of income (as proxied by GDP

or lights in logs, levels or flexible quintile dummies) drive the heterogeneity in the night-lights elasticity of GDP across regime types. The evidence indicates that this is not the case. Also related to the level of development, Table A12 verifies that the results are robust to allowing for heterogeneity in the mapping from lights to GDP by various measures of human capital (education, health) and informality.

Tables A13-A14 examine whether the autocracy gradient in the night-lights elasticity of GDP is driven by lower state capacity in more authoritarian regimes. Table A13 shows that the autocracy gradient is unrelated to differences in various measures of statistical capacity, such as having a vital registration system or having conducted a population or agricultural census during the sample period. Table A14 looks at complementary measures of state capacity. For this purpose, I use data by Chong et al. (2014) on the number of days it takes for a letter with the wrong address to be returned. Once again, the autocracy gradient is hardly affected if I allow the mapping from lights to GDP to vary according to this metric.

Another plausible alternative explanation is that the autocracy gradient is a reflection of more inefficient government spending in autocracies, rather than manipulation of official statistics. I use data on corruption from two different sources (Transparency International, World Bank) to study this possibility, insofar as many forms of inefficient public spending would appear to go hand-in-hand with corruption. I also consider the transparency index produced by Hollyer et al. (2014). Table A15 shows that heterogeneity associated with any of these measures fails to explain away the autocracy gradient in the night-lights elasticity of GDP. However, countries classified as less transparent by Hollyer et al. (2014) (as proxied by missing data on certain economic indicators) also have a robustly larger night-lights elasticity of GDP.

It is worth noting that the introduction of many of the additional variables used for these robustness checks imply sometimes substantial reductions to the number of countries or years in the sample. For instance, the variables on statistical capacity used in Table A13 are only available for 117 developing countries (35% reduction). Hence, these checks are also indicative that the results are robust to changes to the composition of the sample. Figure A3 in the appendix provides additional evidence that the results are robust to the exclusion of any one of the 22 subregions defined by the United Nations. Figure A4 further shows that the results are robust to using different vintages of the WDI for a fixed sample period.

4.4 The nightlights elasticity of subnational GDP: China vs US

I further validate the methodology by comparing the nightlights elasticity of GDP across Chinese provinces and US states. China and the United States stand in polar opposites

of the political regime classification. China is consistently classified as one of the most authoritarian countries with an average FiW index of 5.7, while the US is one of the most established democracies and has an average FiW of zero. Additionally, while subnational GDP figures for the US are centrally produced by the Bureau of Economic Analysis (BEA), national GDP figures for China are consolidated by the National Bureau of Statistics (NBS) based on subnational estimates provided by provincial authorities. Bureaucrats working in the Chinese provincial administration face strong career incentives to deliver high levels of economic growth, further incentivizing inflation of official figures (Chen et al., 2005; Li and Zhou, 2005; Wallace, 2016; Jia et al., 2015). Hence, we expect the nightlights elasticity of GDP to be higher in Chinese provinces than in US states.

Using data from Hodler and Raschky (2014), I average the lights digital number across all counties within each US state and each Chinese province for every year between 1992 and 2013. I combine this information with official subnational real GDP figures from the respective national statistical agencies, BEA and NBS. Figure 3 shows separate binned scatterplots of yearly growth in lights and GDP for China and the US. We observe a positive relationship between GDP growth and growth in lights for both countries. However, as expected, GDP growth in Chinese provinces is substantially higher than in US states for any amount of growth in lights. The results in Table A16 in the appendix indicate that the nightlights elasticity of GDP is more than twice as large in China than in the US. I verify that the results are not driven by differences in population, initial level of luminosity or by generic fluctuations in the nightlights elasticity of GDP over time.

These findings lend support to the hypothesis that GDP growth in China is overstated (Young, 2003; Madisson, 2006; Chen et al., 2019). However, it is not possible to distinguish between the effect of the absence of democratic institutions and the tournament structure guiding the promotion of local and provincial bureaucrats. In this regard, an advantage of the previous cross-country analysis is that such country-specific institutional idiosyncrasies are likely to wash away when averaging across many countries belonging to each regime type.

5 Inflation of GDP Growth: Incentives and Constraints

This section presents results from several additional exercises that help characterize the factors that affect the autocracy gradient in the night-lights elasticity of GDP. Overall, the evidence indicates that the autocracy gradient is larger in situations in which the ability or willingness of governments to exaggerate economic performance is greater, lending support to data manipulation as the underlying mechanism.

5.1 GDP expenditure decomposition

In this section, I study the relationship between nighttime lights and each of the sub-components of GDP, according to the expenditure decomposition. Using this approach, GDP can be disaggregated into private consumption, investment, government spending and net exports. I test for the presence of an autocracy gradient for each component by replacing ln(GDP) in equation (7) with the respective log value.

The top row in Table 3 shows that within-country growth in nighttime lights is strongly correlated with growth in each of the GDP sub-components, validating the use of lights as a broad proxy for economic activity. The coefficients for the interaction between lights and FiW in the bottom row indicate that only in the cases of investment (column 2) and government expenditure (column 3) is the mapping from night lights to the GDP component heterogeneous by regime type. There is no evidence of an autocracy gradient for household final consumption, exports or imports. These results are consistent with the finding by Chen et al. (2019) that the exaggeration of GDP growth by subnational governments in China is driven by investment.

The specific GDP sub-components for which we observe an autocracy gradient lend support to data manipulation as the underlying mechanism, insofar as the figures on investment and government expenditure are both highly dependent on government-provided information. Naturally, the government itself is the primary source on government spending, but the estimate for investment also relies on information provided by the government, since it incorporates sub-estimates of public investment (Lequiller and Blades, 2014). On the other hand, the estimate for exports and imports must roughly align with those reported by trade partners (but see Fisman and Wei, 2004). Similarly, the figures on private consumption can be cross-checked using household surveys and retail sales data, which are more difficult to manipulate.[13] It seems likely that the availability of some form of third-party verification for these other components hinders government manipulation of the corresponding growth rates.

These results are also potentially consistent with authoritarian regimes increasingly engaging in inefficient government spending and investment. However, as part of the robustness checks I verified that the autocracy gradient in the night-lights elasticity of GDP is not con-

[13]Consumption in the national accounts is often obtained as a residual, following the commodity flow method (Deaton, 2005). This method involves first establishing the amount (value) of each product or group of products available for domestic use and then allocating them to the various expenditure components of GDP. Overstatement of government consumption will not lead to understatement of household final consumption as long as there is little overlap in the product categories consumed by households and national and subnational governments, which seems highly likely. Furthermore, the larger presence of state-owned enterprises in authoritarian regimes (e.g., China) can also lead to overstatement of domestic output in the initial stage.

founded by increased corruption in more authoritarian regimes (Table A15). It seems likely that inefficient spending is correlated with corruption and that for every 'white elephant' there is a bank account in a tax haven with an increasing balance. Furthermore, if such inefficient spending is associated with a wide patronage network fueled by government transfers, we would expect the government share of GDP to rise accordingly. But Table A8 shows that the autocracy gradient is not confounded by differences in the size of government.

The fact that the autocracy gradient happens to only be present in the two GDP subcomponents that incorporate mostly unverifiable information provided by the government itself also makes it quite unlikely that the results are the product of chance. Additionally, the heterogeneity suggests that the exaggeration does not take place at the time of reporting the aggregate growth rate, but rather that it goes back to the collection of some of the informational inputs.

5.2 Institutional constraints

This section provides evidence that variation in the institutional arrangement across and within political regimes is associated with fluctuations in the observed heterogeneity in the relationship between night lights and GDP. I first examine the effect of observable formal institutions. I then characterize the specific democratic and non-democratic forms of government that shape the autocracy gradient in the night-lights elasticity of GDP.

In Table 4, I show the relevant estimates from triple-difference regressions that extend equation (7) by including a dummy for the presence of the institution in the header and a full set of interactions with ln(lights) and FiW.[14] The coefficients for the triple interactions in the bottom row tell us whether the effect of a one-unit increase in FiW on the mapping from lights to GDP changes in the presence of the institution in question. This exercise exploits variation in the FiW index between country-years that share a certain institution, as well as between those that have a common FiW but differ in their institutional arrangement.

The results on political institutions show that the autocracy gradient is smaller for countries with an elected legislature (column 1) or an elected executive (column 2). Columns 3 and 4 then examine the role of judiciary and economic institutions. I find that the autocracy gradient is also smaller in countries where the central bank has authority over monetary policy (column 3), as well as in those with a national constitutional court (column 4). These results indicate that independent political, economic and judicial institutions help to restrain the executive's impulse to exaggerate economic performance, even after broadly controlling for regime type with the FiW index. Of course, each of these regressions only captures

[14]See Appendix for full results. Data in columns 1-4 from the IAEP dataset by Wig et al. (2015). Communist history in column 5 was hand-coded from various sources.

the effect of one particular institution in what is a highly multi-dimensional institutional arrangement. Hence, it is not surprising that I still observe a mostly significant autocracy gradient after controlling for the heterogeneity associated with each institution.

In column 5, I distinguish between countries that have had a communist regime at some point in their history and those that have not. This is an interesting dimension to study because there is substantial variation in political institutions among these countries during the sample period. Most former members of the Soviet bloc in Eastern Europe quickly democratized during the 1990s, but several of the former Soviet republics remained highly authoritarian. Studying the legacy of communism is also interesting because these communist regimes have been known for the systematic manipulation of information. The censoring and fabrication of census data, photographs and art in the USSR has been previously documented (Merridale, 1996; King, 1997). More recently, King et al. (2013, 2017) have provided evidence of censoring and fabrication of social media content in communist China. In line with these previous studies, the results in column 5 indicate that the autocracy gradient is substantially larger among countries with a history of communism. The gradient is still present for non-democracies lacking such a history, indicating that any difficulty in measuring economic activity in former or current planned economies is not driving the baseline result.

To further understand the role of political institutions, I use the sub-categories into which dictatorships and democracies are divided in the DD dataset by Cheibub et al. (2010). These authors classify democracies as parliamentary, semi-parliamentary or presidential. Autocracies are also divided into three sub-categories: civilian, military and royal. 51% of the entire sample corresponds to country years classified as parliamentary democracies or civilian dictatorships, with the remaining forms of democracy representing a further 30%. Studying the nightlights elasticity of GDP across these more specific regime types provides an opportunity for a more nuanced understanding of the relationship between autocracy and the manipulation of official statistics.

Figure 4 plots estimates of the interactions with ln(lights) from a modified version of equation (7) that replaces the FiW index with dummies for each of these sub-regime types. The omitted category is parliamentary democracy. The graph shows the existence of a clear gradient within democracies, with presidential ones having a larger elasticity than semi-presidential ones, which in turn have a larger elasticity than parliamentary ones. This gradient aligns with the strength of democracy across these categories, as measured by the average FiW shown next to each marker in the figure. These results are consistent with the hypothesis that the established parliamentary democracies in western Europe, Canada or Japan are more successful at preventing exaggeration of GDP growth than the weaker presidential democracies of Africa and Latin America.

Turning to dictatorial regimes, civilian dictatorships, which have an even higher average FiW than presidential democracies, have the largest night-lights elasticity of GDP. The implied $\hat{\sigma}$ for these countries indicates that they inflate yearly GDP growth figures by a factor of 1.23. The elasticity is significantly lower for military and royal dictatorships, despite them having an even higher average FiW. One explanation for the observed difference among these categories is that royal and military dictatorships can deal with the threat of political turnover by means other than manipulation of information. In the case of royal dictatorships, these are mostly oil-rich 'rentier' states with low or no taxation and extensive patronage networks (Mahdavy, 1970).[15] Military dictatorships, on the other hand, have been found to engage in repression and human rights abuses more often than other forms of autocracy (Geddes et al., 2014).

Taken together, the analysis of the finer regime classification provided by Cheibub et al. (2010) indicates that the night-lights elasticity of GDP is greater when the incentives for exaggeration of economic performance are greater (e.g. civilian vs military dictatorship) and when the constraints on the manipulation of official statistics are weaker (e.g. civilian dictatorship vs parliamentary democracy). Although these different types of regimes tend to concentrate in different areas, Table A4 shows that the broader autocracy gradient in the night-lights elasticity of GDP is not driven by heterogeneity in the elasticity across tightly-defined geographic sub-regions, while Table A11 shows that it is not driven by differences in the initial level of economic development.

5.3 Regime transitions and within-country variation in democracy

Further proof of the importance of democratic institutions can be obtained from examining within-country variation in regime-type. A first approach involves tracking the night-lights elasticity of GDP as countries transition into and out of autocracy. For this purpose, I estimate specially-modified versions of the flexible specification with the discrete regime categories. I first disaggregate the interaction of ln(lights) with the dummy for not-free countries into separate ones for countries that experience a transition into this category lasting at least five years (to rule out composition effects) and for all other not-free country-years. I then further disaggregate the interaction for the transition episodes by event year.

Panel (a) of Figure 5 shows the point estimates and 95% confidence intervals for these interactions. I find that the night-lights elasticity of GDP quickly increases as a country shifts towards autocracy and that it becomes statistically different from that of free countries after two years. Over time, the elasticity roughly converges to that of other not-free country-

[15] On average, oil rents represent 18% of GDP in royal dictatorships, 8% in other dictatorships and 1.4% in democracies.

years. Panel (b) replicates the exercise for transitions out of autocracy, which take place when countries move from being classified as not-free to being labelled as partially-free. In this case, we only observe a weak decrease in the elasticity, which remains closer to that of not-free countries than to the rest of the partially-free category, even after five years. Furthermore, the estimate for the excess elasticity in the year before a transition out of autocracy is very noisy, which could be indicating that the end of a dictatorship involves substantial economic disruption.

More generally, these exercises indicate that the implications of regime change for the effective checks and balances that a government faces are likely to not be symmetric. In particular, transitions into autocracy are associated with a rapid deterioration of the institutional environment, which allows for increased manipulation of official statistics. Transitions out of autocracy, on the other hand, probably require a sustained effort in institution-building before they manifest themselves into an effective system of constraints on the executive.

A second approach involves allowing for a country-specific night-lights elasticity of GDP. This ensures that only within-country variation in democracy informs the estimation. A specification of this nature is obviously quite demanding. It enhances the credibility of the findings, as we are now only exploiting FiW changes within countries over time, but the country-specific elasticities absorb a lot of useful variation in regime type, especially if regimes vary more across countries than within them.

Results from such a specification for the fully disaggregate model are shown in Figure 2 (light diamond markers). The results point to a weakly increasing elasticity as we move to higher values of the FiW index. For most intermediate values, the elasticity is larger than the one for the baseline category, corresponding to the most democratic countries, although the difference is not statistically significant. We still observe a jump in the elasticity for the most authoritarian regimes, but its magnitude is reduced by almost half relative to the previous estimates. Nevertheless, this increase is statistically significant at the 10% level (p=0.085) and indicates that countries that fall into the most autocratic category exaggerate their GDP estimates by a factor of 1.22 relative to the most democratic ones.

5.4 Extra incentives: low growth, elections, foreign aid

In this section, I examine whether the autocracy gradient in the night-lights elasticity of GDP increases when there is a greater incentive to exaggerate economic performance. I consider three different sources of heightened incentives for inflation of GDP growth: relative economic underperformance, proximity to elections and ineligibility for foreign aid.

I begin by examining whether the autocracy gradient is larger at times of low economic

growth. The hypothesis underlying this exercise is that the incentive to exaggerate economic performance is weaker when the economy is, in fact, performing relatively well. I characterize low-growth country-years by demeaning ln(lights) by country and year and creating a dummy equal to one if the demeaned value of ln(lights) is negative. In these cases, growth in lights is below the world average for that year, after adjusting for average differences in luminosity across countries. The final step involves estimating an enlarged version of equation (7) that includes this dummy and a full set of interactions.

Column 1 of Table 5 shows the relevant estimates (see Appendix for full results). The coefficient for the triple-interaction is positive and statistically significant (p=0.067). It corresponds to an 80% increase in the autocracy gradient relative to the one observed in years in which the economy is performing better than average, which remains positive but is smaller and imprecisely estimated (p=0.151). In other words, the heterogeneity in the mapping from lights to GDP across regimes appears to be mostly driven by years in which the economy is growing less than the world average. Column 2 shows results using the indicators for countries classified as partially-free and not-free. In this case, the excess elasticity in the most authoritarian regimes almost triples at times of low growth.

These new findings lend further support to data manipulation as the mechanism driving the main results. They indicate that the autocracy gradient is indeed larger when there is a stronger incentive to exaggerate growth. But exaggerating at times of low growth also means making up a smaller absolute amount of growth. Inflating GDP growth by a factor of 1.2 means adding two percentage points when the true growth rate is ten percent, but it also means adding just 0.2 points when the true growth rate is one percent. Detecting the bias would appear to be more difficult in the latter case. Similarly, the fact that manipulation of GDP growth only happens in certain years also makes detection more difficult and seems desirable from the perspective of an incumbent that wishes to go undetected.

I turn next to the effect of elections and the imminent possibility of political turnover. It seems plausible that, as a result of limited attention or memory, voters' assessment of the incumbent assigns more weight to events occurring closer to election day. Hence, the incentive to exaggerate economic performance should be stronger right before elections take place. We can test this hypothesis thanks to the fact that a growing number of countries classified as non-democratic are hybrid regimes that hold elections during the sample period (Levitsky and Way, 2010).

To study the effect of elections, I use the data on election years in the IAEP dataset by Wig et al. (2015) and create a binary variable equal to one if the country has an election in the following year.[16] This data is only available for a smaller number of countries, so I

[16]I focus on the year before elections as the lag in the publication of GDP figures makes this the more likely

first show in column 3 that the autocracy gradient is present in this smaller sample. Column 4 shows results from the corresponding triple-difference specification. The estimates show a 20% increase in the autocracy gradient the year before elections, which is marginally insignificant (p=0.121). However, the estimates with the discrete regime dummies in column 6 show a large and significant increase in the elasticity for the not-free group in the year before elections. This result indicates that highly authoritarian regimes exaggerate economic performance even more in the run-up to elections.

I consider next the incentives for inflation of GDP growth resulting from the criteria for eligibility for foreign aid. Since 1960, the World Bank has been providing grants and subsidized loans to the world's poorest countries through the International Development Association (IDA). In order to remain eligible for IDA assistance, countries must have a level of Gross National Income (GNI) per capita below a threshold value that is adjusted every year. Once countries surpass the threshold, they start a graduation process that is completed when they are deemed to be creditworthy enough to apply for financing to the International Bank for Reconstruction and Development (IBRD).[17] Even if it does not automatically trigger graduation from the program, exceding the threshold does lead to a substantial reduction in the amount of foreign aid that countries receive. Galiani et al. (2017) estimate that aid flows as a share of GNI drop 59% after countries cross the threshold.

As a result of these incentives, the willingness of governments to exaggerate GDP growth should increase after crossing the GNI threshold. For countries below the threshold, the benefit resulting from artificially inflating GDP growth is offset by the potential loss in foreign aid, insofar as a country growing at a higher rate will be expected to cross the GNI threshold sooner rather than later. In Table 6, I test for this possibility using data for the universe of 82 low-income countries that were beneficiaries of IDA loans and grants at the start of the sample period. Column 1 in Table 6 verifies the strong correlation between night lights and GDP in this sample, while column 2 shows the autocracy gradient in this sample.

In column 3, I introduce an indicator variable for years in which a country's GNI per capita is above the threshold value set by IDA for continued eligibility. 27 countries cross the threshold during the sample period. Consistent with the prediction of increased incentives for exaggeration of GDP growth, I observe an increase in the night-lights elasticity of GDP after countries cross the threshold. Of course, countries that cross have higher levels of GNI per capita and the variation in the elasticity could be reflecting that. Column 4 shows that the jump in the elasticity is even larger and more precisely measured after allowing for

year for exaggeration. The IAEP data has the desirable feature that it only includes scheduled elections, assuaging concerns about endogenous timing.

[17] Additional information on the types of loans and grants available through IDA can be found in Galiani et al. (2017) and Kerner et al. (2017).

heterogeneity in the night-lights elasticity of GDP as GNI per capita increases.

Column 5 shows estimates of the triple difference specification that allows for a change in the autocracy gradient after countries cross the GNI threshold. The interaction of ln(lights) and FiW becomes small and insignificant, while the triple interaction is much larger and is estimated more precisely. These results indicate that the autocracy gradient in the night-lights elasticity of GDP only arises after countries cross the GNI threshold and become ineligible for IDA loans and grants. In other words, autocracies do not exaggerate economic growth when they are in peril of losing foreign aid, but they begin to do so once they cross the threshold and this loss becomes a sunk cost.

Columns 6 to 8 provide several robustness tests of the finding in column 5. In column 6, I use the crossing countries and dates reported by Galiani et al. (2017), which differ in some cases from the ones I obtain by directly comparing the GNI data from the World Development Indicators to the IDA cut-offs. In column 7, I include in the sample the only three countries that satisfied the GNI criterion for eligibility (and also crossed the threshold during the sample period), but were excluded from the IDA program. These are Syria, Turkmenistan and Ukraine. Finally, in column 8, I drop Guyana and Indonesia, as they cross the threshold more than once. The results are robust to all of these modifications.

6 Bias in GDP Statistics: Correction and Prevention

In this section, I use the estimates of the rate of exaggeration of GDP growth figures in weak and non-democracies to correct the data and I examine how this affects countries' relative economic performance over the sample period. I then show that the unadjusted data can lead to erroneous conclusions on the effects of foreign aid on economic growth. Finally, I study the impact of international standards for official statistics on GDP growth exaggeration.

6.1 Adjustment of GDP figures for exaggeration in autocracies

Panel (a) in Figure 6 shows the difference in ln(GDP) between 1992/3 and 2005/6 for the 20 economies with the largest growth according to the raw data, classified according to their average FiW. In this ranking, only four countries are classified as free and five others as partially free. More than half of the top-20 countries with highest GDP growth between 1992 and 2006 have an authoritarian regime and are classified as not-free by Freedom House.

Panel (b) shows the corresponding top-20 based on final household consumption. As mentioned in section 5.1, there is no evidence of exaggeration of growth in this GDP sub-component by authoritarian regimes. Consistently with this finding, panel (b) shows that

eight of the top-20 countries with highest growth according to this metric are classified as free and a further seven as partially-free. Panel (c) replicates the analysis for nighttime luminosity. We observe again a more balanced composition of political regimes, although this ranking is dominated by countries that experienced significant episodes of violence and substantial economic disruption during the sample period or shortly before it.[18]

Panel (d) shows the top-20 after the GDP growth series has been adjusted for manipulation. For this purpose, I calculate a country-specific GDP exaggeration rate based on its average FiW and the long-run estimate of σ from Table 2. I then use this number to deflate the reported long-run GDP growth rate. Once adjusted, the top-20 includes nine free countries and only seven not-free ones, resembling the composition of those for final household consumption and nighttime lights. In particular, the free countries of Cape Verde, Estonia, Latvia, South Korea and the Dominican Republic replace the not-free countries of Bhutan, Laos, UAE, Sudan and Ethiopia. At the very top of the ranking, aggregate GDP growth for China and Myanmar drops from above 1.2 log points to slightly less than 0.9.[19] The adjustment to relative long-run economic performance is even starker for countries in the middle of the distribution of long-run GDP growth, as shown in Figure A6 in the appendix. On average, free countries jump 9.6 positions in the distribution, while not-free ones lose 13.3 spots. However, the results from this exercise must be interpreted with caution, especially when singling out any one country, as it relies on average estimated rates of GDP growth inflation for all countries with the same average FiW index.

6.2 Application: foreign aid and economic growth

To illustrate the implications of correcting the GDP data, I return to the beneficiaries of IDA loans and grants discussed in section 5.4. The aforementioned GNI threshold for IDA eligibility provides plausibly exogenous variation in foreign aid, which can be used to estimate the effects of aid on GDP growth. This setting provides an ideal laboratory to test the implications of manipulation of GDP growth figures, insofar as the findings above indicate that authoritarian regimes only engage in this practice after crossing the GNI threshold. Hence, it seems likely that the effect on GDP growth of the reduction in aid resulting from crossing the threshold will be upward biased.

Exploiting this natural experiment, Galiani et al. (2017) find a positive effect of aid on

[18] Figure A5 in the appendix shows the ranking in terms of growth in lights and GDP for every country in the sample. We observe a strong positive correlation.

[19] A constant yearly GDP growth rate of 4.9% leads to an 87% aggregate growth over a 13-year period. A growth rate of 6.3% over the same period leads to an aggregate growth rate of 122%. Hence, the adjustment to aggregate GDP growth for China and Myanmar corresponds to a reduction of the yearly growth rate from 6.3% to 4.9%, which implies an exaggeration bias of 29%, in line with the yearly estimates of manipulation.

growth. Following this study, I focus on the set of countries that cross the GNI threshold during the sample period. However, Galiani et al. (2017) collapse the data into 3-year periods and estimate a first-differenced IV specification that includes as regressor the lagged level of GDP, which requires them to address the twin issues of weak instruments and Nickell bias. I follow instead a more parsimonious approach and focus on the reduced-form effect of crossing the GNI threshold in a specification with country and year fixed effects.

Column 1 in Table 7 indicates that crossing the threshold leads on average to a decrease in aid as a share of GNI of around 20%. Column 2 shows results from a first specification in which the dependent variable is log GDP per capita. To account for the fact that countries crossing the threshold are likely growing at higher rates, I include a country-specific time trend. The estimates in column 2 indicate that crossing the threshold is associated with a 3.8% increase in GDP, which is statistically significant at the 10% level. Column 3 replicates the analysis using the adjusted GDP data to construct the dependent variable. The point estimate drops almost 30% and is no longer significant. As an alternative specification, in columns 4 and 5 I first-difference the dependent variable and drop the country time trend. The consequences of correcting the GDP series are even starker in this case. While the coefficient from the regression using the raw data is small and imprecise, the one using the adjusted series is three times larger and it is statistically significant at the five percent level. Consistently with Galiani et al. (2017), I find that the drop in foreign aid after crossing the GNI threshold leads to a decrease in GDP growth. However, this result crucially depends on adjusting the GDP data for exaggeration in non-democracies.

6.3 Preventive policies: The IMF's SDDS

Launched in 1996, the International Monetary Fund's (IMF) Special Data Dissemination Standard (SDDS) is a set of guidelines for the production, timeliness and availability of official economic and financial data. The IMF's stated objective with the SDDS was to facilitate access to financial markets by member countries. Subscription is voluntary and involves the commitment to follow the prescribed guidelines and to provide the IMF with information on government statistical practices.

During the sample period, 48 countries subscribe to the SDDS. According to their average FiW, 33 are free, 9 are partially free and 6 are not free. The average value of the FiW index among subscribers is 1.66, while among non-subscribers it is 2.67. These averages already indicate that more authoritarian regimes are less willing to commit to policies favouring transparency in the production and release of official statistics. Unfortunately, the small sample size and the non-random assignment limit our ability to learn from this policy.

To get a better sense of the magnitude of this selection effect, column 1 in Table 8 shows triple-difference estimates of the difference in the autocracy gradient of the night-lights elasticity of GDP for countries that subscribe to the SDDS. Although the triple-difference coefficient is somewhat imprecise (p=0.15), its magnitude indicates that the autocracy gradient is non-existent among countries that subscribe to the program (p=0.78). As expected, only countries that have nothing to hide have an incentive to join a transparency agreement of this nature.

The estimates with the indicators for countries classified as partially-free and not-free in column 2 paint a more nuanced picture, though. The triple-difference estimates suggest that partially-free countries that join the SDDS have a lower excess elasticity than those that do not, while the not-free countries that do join have an even higher excess elasticity than the ones that do not. However, these estimates should be interpreted with caution, as the standard errors are quite large.

In columns 3 and 4, I use information on the specific year in which each country subscribed to the SDDS and add additional interactions with a dummy equal to one from that year onward. These specifications correspond to a fourth-difference research design, as the subscription dummy only equals one if the dummy for subscribing countries also equals one. The fourth-difference coefficient in column 3 points to a small and imprecisely-estimated decrease in the autocracy gradient. However, the corresponding estimates for the more flexible specification in column 4 show a large and statistically significant decrease in the excess elasticity for not-free countries after they subscribe to the SDDS. Formally, I fail to reject the hypothesis that the excess elasticity for not-free countries that join SDDS becomes zero in the years after subscription (p=0.5).

Taken together, the evidence on the SDDS suggests that the program is broadly associated with a weakening of the autocracy gradient in the night-lights elasticity of GDP, even if disentangling the relative contribution of selection and the treatment is complicated by the small number of countries that join. This additional piece of evidence points once again to manipulation of GDP statistics as the mechanism underlying the autocracy gradient, as it directly concerns practices related to the production and distribution of such statistics.

7 Concluding Remarks

This paper uses nighttime lights to detect and measure the manipulation of GDP growth figures taking place in non-democracies. I study the heterogeneity in the mapping from night lights to GDP across political regimes, exploiting the fact that GDP growth statistics are self-reported by governments and prone to manipulation, while the nighttime lights recorded

by satellites from outer space are not.

I document a positive and robust autocracy gradient in the night-lights elasticity of GDP. This gradient is not confounded by potential differences across countries in an exhaustive list of factors. Additional evidence indicates that this autocracy gradient is larger in situations in which the incentive to exaggerate economic performance is stronger, as well as in those in which the constraints on such exaggeration are weaker. The bulk of the evidence points to increased manipulation of GDP figures in non-democracies as the driving mechanism.

The magnitude of this manipulation is substantial. I estimate that the most authoritarian regimes inflate yearly GDP growth rates on average by a factor of 1.15-1.3. Adjustment of the GDP growth figures for manipulation changes our understanding of relative economic performance at the turn of the XXI century and downplays the apparent economic success of countries with non-democratic forms of government. Furthermore, the results constitute new evidence on the disciplining role of democratic institutions for the functioning of government.

The findings in this paper are a warning sign for academics, policy-makers and other consumers of official economic statistics. They provide an incentive to develop and use robust measures of economic activity. The manipulation of GDP figures in non-democracies that I uncover is not easily anticipated or corrected.[20] The autocracy gradient in the night-lights elasticity of GDP is not explained by variation in publicly-available measures of corruption and does not disappear as GDP data gets revised over time. However, transparency initiatives such as the IMF's SDDS do appear to be successful at screening out the countries that fiddle with their economic statistics.

[20]Levy and Peart (2011) document the systematic overestimation of the Soviet Union's GDP growth rate in popular economics textbooks of the XX century and how it persistently affected the comparative analysis of capitalist and socialist economies.

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Table 1: Average growth in GDP and nighttime lights across regime types

	Average growth rate	
	GDP	Lights
	(1)	(2)
Full sample (N=2,724)	0.040	0.052
	[0.001]	[0.005]
Free (N=1,182)	0.036	0.050
	[0.001]	[0.008]
Partially free (N=761)	0.041	0.057
	[0.002]	[0.007]
Not free (N=781)	0.045	0.050
	[0.003]	[0.007]
p-value H_0: Free = Partially Free	0.054	0.480
p-value H_0: Free = Not Free	0.001	0.985
p-value H_0: Partially Free = Not Free	0.193	0.478

Notes: Top row shows the average yearly growth rates of GDP and nighttime lights in the sample. The latter is the within-country area-weighted average of grid-level lights digital numbers (0-63). Rows 2-4 show disaggregate averages for observations (country-years) classified as 'free' (row 2), 'partially free' (row 3) and 'not free' (row 4), according to the adjusted Freedom in the World (FiW) index. FiW ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW$<$ 2, "Partially Free" if 2 $\leq$FiW$\leq$ 4 and "Not Free" if FiW$>$ 4. Sample period: 1993-2008. Standard errors in brackets.

Table 2: The autocracy gradient in the night-lights elasticity of GDP

Dependent variable: $\ln(\text{GDP})_{i,t}$	Yearly fluctuations					Long-run growth
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\text{lights})_{i,t}$	0.283***	0.279***	0.238***	0.238***	0.265***	0.264***
	[0.031]	[0.031]	[0.034]	[0.035]	[0.032]	[0.042]
$\text{FiW}_{i,t}$		-0.017*	-0.005	-0.004		-0.054
		[0.009]	[0.010]	[0.022]		[0.037]
$\text{FiW}_{i,t}{}^2$				-0.000		0.010
				[0.004]		[0.007]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$			0.012***	0.012***		0.018**
			[0.004]	[0.004]		[0.007]
$\text{D(Partially Free)}_{i,t}$					-0.008	
					[0.017]	
$\text{D(Not Free)}_{i,t}$					0.011	
					[0.036]	
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t}$ [a]					0.015	
					[0.011]	
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t}$ [b]					0.032**	
					[0.014]	
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,914	2,914	2,914	2,914	2,914	334
Countries	179	179	179	179	179	167
(Within) R^2	0.218	0.224	0.236	0.236	0.224	0.322
p-value H_0: a = b	-	-	-	-	0.086	-

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW< 2, "Partially Free" if 2 ≤FiW≤ 4 and "Not Free" if FiW> 4. D(Free) and its interaction with ln(lights) are the omitted categories in column 5. In columns 1-5, the sample period is 1992-2008. In column 6, the average of all variables for the years 1992/93 and 2005/06 is used instead. Robust standard errors clustered by country in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table 3: The autocracy gradient in the night-lights elasticity of GDP sub-components

Dependent variable:	ln(Consumption)	ln (Investment)	ln(Government)	ln(Exports)	ln(Imports)
	(1)	(2)	(3)	(4)	(5)
$\ln(\text{lights})_{i,t}$	0.161***	0.356***	0.202***	0.340***	0.262***
	[0.033]	[0.121]	[0.051]	[0.082]	[0.059]
$\text{FiW}_{i,t}$	-0.016	-0.007	-0.048	-0.042	-0.056
	[0.031]	[0.057]	[0.039]	[0.058]	[0.038]
${\text{FiW}_{i,t}}^2$	0.001	-0.004	0.008	0.001	0.002
	[0.005]	[0.011]	[0.007]	[0.010]	[0.006]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.006	0.022**	0.027***	0.005	0.008
	[0.006]	[0.011]	[0.008]	[0.012]	[0.009]
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	2,623	2,621	2,623	2,623	2,623
Countries	166	166	166	166	166
(Within) R^2	0.076	0.077	0.095	0.068	0.082

Notes: Dependent variable in the header (natural logarithm of amount in constant local currency units): household final consumption expenditure in column 1; gross capital formation in column 2; general government final consumption in column 3; exports of goods and services in column 4; imports of goods and services in column 5. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Robust standard errors clustered by country are shown in brackets. Sample period: 1992-2008. *** p<0.01, ** p<0.05, * p<0.1

Table 4: The role of institutions in the manipulation of GDP figures

Dependent variable: $\ln(\text{GDP})_{i,t}$	Elected legislature	Elected executive	Central bank independence	Constitutional court	Communist history
	(1)	(2)	(3)	(4)	(5)
$\ln(\text{lights})_{i,t}$	0.098	0.220***	0.194***	0.225***	0.203***
	[0.102]	[0.040]	[0.046]	[0.032]	[0.032]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$ [a]	0.049**	0.019***	0.025***	0.024***	0.011**
	[0.021]	[0.006]	[0.008]	[0.007]	[0.004]
$\ln(\text{lights})_{i,t} \times \text{D(Institution)}_{i,t}$	0.168*	0.041**	0.025	0.021	0.032
	[0.092]	[0.020]	[0.025]	[0.016]	[0.057]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(Institution)}_{i,t}$ [b]	-0.040*	-0.012**	-0.011**	-0.013*	0.022**
	[0.022]	[0.006]	[0.005]	[0.007]	[0.010]
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	2,451	2,490	2,073	2,416	2,914
Countries	153	154	139	152	179
(Within) R^2	0.280	0.269	0.211	0.242	0.258
p-value H_0: a + b = 0	0.074	0.124	0.010	0.003	0.001

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Each column includes the dummy variable in the for the presence of the institution in the header, D(Institution), and all its interactions with ln(lights) and FiW: elected legislature in column 1, elected chief executive in column 2, central bank with authority over monetary policy in column 3; existence of national constitutional court in column 4; communist regime at some point in column 5. All of these variables are time-varying with the exception of the dummy for communist history in column 5. Only the estimates for ln(lights) and its interactions displayed. See the online appendix for full results. Sample period: 1992-2008. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Incentives for GDP manipulation I: Economic under-performance and elections

Dependent variable: $\ln(\text{GDP})_{i,t}$	Low GDP growth		Year before national election			
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\text{lights})_{i,t}$	0.241***	0.256***	0.260***	0.261***	0.288***	0.288***
	[0.042]	[0.039]	[0.039]	[0.040]	[0.034]	[0.035]
$\ln(\text{lights})_{i,t} \times \text{D(Event)}_{i,t}$	-0.008	-0.001		-0.002		-0.001
	[0.007]	[0.005]		[0.003]		[0.002]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.006		0.011**	0.010**		
	[0.004]		[0.004]	[0.004]		
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(Event)}_{i,t}$	0.005*			0.002		
	[0.003]			[0.001]		
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t}$		0.011			0.013	0.014
		[0.012]			[0.012]	[0.012]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t}$		0.010			0.028*	0.025*
		[0.015]			[0.015]	[0.014]
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t} \times \text{D(Event)}_{i,t}$		0.001				0.001
		[0.009]				[0.005]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t} \times \text{D(Event)}_{i,t}$		0.028**				0.012*
		[0.013]				[0.006]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,914	2,914	2,500	2,500	2,500	2,500
Countries	179	179	154	154	154	154
(Within) R^2	0.249	0.240	0.245	0.247	0.235	0.239

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW$<$ 2, "Partially Free" if 2 $\leq$FiW$\leq$ 4 and "Not Free" if FiW$>$ 4. D(Free) and its interaction with ln(lights) are the omitted categories in columns 2, 5, 6. In columns 1-2, $\text{D(Event)}_{i,t}$ is a dummy equal to one if the value of ln(lights) demeaned by country and year is negative. In columns 3-6, $\text{D(Event)}_{i,t}$ is a dummy equal to one if there is a national election in the following year. Estimates for single terms and lower order interactions not reported. See appendix for full results. Robust standard errors, clustered by country, are shown in brackets. *** p$<$0.01, ** p$<$0.05, * p$<$0.1

Table 6: Incentives for GDP manipulation II: Eligibility for IDA loans and grants

Dependent variable: $\ln(\text{GDP})_{i,t}$	Baseline results (reduced sample)		Changing elasticity above GNI threshold			Galiani et al. (2017) crossings	Ineligible countries	Crossings ≤ 1
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(\text{lights})_{i,t}$	0.252***	0.210***	0.233***	0.244***	0.226***	0.225***	0.239***	0.234***
	[0.037]	[0.042]	[0.037]	[0.035]	[0.041]	[0.041]	[0.041]	[0.041]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$		0.012*			0.004	0.004	0.004	0.002
		[0.007]			[0.006]	[0.006]	[0.006]	[0.006]
$\ln(\text{lights})_{i,t} \times \text{D(GNI>threshold)}_{i,t}$			0.061*	0.081***	0.001	0.001	-0.000	-0.018
			[0.032]	[0.025]	[0.035]	[0.037]	[0.036]	[0.031]
$\ln(\text{lights})_{i,t} \times \text{GNI}_{i,t}$				-0.048***	-0.043***	-0.040***	-0.046***	-0.046***
				[0.010]	[0.010]	[0.010]	[0.011]	[0.008]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(GNI>threshold)}_{i,t}$					0.023*	0.023*	0.024*	0.028**
					[0.013]	[0.014]	[0.013]	[0.012]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,308	1,308	1,308	1,308	1,308	1,308	1,357	1,274
Countries	82	82	82	82	82	82	85	80
(Within) R^2	0.205	0.225	0.252	0.317	0.359	0.361	0.365	0.369

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. GNI is Gross National Income per capita in thousands of current US dollars using Atlas method. $\text{D(GNI>threshold)}_{i,t}$ equals one if GNI per capita is above the yearly value set by IDA for eligibility for loans and grants. Estimates for single terms and lower order interactions not reported. See appendix for full results. Robust standard errors clustered by country in brackets. Baseline sample includes all countries that were eligible for IDA aid at some point in the sample period (current + graduates). Column 6 uses the crossing dates reported by Galiani et al. (2017). Column 7 includes Syria, Turkmenistan and Ukraine, which were excluded from the IDA program. Column 8 excludes Guyana and Indonesia, which cross the threshold more than once. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Correcting for GDP manipulation: The effect of foreign aid on economic growth

Dependent variable:	$\ln(\text{ODA/GNI})_{i,t}$	$\ln(\text{GDP p.c.})_{i,t}$		$\Delta \ln(\text{GDP p.c.})_{i,t}$	
	(1)	(2)	(3)	(4)	(5)
$\text{D(GNI>threshold)}_{i,t}$	-0.216	0.038	0.027	-0.007	-0.021
	[0.098]**	[0.022]*	[0.017]	[0.010]	[0.009]**
	(0.101)**	(0.023)*	(0.018)	(0.010)	(0.009)**
Observations	431	431	431	409	409
Countries	27	27	27	27	27
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Country-year trend	No	Yes	Yes	No	No
GDP data correction	No	No	Yes	No	Yes
(Within country) R^2	0.274	0.912	0.905	0.130	0.119

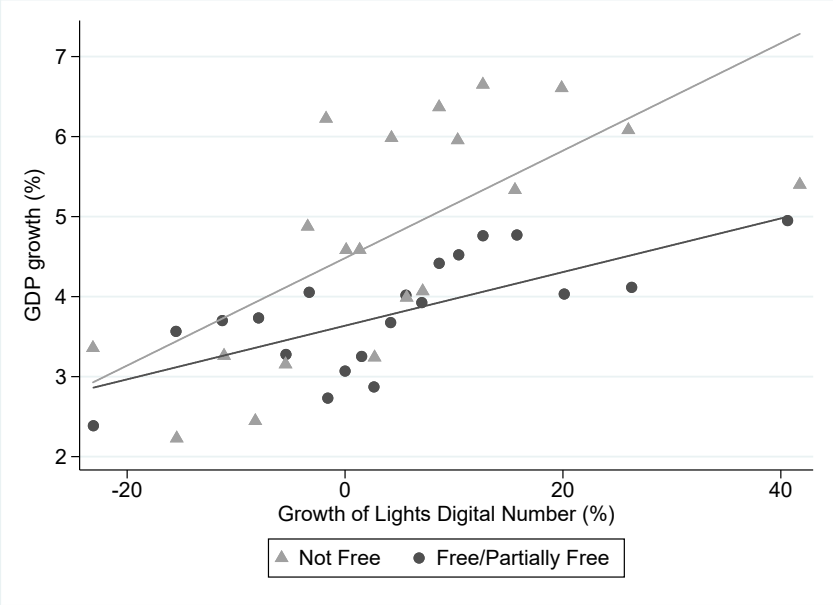
Notes: Dependent variable in column 1 is the natural log of official development assistance (ODA) over Gross National Income (GNI) in US dollars. In columns 2 and 3 it is log GDP per capita in constant local currency units, while in columns 4 and 5 it is the first difference of this variable. $\text{D(GNI>threshold)}_{i,t}$ equals one if GNI per capita is above the yearly value set by IDA for eligibility for loans and grants. Sample includes countries that cross the threshold during the sample period. All regressions include country and year fixed effects. Columns 2 and 3 also include country-specific time (year) trends. Robust standard errors clustered by country in brackets. Wild cluster bootstrap standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 8: Preventing GDP manipulation: The Special Data Dissemination Standard

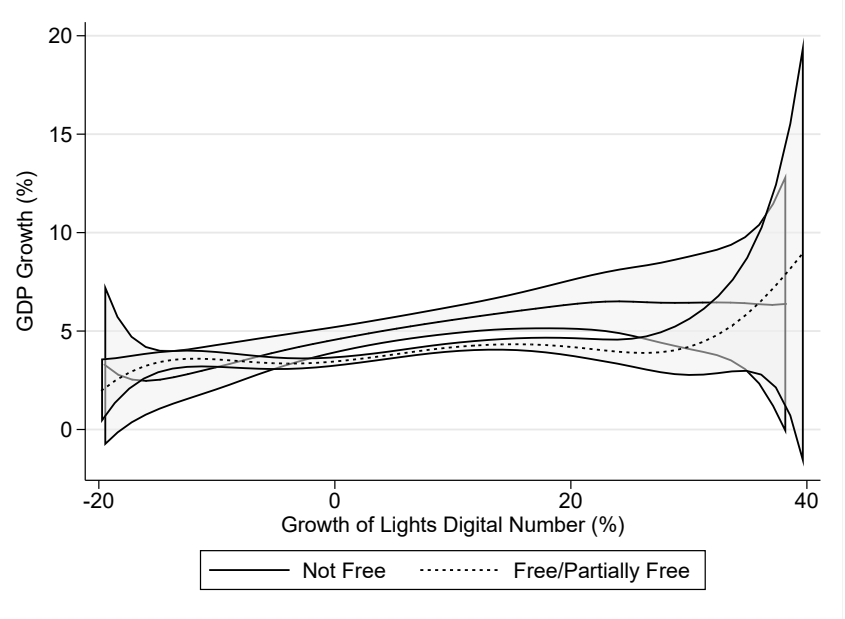
Dependent variable: $\ln(\text{GDP})_{i,t}$	Selection		Treatment effect	
	(1)	(2)	(3)	(4)
$\ln(\text{lights})_{i,t}$	0.231***	0.262***	0.242***	0.270***
	[0.040]	[0.036]	[0.040]	[0.037]
$\ln(\text{lights})_{i,t} \times \text{D(SDDS country)}_i$	0.070	0.023	0.011	-0.024
	[0.055]	[0.051]	[0.053]	[0.049]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$ [a]	0.013**		0.012**	
	[0.005]		[0.005]	
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(SDDS country)}_i$ [b]	-0.016		-0.013	
	[0.011]		[0.012]	
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t}$ [c]		0.017		0.016
		[0.014]		[0.014]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t}$ [d]		0.031*		0.031*
		[0.018]		[0.018]
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t} \times \text{D(SDDS country)}_i$ [e]		-0.008		-0.004
		[0.025]		[0.032]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t} \times \text{D(SDDS country)}_i$ [f]		0.034		0.026
		[0.044]		[0.049]
$\ln(\text{lights})_{i,t} \times \text{D(SDDS suscription)}_{i,t}$			0.010	0.009
			[0.015]	[0.013]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(SDDS suscription)}_{i,t}$ [g]			-0.007	
			[0.009]	
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t} \times \text{D(SDDS suscription)}_{i,t}$ [h]				0.004
				[0.022]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t} \times \text{D(SDDS suscription)}_{i,t}$ [i]				-0.077**
				[0.035]
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	2,914	2,914	2,914	2,914
Countries	179	179	179	179
(Within) R^2	0.239	0.225	0.249	0.236
p-value H_0: a + b = 0	0.776		0.975	
p-value H_0: c + e = 0		0.686		0.659
p-value H_0: d + f = 0		0.107		0.212
p-value H_0: a + b + g = 0			0.492	
p-value H_0: c + e + h = 0				0.379
p-value H_0: d + f + i = 0				0.495

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW$<$ 2, "Partially Free" if 2 $\leq$FiW$\leq$ 4 and "Not Free" if FiW$>$ 4. D(Free) and its interaction with ln(lights) are the omitted categories in even-numbered columns. D(SDDS country)_i is a dummy equal to one for countries that joined the SDDS during the sample period. $\text{D(SDDS suscription)}_{i,t}$ is a dummy equal to one in the years after subscription to the SDDS. Estimates for single terms and lower order interactions not reported. See appendix for full results. Sample period: 1992-2008. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Figure 1: Non-parametric estimation



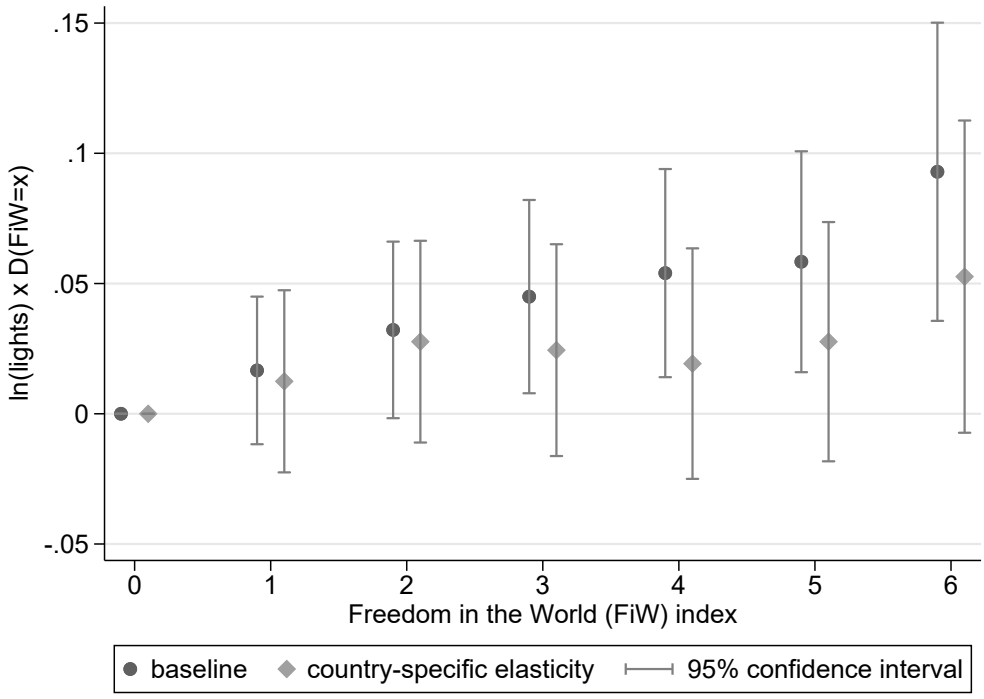
(a) Binned scatter plot



(b) Local polynomial smoothing

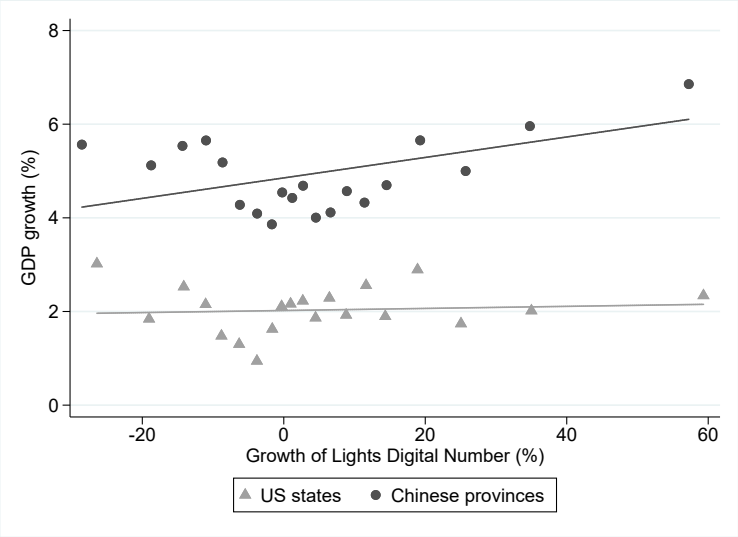
Note: Panel (a) shows separate (binned) scatterplots of yearly growth in real GDP and nighttime lights (DN) for observations classified by Freedom House as "Not Free" and all others, according to the adjusted Freedom in the World (FiW) index. FiW ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW<2, "Partially Free" if $2 \leq$FiW≤ 4 and "Not Free" if FiW>4. Panel (b) shows estimates and 95% confidence intervals of kernel-weighted local polynomial regressions for "Not Free" observations and all others, using a quartic kernel, third-order polynomial and bandwidth of 0.3. For these figures, observations with growth of lights in the top and bottom 2.5% are excluded. Sample includes 2,827 observations. Sample period: 1993-2008.

Figure 2: The night-lights elasticity of GDP at each value of the FiW index



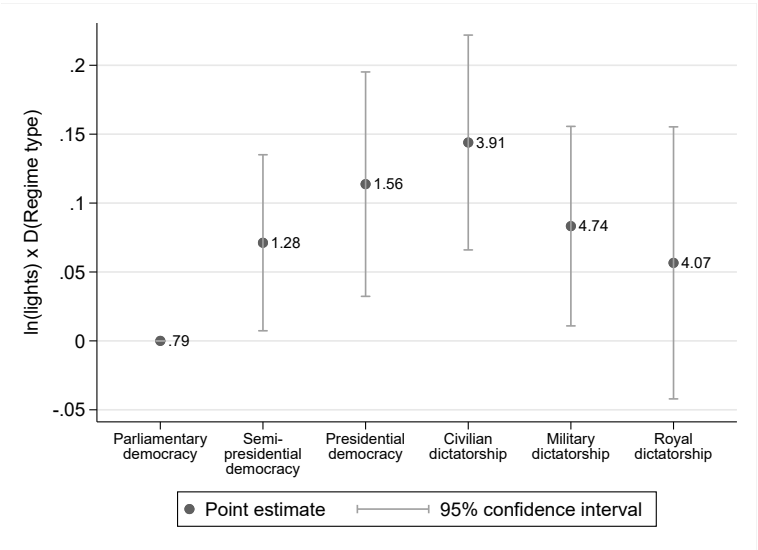
Note: The graph shows point estimates and 95% confidence intervals of a regression of ln(GDP) on the interaction of ln(lights) with each value of the adjusted Freedom in the World (FiW) index (rounded to the nearest integer). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Non-reported regressors include ln(lights) and separate indicators for each value of FWI [omitted category is FWI=0]. The round markers correspond to the baseline specification with country and year fixed effects (i.e. a fully disaggregated version of column 5 of Table 2). The diamond markers show results from an enlarged specification with a full set of interactions of ln(lights) with country dummies [not reported]. Sample for both regressions includes 2,914 observations from 179 countries. Sample period: 1992-2008. Standard errors clustered by country.

Figure 3: The night-lights elasticity of GDP: Chinese provinces vs US states



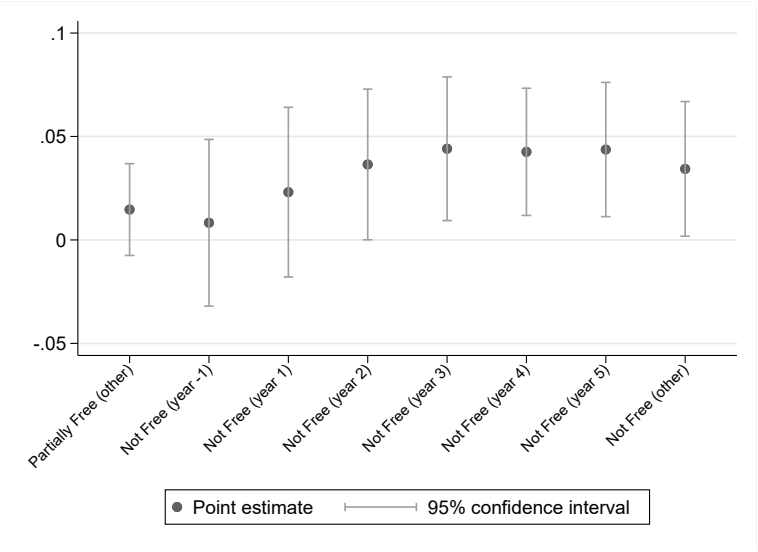
Note: Graph shows separate (binned) scatterplots of yearly growth in real GDP and nighttime lights (DN) for the 50 US states (plus the dictrict of Columbia) and 31 Chinese provinces. DN is the average lights digital number (0-63) across geographic sub-units (ADM2). Sample period: 1993-2013.

Figure 4: The night-lights elasticity of GDP across regime types

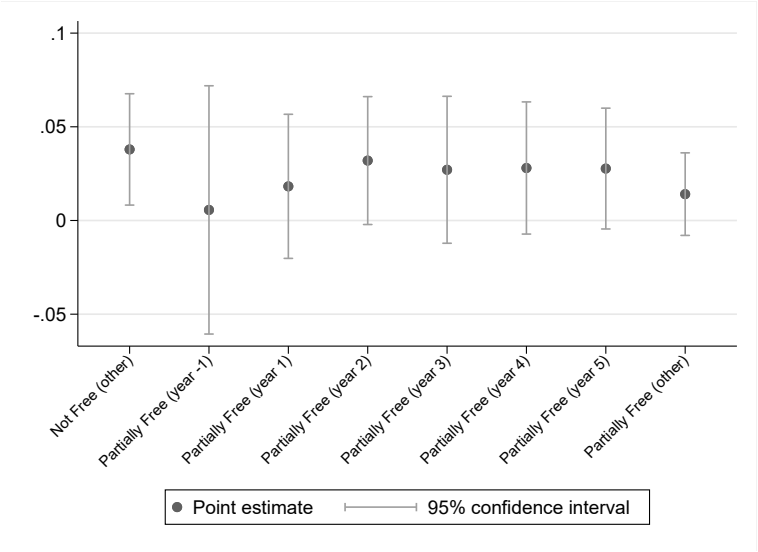


Note: The graph shows point estimates and 95% confidence intervals of a regression of ln(GDP) on the interaction of ln(lights) and five regime-type dummies. Other regressors include ln(lights) and the five regime-type dummies [estimates not reported]. The omitted category is 'parliamentary democracy'. Reported next to each marker is the average value of the adjusted Freedom in the World (FiW) index for that regime type. The regression also includes country and year fixed effects. Sample: 2,911 observations from 179 countries, 1992-2008. Standard errors clustered by country.

Figure 5: Political transitions and the night-lights elasticity of GDP



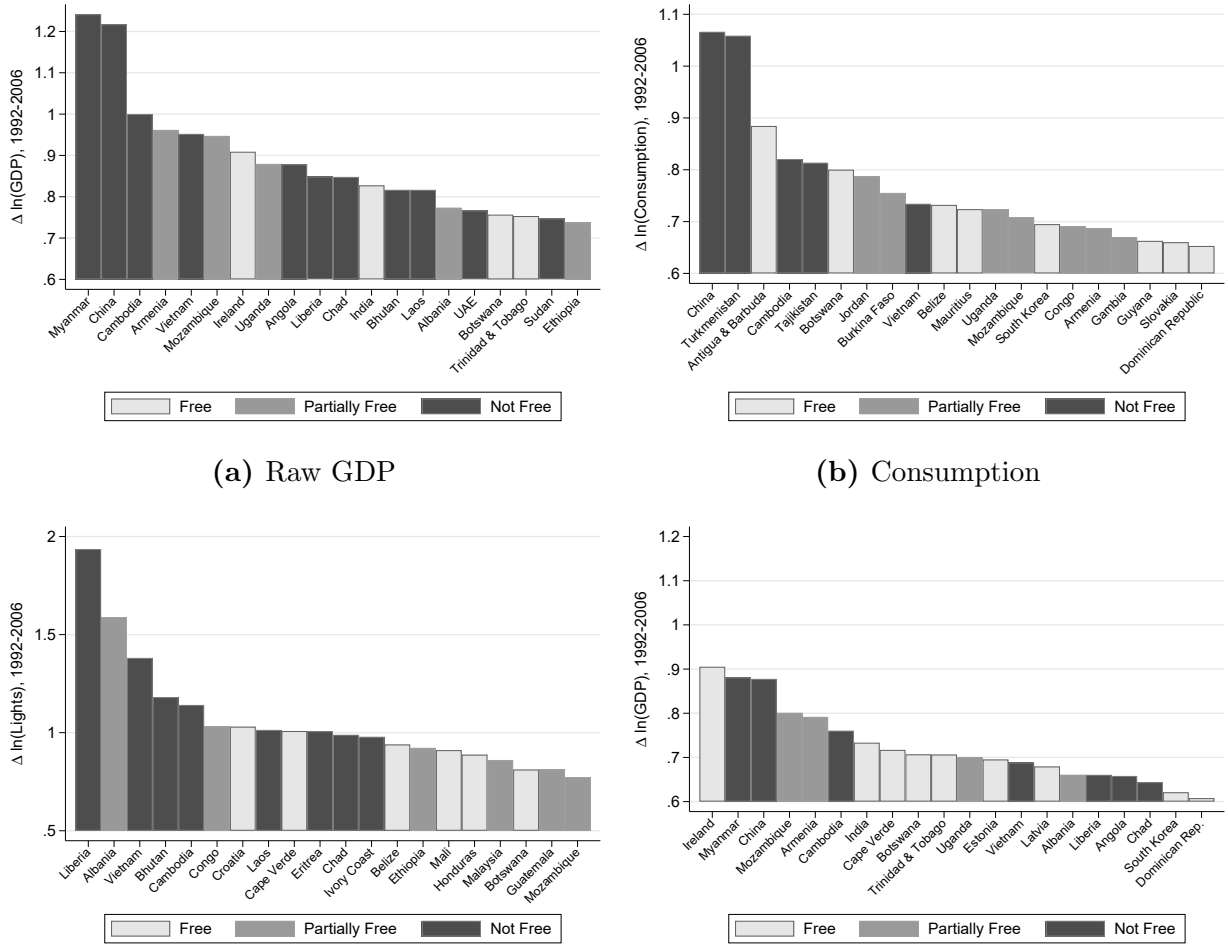
(a) Into Autocracy



(b) Out of Autocracy

Note: Each panel shows point estimates and 95% confidence intervals of a fixed-effects regression (country and year) of ln(GDP) on ln(lights) [not reported] and its interaction with dummies for "Partially Free" and "Not Free" observations. The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW$<$ 2, "Partially Free" if 2 $\leq$FiW$\leq$ 4 and "Not Free" if FiW$>$ 4. In panel (a), the "Not Free" category is disaggregated into individual ones for the first six years after a transition from "Partially Free" and a separate interaction for all other "Not Free" observations. Only countries with six consecutive years of "Not Free" status after a transition included in the transition estimates. Panel (b) includes a similar disaggregation for the first six years after a transition from "Not Free" to "Partially Free." Both regressions also include dummies for the relevant "Partially Free" and "Not Free" subcategories [not reported]. D(Free) and its interaction with ln(lights) are the omitted categories. Sample for both regressions includes 2,914 observations from 179 countries. Sample period: 1992-2008. Standard errors clustered by country.

Figure 6: Top 20 Fastest-Growing Economies: 1992/3 - 2005/6



(a) Raw GDP

(b) Consumption

(c) Night lights

(d) Adjusted GDP

Note: Panel (a) shows the 20 countries with the largest change in ln(GDP) between 1992/3 and 2005/6 (two-year average in both cases), as reported in the World Bank's World Development Indicators. Countries are classified according to the average value of the Freedom in the World (FiW) index. according to the adjusted Freedom in the World (FiW) index. FiW ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW<2, "Partially Free" if $2 \leq$FiW≤ 4 and "Not Free" if FiW>4. Panel (b) shows the 20 countries with the largest change in ln(Consumption) over the same period. Panel (c) shows the same information for nighttime luminosity. Panel (d) shows the the 20 countries with the largest change in ln(GDP) after the GDP series has been adjusted for manipulation. The adjustment is based on the estimate of the bias parameter σ implied by the results in column 6 of Table 2. See Section 3.2 for the underlying empirical model.

APPENDIX (for online publication)

Appendix A Extensions of the Econometric Model

A.1 Heterogeneous mapping of real growth to GDP across regimes

Keeping equations (1), (3) and (4) unchanged, we can modify equation (2) to further allow GDP to differentially reflect real economic growth in democracies and autocracies:

$$\text{gdp}_{i,t} = \beta^d y^d_{i,t} + \beta^a \alpha \text{ autocracy}_{i,t} + \epsilon_{i,t} \tag{2'}$$

Combining all four equations we observe that the equivalent of the 'naive' regression of GDP growth on growth in lights and the autocracy indicator given by equation (5) estimates:

$$\widehat{\text{gdp}}_{i,t} = \frac{\beta^d}{\gamma^d}\text{lights}_{i,t} + (\bar{\lambda} + \theta) \text{ autocracy}_{i,t} + \bar{\eta}_{i,t} \tag{5'}$$

where $\bar{\lambda} \equiv \frac{\alpha}{\gamma^d}\left[\beta^a\gamma^d - \beta^d\gamma^a\right]$. In this case, the coefficient on the autocracy indicator will only capture the constant inflation of growth figures in autocracies, θ, in the knife-edge case in which $\beta^a\gamma^d = \beta^d\gamma^a$, leading to $\bar{\lambda} = 0$. If we replace equation (3) with (3'), as in the main analysis, we obtain the following specification:

$$\begin{aligned}\widehat{\text{gdp}}_{i,t} =& \frac{\beta^d}{\gamma^d}\text{lights}_{i,t} + \frac{\beta^d\sigma}{\gamma^d}\left(\text{lights}_{i,t} \times \text{autocracy}_{i,t}\right) + \left(\bar{\lambda} + \theta + \sigma\epsilon_{i,t} - \frac{\sigma\beta^d}{\gamma^d}u_{i,t}\right) \text{ autocracy}_{i,t} \\ &+ \sigma\bar{\lambda} \text{ autocracy}^2_{i,t} + \bar{\nu}_{i,t}\end{aligned} \tag{6'}$$

It is still the case that the coefficient for the interaction of growth in lights and autocracy is increasing in σ, which is the proportional exaggeration of GDP growth that takes place in autocracies. It is also still true that we can back out σ by dividing the point estimate for the interaction by the estimate for lights.

A.2 Differential electrification policy across regimes

Assume that GDP growth noisily captures real economic growth. Growth in nighttime lights also noisily captures real economic growth, but it is also affected by electrification policies that differ across political regimes, conditional on income:

$$\text{gdp}_{i,t} = \beta\tilde{y}_{i,t} + \epsilon_{i,t} \tag{2"}$$

$$\text{lights}_{i,t} = \gamma\tilde{y}_{i,t} + \phi \text{ autocracy}_{i,t} + u_{i,t} \tag{4'}$$

Combining these two equations with equation (3), we obtain:

$$\widehat{\text{gdp}}_{i,t} = \frac{\beta}{\gamma}\text{lights}_{i,t} + (\theta - \frac{\beta\phi}{\gamma}) \text{ autocracy}_{i,t} + \bar{\bar{\eta}}_{i,t} \tag{5"}$$

In this modified model it is still the case that the autocracy dummy fails to capture the constant exaggeration of GDP growth in autocracies. Min (2015) provides evidence supporting that democracies provide more electricity than autocracies after controlling for income. If this is the case, $\phi < 0$ and the autocracy dummy overestimates GDP growth inflation in authoritarian regimes.

If we replace equation (3) with (3'), we obtain:

$$\widehat{\text{gdp}}_{i,t} = \frac{\beta}{\gamma}\text{lights}_{i,t} + \frac{\beta\sigma}{\gamma}\left(\text{lights}_{i,t} \times \text{autocracy}_{i,t}\right) + \left(\theta + \frac{\beta}{\gamma}\left(\sigma(u_{i,t} + \epsilon_{i,t}) - \phi\right)\right) \text{autocracy}_{i,t} + \frac{\sigma\phi\beta}{\gamma}\,\text{autocracy}_{i,t}^2 + \bar{\bar{\nu}}_{i,t} \tag{6"}$$

Similarly to the baseline model, the coefficient for the interaction of growth in lights and autocracy is increasing in σ, which is the proportional exaggeration of GDP growth that takes place in autocracies. It is also still true that we can back out σ by dividing the point estimate for the interaction by the estimate for lights.

Appendix B Additional Tables and Figures

Table A1: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	N	Countries	Source
				Main variables			
ln(lights)	-0.15	2.00	-5.95	3.89	2,914	179	Henderson et al. (2012)
ln(GDP)	25.37	4.06	0.38	35.27	2,914	179	Henderson et al. (2012)
FiW index	2.41	1.92	0	6	2,914	179	Freedom House
				Other regime classifications			
Polity 2	3.35	6.47	-10	10	2,531	155	Polity IV
D(Authoritarian)	0.37	0.48	0	1	2,881	177	Freedom House
D(Authoritarian)	0.43	0.49	0	1	1,936	167	Papaioannou and Siourounis (2008)
D(Authoritarian)	0.42	0.49	0	1	2,911	179	Cheibub et al. (2010)
D(Authoritarian)	0.34	0.48	0	1	2,911	179	Acemoglu et al. (2016)

Table A2: Correlates of the FiW index

	Point estimate	Standard error	N
	(1)	(2)	(3)
A: Dependent variable: FiW_i (average)			
D(Official state party)$_i$ [1]	0.858**	[0.367]	157
D(Banned parties)$_i$ [1]	0.490*	[0.256]	157
D(Registration required to vote)$_i$ [1]	-1.183***	[0.369]	155
D(Legislature elected through national elections)$_i$ [2]	-1.326***	[0.273]	156
D(Executive elected through national elections)$_i$ [2]	0.114	[0.299]	157
Share of years with national elections$_i$	-3.080***	[0.954]	157
Average turnout for legislative elections (% eligible pop.)$_i$	0.00461	[0.00887]	145
D(No party with seats $\geq$ 90% of lower house of legislature)$_i$ [2]	-1.166***	[0.309]	146
D(National elections boycotted by major party)$_i$ [1]	0.455	[0.284]	148
D(Election outcome provokes protest or violence)$_i$ [1]	0.443	[0.273]	149
D(Scheduled elections postponed or cancelled)$_i$ [1]	0.339	[0.272]	149
D(New Constitution)$_i$ [1]	0.748***	[0.249]	153
D(Unicameral legislature)$_i$ [1]	0.631**	[0.251]	156
D(Executive can propose constitutional amendments)$_i$ [1]	0.124	[0.275]	155
D(Executive can veto legislation)$_i$ [1]	-0.440	[0.279]	155
D(Executive can dissolve the legislature)$_i$ [1]	-0.497*	[0.282]	155
D(Executive has power to call elections)$_i$ [1]	-0.307	[0.250]	155
D(National constitutional court)$_i$ [1]	-0.965***	[0.244]	155
D(Central bank has authority over monetary policy)$_i$ [1]	0.0528	[0.275]	140
B: Dependent variable: $\text{FiW}_{i,t}$ (yearly)			
D(Official state party)$_{i,t}$	0.204	[0.288]	2,442
D(Banned parties)$_{i,t}$	0.180*	[0.103]	2,447
D(Registration required to vote)$_{i,t}$	-0.0748	[0.0811]	2,394
D(Legislature elected through national elections)$_{i,t}$	-0.316**	[0.143]	2,451
D(Executive elected through national elections)$_{i,t}$	-0.536***	[0.196]	2,490
D(Election year)$_{i,t}$	-0.0411*	[0.0214]	2,499
Turnout in last legislative election$_{i,t}$	0.000580	[0.00303]	2,028
D(No party with seats $\geq$ 90% of lower house of legislature)$_{i,t}$	-0.0504	[0.160]	2,051
D(Last election boycotted by major party)$_{i,t}$	0.109	[0.0951]	2,142
D(Last election outcome provoked protest or violence)$_{i,t}$	0.262***	[0.0913]	2,146
D(Last election postponed or cancelled)$_{i,t}$	-0.0566	[0.0707]	2,148
D(New Constitution)$_{i,t}$	0.0306	[0.0797]	2,372
D(Unicameral legislature)$_{i,t}$	-0.0694	[0.153]	2,453
D(Executive can propose constitutional amendments)$_{i,t}$	0.0835	[0.110]	2,439
D(Executive can veto legislation)$_{i,t}$	0.0876	[0.138]	2,337
D(Executive can dissolve the legislature)$_{i,t}$	0.0580	[0.151]	2,354
D(Executive has power to call elections)$_{i,t}$	-0.105	[0.0973]	2,394
D(National constitutional court)$_{i,t}$	-0.0992	[0.211]	2,416
D(Central bank has authority over monetary policy)$_{i,t}$	-0.0477	[0.0908]	2,073

Notes: The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Panel A shows results of bivariate cross-sectional regressions of the average value of FiW between 1992 and 2008 on the variable in the leftmost column. Regressions include 14 subregion fixed effects. Panel B shows similar results in a panel setting with the yearly value of FiW as the dependent variable and country and year fixed effects. Robust standard errors in brackets in column 2 (clustered by country in panel B). *** p<0.01, ** p<0.05, * p<0.1

[1] At any point in sample period. [2] Throughout the sample period.

Table A3: Robustness checks I: Other regime classifications

Dependent variable: $\ln(\text{GDP})_{i,t}$	Polity IV			Binary indicators			
	Polity2	Democracy	Autocracy	Freedom House	Cheibub et al. (2010)	Papaioannou & Siourounis (2008)	Acemoglu et al. (2010)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln(\text{lights})_{i,t}$	0.293***	0.267***	0.247***	0.261***	0.274***	0.272***	0.272***
	[0.029]	[0.032]	[0.030]	[0.031]	[0.032]	[0.045]	[0.031]
Autocracy measure$_{i,t}$	-0.004*	0.005	-0.015	0.050**	0.017	0.053*	0.028
	[0.002]	[0.010]	[0.012]	[0.021]	[0.023]	[0.031]	[0.021]
Autocracy measure$_{i,t}^2$	0.000	0.000	0.003*				
	[0.000]	[0.001]	[0.002]				
$\ln(\text{lights})_{i,t} \times$ Autocracy measure$_{i,t}$	-0.002**	-0.002	0.005**	0.031***	0.016	0.040***	0.022***
	[0.001]	[0.002]	[0.002]	[0.010]	[0.011]	[0.015]	[0.008]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,530	2,458	2,458	2,881	2,911	1,936	2,911
Countries	155	155	155	177	179	167	179
(Within) R^2	0.224	0.180	0.189	0.223	0.221	0.277	0.224

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The Polity2 score from the Polity IV project (column 1) is the difference between the democracy and autocracy scores and ranges from -10 to 10 (most democratic). The democracy (column 2) and autocracy (column 3) scores range from 0 to 10, with larger values corresponding to more democratic and autocratic regimes, respectively. In columns 4-7, the autocracy measure is a binary indicator. It equals one minus the 'electoral democracy' dummy produced by Freedom House in column 4. Column 5 uses the dummy for dictatorship from the Cheibub et al. (2010) DD dataset, which is an updated version of the Przeworski et al. (2000) dataset. Column 6 uses the democracy indicator produced by Papaioannou and Siourounis (2008). In column 7, the autocracy dummy is constructed following Acemoglu et al. (2016) and equals one if the observation is classified by Freedom House as 'not free' or the Polity score is less than or equal to zero, with missing observations form both sources classified according to the DD dataset. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A4: Robustness Checks II: Characteristics of nighttime lights

	Dependent variable: $\ln(\text{GDP})_{i,t}$								
	Lights quartic	Year-specific	Latitude, longitude	Subregion-x specific	Area	Top-coding	Unlit cells	Lights Gini	Electricity consumption
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\ln(\text{lights})_{it}$	0.233***	0.231***	0.232***		0.054	0.225***	0.050	0.438***	
	[0.043]	[0.034]	[0.047]		[0.100]	[0.036]	[0.097]	[0.114]	
$\text{FiW}_{i,t}$	-0.003	-0.003	-0.003	-0.008	-0.001	-0.001	-0.001	-0.005	-0.234***
	[0.023]	[0.022]	[0.023]	[0.023]	[0.023]	[0.022]	[0.023]	[0.023]	[0.131]
$\text{FiW}_{i,t}{}^2$	-0.000	-0.000	-0.000	0.000	-0.001	-0.001	-0.001	0.000	0.001
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.005]
$x_{i,t}$						0.013**	-0.067**	0.506*	0.250***
						[0.006]	[0.028]	[0.278]	[0.051]
$\ln(\text{lights})_{it} \times \text{FiW}_{i,t}$	0.011***	0.013***	0.011***	0.009**	0.010**	0.012***	0.011***	0.012***	
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	
$\ln(\text{lights})_{it} \times x_{i,t}$					0.017*	0.001	0.017*	-0.195*	
					[0.009]	[0.002]	[0.009]	[0.108]	
$x_{it} \times \text{FiW}_{i,t}$									0.009*
									[0.005]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,914	2,914	2,914	2,914	2,914	2,914	2,914	2,914	1,851
Countries	179	179	179	179	179	179	179	179	128
(Within) R^2	0.246	0.241	0.248	0.0147	0.242	0.242	0.243	0.241	0.235

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. The model in column 1 includes a quartic polynomial in ln(lights) [estimates not shown]. Other columns include the variable x in the header (if time-varying) and its interaction with ln(lights): In column 2, a full set of year fixed effects [estimates not shown]; in column 3, quadratics for both the longitude and latitude of the country's capital [estimates not shown]; in column 4, 22 subregional fixed effects based on the UN geoscheme [estimates not shown]; in column 5, the natural log of permanent ice-free land area in square km; in columns 6 and 7, the natural log of the number of top-coded (DN=63) and unlit (DN=0) cells, respectively; In column 8, the natural log of the Gini coefficient of night lights. In column 9, I replace ln(lights) with ln(electricity consumption). Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A5: Robustness Checks III: Other measures of lights + extra years

Source on lights:	Dependent variable: $\ln(\text{GDP})_{i,t}$ [WDI 2015 vintage]					
	Henderson et al. (2012)		Pinkovskiy & Sala-i-Martin (2016a)		Hodler & Raschky (2014)	
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\text{lights})_{i,t}$	0.242***	0.240***	0.210***	0.213***	0.176***	0.164***
	[0.039]	[0.039]	[0.041]	[0.040]	[0.045]	[0.042]
$\text{FiW}_{i,t}$	0.004	0.007	-0.211**	-0.246**	-0.019	-0.037
	[0.023]	[0.023]	[0.102]	[0.103]	[0.023]	[0.026]
${\text{FiW}_{i,t}}^2$	-0.002	-0.003	-0.005	-0.006	-0.002	-0.000
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.005]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.011**	0.011**	0.009**	0.010**	0.019***	0.028***
	[0.005]	[0.005]	[0.004]	[0.004]	[0.006]	[0.006]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Final year	2008	2008	2008	2010	2008	2013
Observations	2,886	3,018	2,919	3,269	2,774	3,592
Countries	179	184	176	176	167	167
(Within) R^2	0.244	0.230	0.207	0.210	0.191	0.205

Notes: Dependent variable is ln(GDP) in constant local currency units from the WDI 2015 vintage. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (DN) from Henderson et al. (2012) in columns 1-2. In columns 3-4, it is the natural log of the unweighted average of DN across pixels from Pinkovskiy and Sala-i Martin (2016a). In columns 5-6, it is the natural log of the unweighted average of DN across level-2 administrative areas from Hodler and Raschky (2014). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. The initial year in the sample is 1992 in all columns. Robust standard errors clustered by country in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A6: Robustness Checks IV: Growth rates

	Dependent variable: GDP growth rate$_{i,t}$					
	(1)	(2)	(3)	(4)	(5)	(6)
Lights growth rate$_{i,t}$	0.041**	0.041**	0.012*	0.011	0.011*	0.019*
	[0.018]	[0.018]	[0.007]	[0.007]	[0.006]	[0.010]
FiW$_{i,t}$		-0.006	-0.007	0.026***	0.024***	
		[0.004]	[0.004]	[0.008]	[0.008]	
FiW$_{i,t}{}^2$				-0.005***	-0.005***	
				[0.002]	[0.002]	
Lights growth rate$_{i,t}$ × FiW$_{i,t}$			0.019***	0.019***	0.018***	
			[0.006]	[0.006]	[0.006]	
D(Partially Free)$_{i,t}$						-0.002
						[0.004]
D(Not Free)$_{i,t}$						-0.015
						[0.014]
Lights growth rate$_{i,t}$ × D(Partially Free)$_{i,t}$ [a]						0.041**
						[0.020]
Lights growth rate$_{i,t}$ × D(Not Free)$_{i,t}$ [b]						0.090***
						[0.030]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Common support	Yes	Yes	Yes	Yes	No	Yes
Observations	2,702	2,702	2,702	2,702	2,830	2,702
Countries	179	179	179	179	184	179
(Within) R^2	0.0254	0.0282	0.0537	0.0703	0.0579	0.0483
p-value H_0: a = b	-	-	-	-	-	0.110

Notes: Dependent variable is the GDP growth rate. The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW< 2, "Partially Free" if 2 ≤FiW≤ 4 and "Not Free" if FiW> 4. D(Free) and its interaction with ln(lights) are the omitted categories in column 6. Column 5 includes observations with missing data on GDP level in local currency units. Sample period: 1993-2008. Robust standard errors clustered by country in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A7: Robustness Checks V: Specification checks

	Dependent variable: $\ln(\text{GDP})_{i,t}$				Dependent variable: $\Delta\ln(\text{GDP})_{i,t}$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(\text{lights})_{i,t}$	0.156***	0.167***	-0.013	0.002				
	[0.036]	[0.029]	[0.014]	[0.027]				
$\Delta\ln(\text{lights})_{i,t}$					0.063**	0.001	0.006	
					[0.025]	[0.013]	[0.013]	
$\text{FiW}_{i,t}$	0.016	-0.001	0.008	-0.001		0.018**	0.017**	0.026
	[0.018]	[0.024]	[0.009]	[0.018]		[0.008]	[0.008]	[0.019]
$\text{FiW}^2_{i,t}$	-0.002	-0.001	-0.001	-0.001		-0.004***	-0.004***	-0.008***
	[0.003]	[0.004]	[0.002]	[0.003]		[0.001]	[0.002]	[0.003]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.009**	0.011**	0.009***	0.013***				
	[0.004]	[0.004]	[0.003]	[0.005]				
$\Delta\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$						0.027***	0.024***	0.029***
						[0.009]	[0.009]	[0.009]
$\ln(\text{lights})_{i,t-1}$		0.098***						
		[0.025]						
$\ln(\text{GDP})_{i,t-1}$			0.870***	1.000***			-0.104***	0.048
			[0.030]	[0.078]			[0.020]	[0.049]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,914	2,736	2,724	2,724	2,724	2,724	2,724	2,724
Countries	179	179	179	179	179	179	179	179
(Within) R^2	0.906	0.242	0.830	-	0.0376	0.0920	0.150	-
Country-specific trend	Yes	No	No	No	No	No	No	No
Estimation	OLS	OLS	OLS	GMM	OLS	OLS	OLS	GMM

Notes: The dependent variable in columns 1-4 is ln(GDP) in constant local currency units. The dependent variable in columns 5-8 is the yearly change in ln(GDP). ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Column 1 includes a country-specific time trend. The method of estimation in columns 4 and 8 is system-GMM (Blundell-Bond). Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A8: Robustness checks VI: GDP composition

	Dependent variable: $\ln(\text{GDP})_{i,t}$						
	Baseline	Consumption	Investment	Government	Exports	Imports	All
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln(\text{lights})_{i,t}$	0.215***	0.199***	0.194***	0.241***	0.216***	0.208***	0.219***
	[0.030]	[0.038]	[0.028]	[0.033]	[0.031]	[0.033]	[0.049]
$\text{FiW}_{i,t}$	0.003	0.001	0.003	-0.000	0.005	0.003	-0.002
	[0.023]	[0.023]	[0.023]	[0.022]	[0.022]	[0.022]	[0.022]
$\text{FiW}_{i,t}{}^2$	-0.001	-0.001	-0.001	-0.000	-0.001	-0.001	-0.000
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]
$x_{i,t}$		-0.004***	0.004***	-0.004**	0.002	-0.001	
		[0.001]	[0.001]	[0.002]	[0.001]	[0.001]	
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.008*	0.008**	0.008*	0.008*	0.007*	0.009**	0.008**
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]
$\ln(\text{lights})_{i,t} \times x_{i,t}$		-0.000	0.001*	-0.001	-0.000	0.000	
		[0.000]	[0.000]	[0.001]	[0.000]	[0.000]	
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,623	2,623	2,623	2,623	2,623	2,623	2,623
Countries	166	166	166	166	166	166	166
(Within) R^2	0.176	0.278	0.211	0.185	0.190	0.188	0.307

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Column 1 replicates the baseline specification for the reduced sample for which data on GDP subcomponents is available. Regressions in columns 2-6 include the percentage of GDP corresponding to the category in the header and its interaction with ln(lights) as additional controls: household final consumption expenditure in column 2; gross capital formation in column 3; general government final consumption in column 4; exports in column 5; imports in column 6. Column 7 includes all subcomponents and their interaction with ln(lights), bar imports. Robust standard errors clustered by country are shown in brackets. Sample period: 1992-2008. *** p<0.01, ** p<0.05, * p<0.1

Table A9: Robustness checks VII: Sectoral composition of the economy

	Dependent variable: $\ln(\text{GDP})_{i,t}$						
	Agriculture		Nat. resources	Oil	Industry	Manufacturing	Services
	(% land)	(% GDP)	(% GDP)	(% GDP)	(% GDP)	(% GDP)	(% GDP)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln(\text{lights})_{i,t}$	0.240***	0.265***	0.230***	0.220***	0.223***	0.199***	0.254***
	[0.043]	[0.044]	[0.037]	[0.052]	[0.043]	[0.045]	[0.039]
$\text{FiW}_{i,t}$	-0.005	0.004	-0.003	0.016	0.001	0.003	0.001
	[0.023]	[0.022]	[0.022]	[0.026]	[0.023]	[0.025]	[0.023]
$\text{FiW}_{i,t}{}^2$	0.000	-0.001	-0.001	-0.005	-0.001	-0.001	-0.000
	[0.004]	[0.004]	[0.004]	[0.005]	[0.004]	[0.005]	[0.004]
$x_{i,t}$	0.000	-0.009***	0.003	0.002	0.003	0.002	-0.000
	[0.002]	[0.002]	[0.002]	[0.003]	[0.002]	[0.002]	[0.001]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.012***	0.013***	0.009**	0.015**	0.012***	0.011**	0.012***
	[0.004]	[0.004]	[0.004]	[0.006]	[0.004]	[0.005]	[0.004]
$\ln(\text{lights})_{i,t} \times x_{i,t}$	-0.000	-0.002**	0.001**	-0.000	0.000	0.002**	-0.000
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,898	2,650	2,877	2,101	2,561	2,455	2,561
Countries	179	170	178	133	166	163	166
(Within) R^2	0.237	0.279	0.252	0.191	0.257	0.214	0.244

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Each column includes the variable in the header (x) and its interaction with ln(lights) as additional controls. All these variables correspond to sectoral shares of GDP (expressed as a percentage) except for column 1, which is the percentage of land devoted to agriculture. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A10: Robustness checks VIII: Urbanization and access to electricity

	Dependent variable: $\ln(\text{GDP})_{i,t}$				
	Population		Access to electricity		
	ln(Total)	Urban share	Total	Urban	Rural
	(1)	(2)	(3)	(4)	(5)
$\ln(\text{lights})_{i,t}$	-0.144	0.287***	0.217***	0.241***	0.223***
	[0.146]	[0.043]	[0.045]	[0.047]	[0.042]
$\text{FiW}_{i,t}$	-0.004	-0.011	-0.002	-0.014	0.002
	[0.024]	[0.022]	[0.023]	[0.025]	[0.023]
${\text{FiW}_{i,t}}^2$	-0.000	0.001	-0.001	0.000	-0.001
	[0.004]	[0.004]	[0.004]	[0.005]	[0.004]
$x_{i,t}$	0.079	0.004	-0.001	0.001	-0.000
	[0.114]	[0.004]	[0.001]	[0.001]	[0.001]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.011***	0.010**	0.012***	0.011**	0.008*
	[0.004]	[0.004]	[0.004]	[0.005]	[0.005]
$\ln(\text{lights})_{i,t} \times x_{i,t}$	0.026**	-0.001*	0.000	-0.000	0.000
	[0.010]	[0.001]	[0.000]	[0.000]	[0.000]
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	2,914	2,914	2,847	2,218	2,776
Countries	179	179	178	168	175
(Within) R^2	0.248	0.244	0.211	0.210	0.201

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Each column includes the variable in the header (x) [if time-varying] and its interaction with ln(lights) as additional controls. In column 1, log total population; in column2, the percentage of population living in urban areas; the percentage of population with access to electricity in column 3; the percentages of urban and rural population with access to electricity, respectively, in columns 4 and 5. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A11: Robustness checks IX: Initial level of development

Dependent variable: $\ln(\text{GDP})_{i,t}$	GDP per capita			Lights Digital Number (DN)			UN
	Level	Log	Quintiles	Level	Log	Quintiles	classification
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln(\text{lights})_{i,t}$	0.248***	0.487***	0.297***	0.232***	0.233***	0.243***	0.258***
	[0.038]	[0.115]	[0.036]	[0.038]	[0.042]	[0.047]	[0.079]
$\text{FiW}_{i,t}$	-0.005	-0.007	-0.008	-0.005	-0.004	-0.004	-0.004
	[0.023]	[0.023]	[0.022]	[0.022]	[0.022]	[0.022]	[0.023]
$\text{FiW}_{i,t}{}^2$	0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.012***	0.009*	0.010**	0.012***	0.012***	0.012***	0.012***
	[0.004]	[0.005]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]
$\ln(\text{lights})_{i,t} \times x_i$	-0.000	-0.036**		0.005	0.008		
	[0.000]	[0.015]		[0.006]	[0.029]		
$\ln(\text{lights})_{i,t} \times \text{D(Quintile=2)}_i$			-0.017			-0.045	
			[0.065]			[0.068]	
$\ln(\text{lights})_{i,t} \times \text{D(Quintile=3)}_i$			-0.148***			0.041	
			[0.047]			[0.064]	
$\ln(\text{lights})_{i,t} \times \text{D(Quintile=4)}_i$			-0.075			-0.027	
			[0.047]			[0.062]	
$\ln(\text{lights})_{i,t} \times \text{D(Quintile=5)}_i$			-0.060			0.028	
			[0.084]			[0.063]	
$\ln(\text{lights})_{i,t} \times \text{D(Developing)}_i$							-0.038
							[0.081]
$\ln(\text{lights})_{i,t} \times \text{D(Least developed)}_i$							-0.014
							[0.084]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,863	2,863	2,863	2,914	2,914	2,914	2,914
Countries	175	175	175	179	179	179	179
(Within) R^2	0.251	0.258	0.263	0.237	0.236	0.240	0.237

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Column 1 includes the interaction of initial GDP per capita in constant USD with ln(lights) as an additional control, while column 2 includes the interaction with the natural log of initial GDP. Column 3 includes separate interactions with dummies for each quintile in the distribution of initial GDP per capita. The omitted category is the first quintile. Columns 4-6 replicate the analysis for the initial value of the lights digital number. Column 7 includes interactions with separate dummies for countries classified as "Developing" and "Least Developed" by the United Nations. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A12: Robustness Checks X: Human capital and informality

	Dependent variable: $\ln(\text{GDP})_{i,t}$							
	Education		Health		Informality			
	Mean years of schooling	Net primary enrolment rate	Life expectancy	Infant mortality rate	Firms starting formal	Years before formalizing	Competition from informals	Constrained by informals
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(\text{lights})_{i,t}$	0.236***	0.195***	0.165*	0.256***	0.309**	0.263***	0.279***	0.300***
	[0.045]	[0.054]	[0.086]	[0.040]	[0.130]	[0.046]	[0.071]	[0.062]
$\text{FiW}_{i,t}$	-0.014	0.020	-0.016	-0.024	0.002	0.001	-0.001	-0.001
	[0.024]	[0.026]	[0.023]	[0.022]	[0.026]	[0.026]	[0.025]	[0.024]
$\text{FiW}^2{}_{i,t}$	0.003	-0.002	0.002	0.004	-0.001	-0.001	-0.001	-0.001
	[0.004]	[0.005]	[0.004]	[0.004]	[0.005]	[0.005]	[0.004]	[0.004]
$x_{i,t}$	-0.000	-0.001	0.013***	-0.006***				
	[0.019]	[0.001]	[0.003]	[0.001]				
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.013***	0.011**	0.013***	0.012***	0.010**	0.010**	0.010**	0.010**
	[0.004]	[0.005]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]
$\ln(\text{lights})_{i,t} \times x_{i,t}$	-0.000	-0.001	0.001	-0.001*	-0.001	-0.019	-0.000	-0.002
	[0.005]	[0.001]	[0.001]	[0.000]	[0.001]	[0.022]	[0.001]	[0.002]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,553	1,588	2,855	2,914	2,161	2,161	2,209	2,195
Countries	173	157	178	179	130	130	133	132
(Within) R^2	0.220	0.126	0.260	0.275	0.252	0.252	0.258	0.260

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Each column includes the variable in the header (x) [if time-varying] and its interaction with ln(lights) as additional controls. In column 1, the mean number of years of schooling; In column 2, the net primary enrolment rate; The specification in column 3 includes life expectancy while the one in column 4 uses the infant mortality rate; Columns 5-8 include various time-invariant measures of informality, which were recorded for some countries after the end of the sample period: The percentage of firms formally registered when they started operations in column 5; the number of years that firms operated without formal registration in column 6; the percentage of firms that report facing competition from informal firms in column 7 and the percentage of firms that report being constrained by the activities of informal firms in column 8. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A13: Robustness Checks XI: Data quality and statistical capacity

	Dependent variable: $\ln(\text{GDP})_{i,t}$											
	Baseline (reduced sample)	Nat. acc. base year $\geq$ 1991	CPI base year $\geq$ 1991	Pop. census $\geq$ 1991	Agr. census $\geq$ 1991	BOP manual v5	SDDS	Vital registr. system	External debt is actual	Industrial production index	Imp/Exp price index	Data quality score
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$\ln(\text{lights})_{i,t}$	0.273***	0.248***	0.274***	0.276***	0.279***	0.242***	0.280***	0.253***	0.265***	0.283***	0.279***	0.267***
	[0.045]	[0.046]	[0.059]	[0.045]	[0.052]	[0.072]	[0.048]	[0.047]	[0.071]	[0.048]	[0.047]	[0.069]
$\text{FiW}_{i,t}$	0.010	0.012	0.010	0.010	0.011	0.011	0.008	0.011	0.010	0.007	0.009	0.010
	[0.028]	[0.028]	[0.028]	[0.027]	[0.028]	[0.028]	[0.027]	[0.028]	[0.028]	[0.028]	[0.027]	[0.028]
$\text{FiW}_{i,t}{}^2$	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.008*	0.009**	0.008*	0.008*	0.008*	0.009*	0.007	0.009**	0.008*	0.008	0.008*	0.008*
	[0.005]	[0.004]	[0.005]	[0.004]	[0.005]	[0.005]	[0.005]	[0.004]	[0.005]	[0.005]	[0.005]	[0.005]
$\ln(\text{lights})_{i,t} \times x_i$		0.056	-0.003	-0.004	-0.020	0.038	-0.051	0.044	0.010	-0.051	-0.044	0.001
		[0.060]	[0.054]	[0.055]	[0.051]	[0.070]	[0.048]	[0.066]	[0.069]	[0.071]	[0.060]	[0.012]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,938	1,938	1,938	1,938	1,938	1,938	1,938	1,938	1,938	1,938	1,938	1,938
Countries	117	117	117	117	117	117	117	117	117	117	117	117
(Within) R^2	0.238	0.240	0.238	0.238	0.238	0.239	0.239	0.239	0.238	0.239	0.238	0.238

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Column 1 shows the baseline specification for the reduced sample for which cross-sectional data on statistical capacity is available from the World Bank (2002). Starting in column 2, each column includes the interaction of the variable in the header (x_i) with ln(lights): in columns 2 and 3, respective dummies if the base year of the national accounts or the consumer price index is more recent than 1991. In columns 4 and 5, respective dummies if there was a population or agricultural census after 1991. In columns 6 and 7, dummies for the adoption of the Balance of Payments manual v. 5 or the Special Data Dissemination Standard (SDDS). In column 8, a dummy for the existence of a vital registration system. In column 9, a dummy if information on external debt is actual or preliminary (rather than estimated). In columns 10 and 11, dummies for the availability of a industrial production index or an import/export price index. In column 12, the data quality score, which ranges from 0 to 10 with higher values corresponding to better data quality. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A14: Robustness Checks XII: State capacity

	Dependent variable: $\ln(\text{GDP})_{i,t}$						
	Baseline	ln(Average days for letter return)		Share of letters returned		Share of letters returned (< 90 days)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln(\text{lights})_{i,t}$	0.273***	0.190	0.284	0.317***	0.259***	0.332***	0.288***
	[0.041]	[0.273]	[0.256]	[0.053]	[0.056]	[0.039]	[0.044]
$\text{FiW}_{i,t}$	0.004		0.004		0.004		0.004
	[0.025]		[0.025]		[0.025]		[0.025]
$\text{FiW}_{i,t}{}^2$	-0.002		-0.002		-0.001		-0.002
	[0.004]		[0.004]		[0.004]		[0.004]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.008*		0.008**		0.009**		0.007*
	[0.004]		[0.004]		[0.004]		[0.004]
$\ln(\text{lights})_{i,t} \times x_{i,t}$		0.022	-0.002	-0.018	0.023	-0.085	-0.041
		[0.049]	[0.046]	[0.086]	[0.079]	[0.078]	[0.073]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,455	2,455	2,455	2,455	2,455	2,455	2,455
Countries	150	150	150	150	150	150	150
(Within) R^2	0.247	0.236	0.247	0.235	0.247	0.237	0.247

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Column 1 replicates the baseline specification for the reduced sample for which time-invariant information on state capacity is available in Chong et al. (2014). Regressions in columns 2-6 include the interaction of the variable in the header with ln(lights) as additional control: the log average number of days for a letter to be returned in columns 2 and 3; the share of letters returned in columns 4 and 5; the share of letters returned within 90 days in columns 6 and 7. Robust standard errors clustered by country are shown in brackets. Sample period: 1992-2008. *** p<0.01, ** p<0.05, * p<0.1

Table A15: Robustness Checks XIII: Transparency and corruption

	Dependent variable: $\ln(\text{GDP})_{i,t}$								
	Corruption Perception Index (CPI)			Control of Corruption Index (CCI)			Transparency index (HRV)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\ln(\text{lights})_{i,t}$	0.130***	0.126***	0.086*	0.172***	0.177***	0.162***	0.270***	0.204***	0.195***
	[0.041]	[0.048]	[0.045]	[0.035]	[0.044]	[0.043]	[0.037]	[0.053]	[0.052]
$\text{FiW}_{i,t}$	-0.005		-0.005	0.002		0.009	0.016		0.018
	[0.022]		[0.021]	[0.024]		[0.024]	[0.027]		[0.027]
$\text{FiW}_{i,t}{}^2$	0.000		0.001	-0.001		-0.002	-0.003		-0.004
	[0.005]		[0.005]	[0.004]		[0.004]	[0.005]		[0.005]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.020***		0.020***	0.009*		0.008*	0.009**		0.007*
	[0.007]		[0.007]	[0.005]		[0.004]	[0.004]		[0.004]
$x_{i,t}$		0.023*	0.024*		0.047*	0.044*		0.012	0.012
		[0.013]	[0.013]		[0.026]	[0.025]		[0.008]	[0.007]
$\ln(\text{lights})_{i,t} \times x_{i,t}$		-0.009*	-0.008		-0.010	-0.004		-0.009**	-0.007**
		[0.005]	[0.005]		[0.011]	[0.010]		[0.004]	[0.003]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,309	1,309	1,309	1,703	1,703	1,703	2,015	2,015	2,015
Countries	168	168	168	176	176	176	122	122	122
(Within) R^2	0.094	0.088	0.111	0.127	0.125	0.133	0.283	0.279	0.293

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. The Corruption Perceptions Index (CPI) used in columns 1-3 is produced by Transparency International and has been re-scaled from 0 to 10, with larger values corresponding to decreased perception of corruption. The Control of Corruption Index (CCI) used in columns 4-6 is produced by the World Bank and ranges from -2.5 to 2.5, with larger values corresponding to decreased perception of corruption. The source of the HRV transparency index used in columns 7-9 is Hollyer et al. (2014). The HRV transparency index is based on data availability in the World Bank's WDI, with larger values corresponding to increased availability of information and transparency. Observed values of the HRV index range from -3.04 to 9.98. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A16: The night-lights elasticity of GDP: Chinese provinces vs US states

	Dependent variable: $\ln(\text{GDP})_{i,t}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\text{lights})_{i,t}$	0.737***	0.307***	0.492***	0.044	0.178***	
	[0.049]	[0.045]	[0.080]	[0.051]	[0.053]	
$\ln(\text{lights})_{i,t} \times \text{D(China)}_i$		0.488***	0.654***	0.673***	0.909***	0.955***
		[0.067]	[0.128]	[0.054]	[0.057]	[0.054]
$\text{Population}_{i,t}$			0.039**			
			[0.015]			
$\ln(\text{lights})_{i,t} \times \text{Population}_{i,t}$			0.001			
			[0.002]			
$\ln(\text{lights})_{i,t} \times \text{lights}_{i,1992}$				0.055***		
				[0.010]		
Unit FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,312	1,312	738	1,312	1,722	1,722
Units	82	82	82	82	82	82
(Within) R^2	0.516	0.553	0.620	0.608	0.706	0.739
ln(lights) x year FE	No	No	No	No	No	Yes
Sample period	93-08	93-08	99-08	93-08	93-13	93-13

Notes: Sample includes 50 US states (+ district of Columbia) and 31 Chinese provinces. Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the average lights digital number (0-63) across geographic sub-units (ADM2). In column 3, population is measured in millions. All regressions include unit and year fixed effects. Column six also includes a full set of year fixed effects interacted with ln(lights). Robust standard errors clustered by unit (state/province) in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A17: The role of institutions in the manipulation of GDP figures (Full Table)

Dependent variable: $\ln(\text{GDP})_{i,t}$	Elected legislature	Elected executive	Central bank independence	Constitutional court	Communist history
	(1)	(2)	(3)	(4)	(5)
$\ln(\text{lights})_{i,t}$	0.098	0.220***	0.194***	0.225***	0.203***
	[0.102]	[0.040]	[0.046]	[0.032]	[0.032]
$\text{FiW}_{i,t}$	0.008	-0.019	-0.036	-0.007	-0.007
	[0.059]	[0.025]	[0.039]	[0.029]	[0.023]
${\text{FiW}_{i,t}}^2$	0.003	0.001	0.005	0.002	0.001
	[0.005]	[0.004]	[0.005]	[0.004]	[0.004]
$\text{D(Institution)}_{i,t}$	0.129	0.001	-0.034	-0.012	
	[0.177]	[0.046]	[0.059]	[0.053]	
$\text{FiW}_{i,t} \times \text{D(Institution)}_{i,t}$	-0.026	0.012	0.009	-0.007	-0.033
	[0.047]	[0.015]	[0.030]	[0.016]	[0.023]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$ [a]	0.049**	0.019***	0.025***	0.024***	0.011**
	[0.021]	[0.006]	[0.008]	[0.007]	[0.004]
$\ln(\text{lights})_{i,t} \times \text{D(Institution)}_{i,t}$	0.168*	0.041**	0.025	0.021	0.032
	[0.092]	[0.020]	[0.025]	[0.016]	[0.057]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(Institution)}_{i,t}$ [b]	-0.040*	-0.012**	-0.011**	-0.013*	0.022**
	[0.022]	[0.006]	[0.005]	[0.007]	[0.010]
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	2,451	2,490	2,073	2,416	2,914
Countries	153	154	139	152	179
(Within) R^2	0.280	0.269	0.211	0.242	0.258
p-value H_0: a + b = 0	0.074	0.124	0.010	0.003	0.001

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Each column includes the dummy variable in the for the presence of the institution in the header, D(Institution), and all its interactions with ln(lights) and FiW: elected legislature in column 1, elected chief executive in column 2, central bank with authority over monetary policy in column 3; existence of national constitutional court in column 4; communist regime at some point in column 5. All of these variables are time-varying with the exception of the dummy for communist history in column 5. Sample period: 1992-2008. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A18: Incentives for GDP manipulation I: Economic under-performance and elections (full table)

Dependent variable: $\ln(\text{GDP})_{i,t}$	Low GDP growth		Year before national election			
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\text{lights})_{i,t}$	0.241***	0.256***	0.260***	0.261***	0.288***	0.288***
	[0.042]	[0.039]	[0.039]	[0.040]	[0.034]	[0.035]
$\text{D(Event)}_{i,t}$	0.029*	0.021*		-0.000		0.009**
	[0.015]	[0.011]		[0.007]		[0.004]
$\text{FiW}_{i,t}$	0.001		-0.009	-0.010		
	[0.023]		[0.024]	[0.024]		
${\text{FiW}_{i,t}}^2$	-0.001		0.001	0.001		
	[0.004]		[0.004]	[0.004]		
$\ln(\text{lights})_{i,t} \times \text{D(Event)}_{i,t}$	-0.008	-0.001		-0.002		-0.001
	[0.007]	[0.005]		[0.003]		[0.002]
$\text{D(Event)}_{i,t} \times \text{FiW}_{i,t}$	-0.009			0.004		
	[0.006]			[0.003]		
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$	0.006		0.011**	0.010**		
	[0.004]		[0.004]	[0.004]		
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(Event)}_{i,t}$	0.005*			0.002		
	[0.003]			[0.001]		
$\text{D(Partially Free)}_{i,t}$		0.003			-0.006	-0.001
		[0.019]			[0.018]	[0.019]
$\text{D(Not Free)}_{i,t}$		0.014			0.012	0.004
		[0.035]			[0.036]	[0.035]
$\text{D(Event)}_{i,t} \times \text{D(Partially Free)}_{i,t}$		-0.028*				-0.016**
		[0.016]				[0.007]
$\text{D(Event)}_{i,t} \times \text{D(Not Free)}_{i,t}$		-0.026				0.024**
		[0.028]				[0.012]
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t}$		0.011			0.013	0.014
		[0.012]			[0.012]	[0.012]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t}$		0.010			0.028*	0.025*
		[0.015]			[0.015]	[0.014]
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t} \times \text{D(Event)}_{i,t}$		0.001				0.001
		[0.009]				[0.005]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t} \times \text{D(Event)}_{i,t}$		0.028**				0.012*
		[0.013]				[0.006]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,914	2,914	2,500	2,500	2,500	2,500
Countries	179	179	154	154	154	154
(Within) R^2	0.249	0.240	0.245	0.247	0.235	0.239

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW< 2, "Partially Free" if 2 ≤FiW≤ 4 and "Not Free" if FiW> 4. D(Free) and its interaction with ln(lights) are the omitted categories in columns 2, 5, 6. In columns 1-2, $\text{D(Event)}_{i,t}$ is a dummy equal to one if the value of ln(lights) demeaned by country and year is negative. In columns 3-6, $\text{D(Event)}_{i,t}$ is a dummy equal to one if there is a national election in the following year. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A19: Incentives for GDP manipulation II: Eligibility for IDA loans and grants (full table)

Dependent variable: $\ln(\text{GDP})_{i,t}$	Baseline results (reduced sample)		Changing elasticity above GNI threshold			Galiani et al. (2017) crossings	Ineligible countries	Crossings ≤ 1
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(\text{lights})_{i,t}$	0.252***	0.210***	0.233***	0.244***	0.226***	0.225***	0.239***	0.234***
	[0.037]	[0.042]	[0.037]	[0.035]	[0.041]	[0.041]	[0.041]	[0.041]
$\text{FiW}_{i,t}$		-0.009			-0.014	-0.013	-0.007	-0.009
		[0.037]			[0.034]	[0.034]	[0.034]	[0.034]
$\text{FiW}_{i,t}{}^2$		0.001			-0.000	-0.000	-0.001	-0.002
		[0.006]			[0.005]	[0.005]	[0.005]	[0.005]
$\text{D(GNI>threshold)}_{i,t}$			0.130**	0.077*	-0.166**	-0.182**	-0.198***	-0.168**
			[0.052]	[0.044]	[0.066]	[0.072]	[0.071]	[0.076]
$\text{FiW}_{i,t} \times \text{D(GNI>threshold)}_{i,t}$					0.078***	0.087***	0.087***	0.083***
					[0.024]	[0.026]	[0.025]	[0.026]
$\text{GNI}_{i,t}$				0.112***	0.108***	0.102***	0.125***	0.112***
				[0.036]	[0.034]	[0.034]	[0.037]	[0.033]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$		0.012*			0.004	0.004	0.004	0.002
		[0.007]			[0.006]	[0.006]	[0.006]	[0.006]
$\ln(\text{lights})_{i,t} \times \text{D(GNI>threshold)}_{i,t}$			0.061*	0.081***	0.001	0.001	-0.000	-0.018
			[0.032]	[0.025]	[0.035]	[0.037]	[0.036]	[0.031]
$\ln(\text{lights})_{i,t} \times \text{GNI}_{i,t}$				-0.048***	-0.043***	-0.040***	-0.046***	-0.046***
				[0.010]	[0.010]	[0.010]	[0.011]	[0.008]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(GNI>threshold)}_{i,t}$					0.023*	0.023*	0.024*	0.028**
					[0.013]	[0.014]	[0.013]	[0.012]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,308	1,308	1,308	1,308	1,308	1,308	1,357	1,274
Countries	82	82	82	82	82	82	85	80
(Within) R^2	0.205	0.225	0.252	0.317	0.359	0.361	0.365	0.369

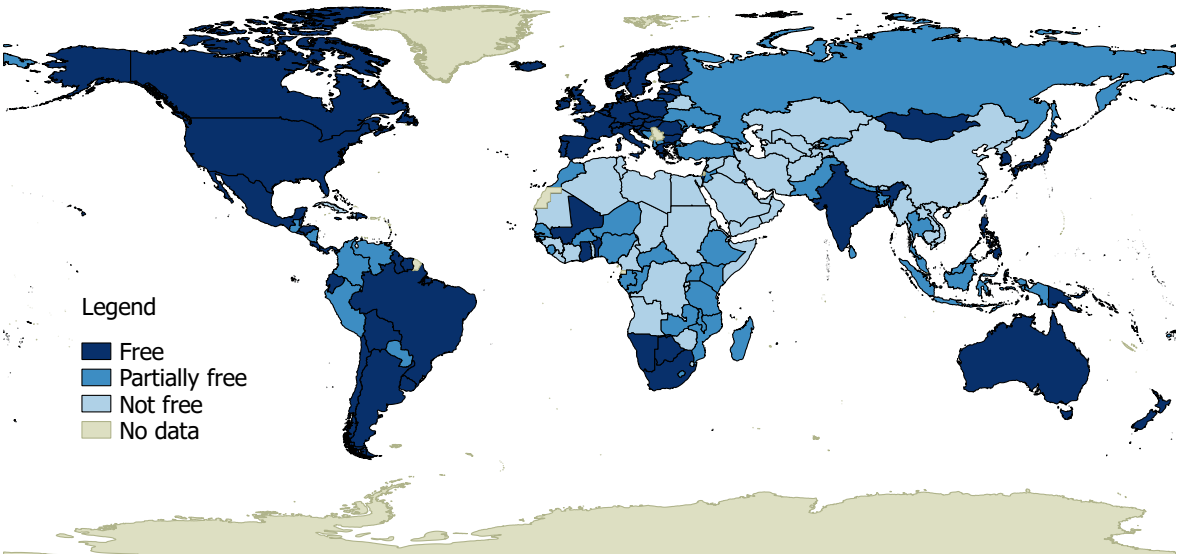
Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. GNI is Gross National Income per capita in thousands of current US dollars using Atlas method. $\text{D(GNI>threshold)}_{i,t}$ equals one if GNI per capita is above the yearly value set by IDA for eligibility for loans and grants. Robust standard errors clustered by country in brackets. Baseline sample includes all countries that were eligible for IDA aid at some point in the sample period (current + graduates). Column 6 uses the crossing dates reported by Galiani et al. (2017). Column 7 includes Syria, Turkmenistan and Ukraine, which were excluded from the IDA program. Column 8 excludes Guyana and Indonesia, which cross the threshold more than once. *** p<0.01, ** p<0.05, * p<0.1

Table A20: Preventing GDP manipulation: The Special Data Dissemination Standard (full table)

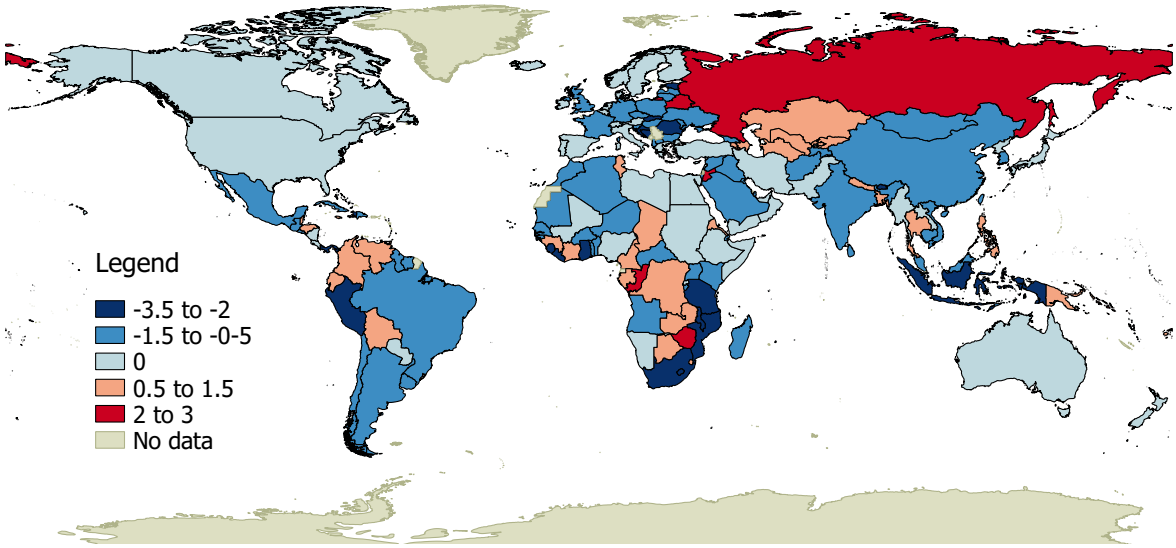
Dependent variable: $\ln(\text{GDP})_{i,t}$	Selection		Treatment effect	
	(1)	(2)	(3)	(4)
$\ln(\text{lights})_{i,t}$	0.231***	0.262***	0.242***	0.270***
	[0.040]	[0.036]	[0.040]	[0.037]
$\text{FiW}_{i,t}$	-0.005		-0.003	
	[0.024]		[0.023]	
$\text{FiW}_{i,t}{}^2$	-0.000		-0.001	
	[0.004]		[0.004]	
$\text{D(SDDS country)}_i \times \text{FiW}_{i,t}$	0.016		0.018	
	[0.017]		[0.018]	
$\ln(\text{lights})_{i,t} \times \text{D(SDDS country)}_i$	0.070	0.023	0.011	-0.024
	[0.055]	[0.051]	[0.053]	[0.049]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t}$ [a]	0.013**		0.012**	
	[0.005]		[0.005]	
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(SDDS country)}_i$ [b]	-0.016		-0.013	
	[0.011]		[0.012]	
$\text{D(Partially Free)}_{i,t}$		-0.004		-0.005
		[0.025]		[0.026]
$\text{D(Not Free)}_{i,t}$		0.001		-0.002
		[0.048]		[0.048]
$\text{D(SDDS country)}_i \times \text{D(Partially Free)}_{i,t}$		-0.002		0.010
		[0.034]		[0.044]
$\text{D(SDDS country)}_i \times \text{D(Not Free)}_{i,t}$		0.061		0.023
		[0.055]		[0.064]
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t}$ [c]		0.017		0.016
		[0.014]		[0.014]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t}$ [d]		0.031*		0.031*
		[0.018]		[0.018]
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t} \times \text{D(SDDS country)}_i$ [e]		-0.008		-0.004
		[0.025]		[0.032]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t} \times \text{D(SDDS country)}_i$ [f]		0.034		0.026
		[0.044]		[0.049]
$\text{D(SDDS suscription)}_{i,t}$			0.036	0.037
			[0.029]	[0.027]
$\text{D(SDDS suscription)}_{i,t} \times \text{FiW}_{i,t}$			0.012	
			[0.011]	
$\text{D(SDDS suscription)}_{i,t} \times \text{D(Partially Free)}_{i,t}$				-0.006
				[0.036]
$\text{D(SDDS suscription)}_{i,t} \times \text{D(Not Free)}_{i,t}$				0.091**
				[0.044]
$\ln(\text{lights})_{i,t} \times \text{D(SDDS suscription)}_{i,t}$			0.010	0.009
			[0.015]	[0.013]
$\ln(\text{lights})_{i,t} \times \text{FiW}_{i,t} \times \text{D(SDDS suscription)}_{i,t}$ [g]			-0.007	
			[0.009]	
$\ln(\text{lights})_{i,t} \times \text{D(Partially Free)}_{i,t} \times \text{D(SDDS suscription)}_{i,t}$ [h]				0.004
				[0.022]
$\ln(\text{lights})_{i,t} \times \text{D(Not Free)}_{i,t} \times \text{D(SDDS suscription)}_{i,t}$ [i]				-0.077**
				[0.035]
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	2,914	2,914	2,914	2,914
Countries	179	179	179	179
(Within) R^2	0.239	0.225	0.249	0.236
p-value H_0: a + b = 0	0.776		0.975	
p-value H_0: c + e = 0		0.686		0.659
p-value H_0: d + f = 0		0.107		0.212
p-value H_0: a + b + g = 0			0.492	
p-value H_0: c + e + h = 0				0.379
p-value H_0: d + f + i = 0				0.495

Notes: Dependent variable is ln(GDP) in constant local currency units. ln(lights) is the natural logarithm of the area-weighted average of grid-level lights digital number (0-63). The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW< 2, "Partially Free" if 2 ≤FiW≤ 4 and "Not Free" if FiW> 4. D(Free) and its interaction with ln(lights) are the omitted categories in even-numbered columns. D(SDDS country)_i is a dummy equal to one for countries that joined the SDDS during the sample period. $\text{D(SDDS suscription)}_{i,t}$ is a dummy equal to one in the years after subscription to the SDDS. Sample period: 1992-2008. Robust standard errors, clustered by country, are shown in brackets. *** p<0.01, ** p<0.05, * p<0.1

Figure A1: The Freedom in the World (FiW) Index



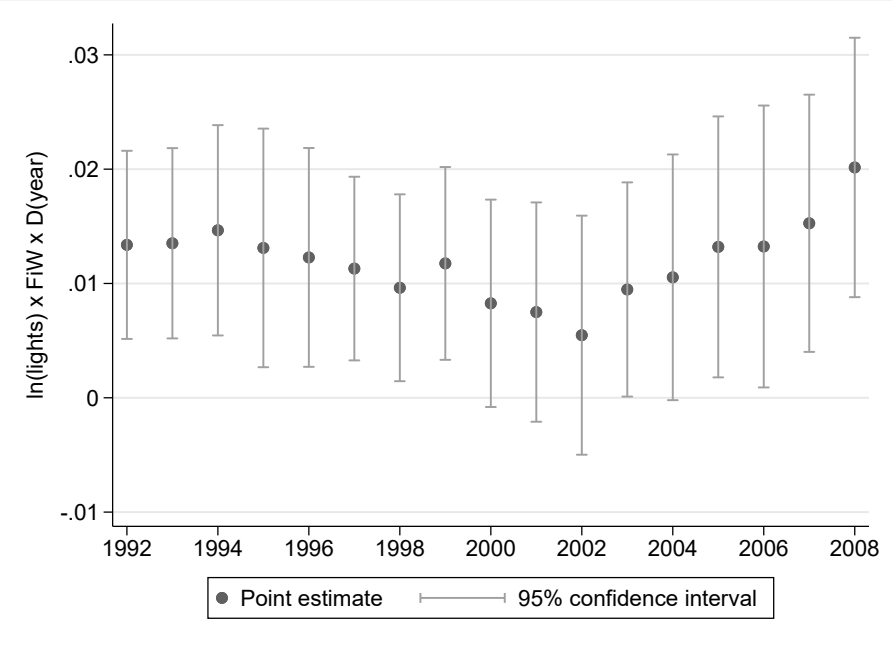
(a) Average 1992-2008



(b) Change between 1992 and 2008

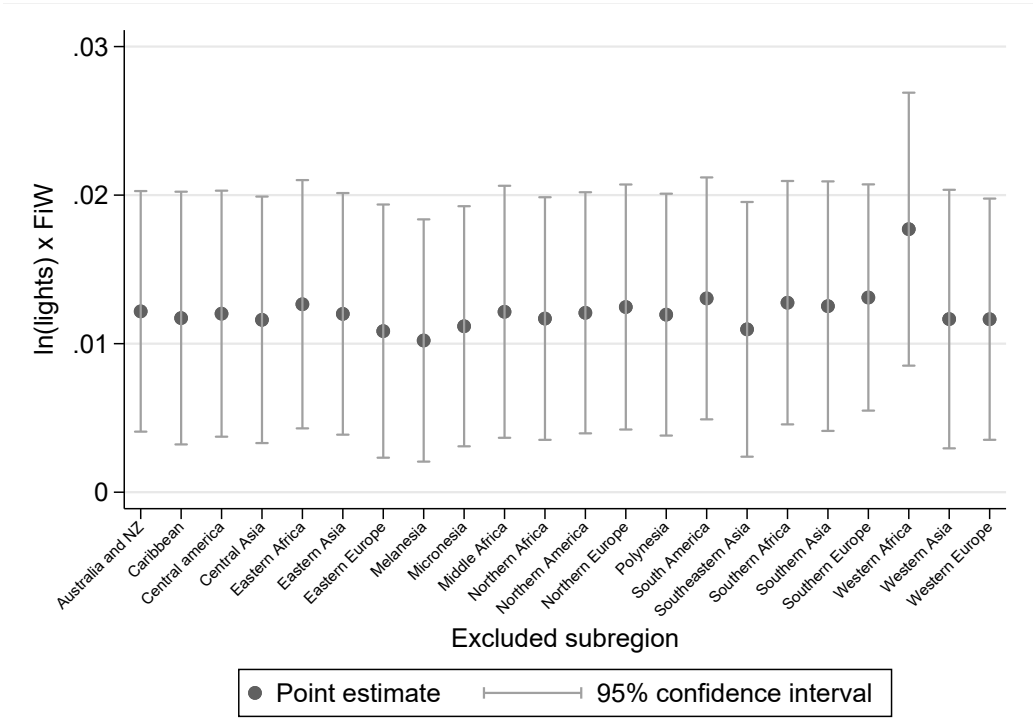
Note: Panel (a) shows the average value of the adjusted Freedom in the World (FiW) index per country for the period 1992-2008. FiW ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Country is "Free" if FiW$<$ 2, "Partially Free" if 2 $\leq$FiW$\leq$ 4 and "Not Free" if FiW$>$ 4. Panel (b) shows the difference in the FiW index between the years 1992 and 2008. For countries lacking data for 1992 the earliest year with available information was used: 1993 for Andorra, Czech Republic, Eritrea and Monaco; 1994 for Palau; 1999 for Timor-Leste and Slovakia.

Figure A2: Year-specific estimates of the autocracy gradient in the night-lights elasticity of GDP



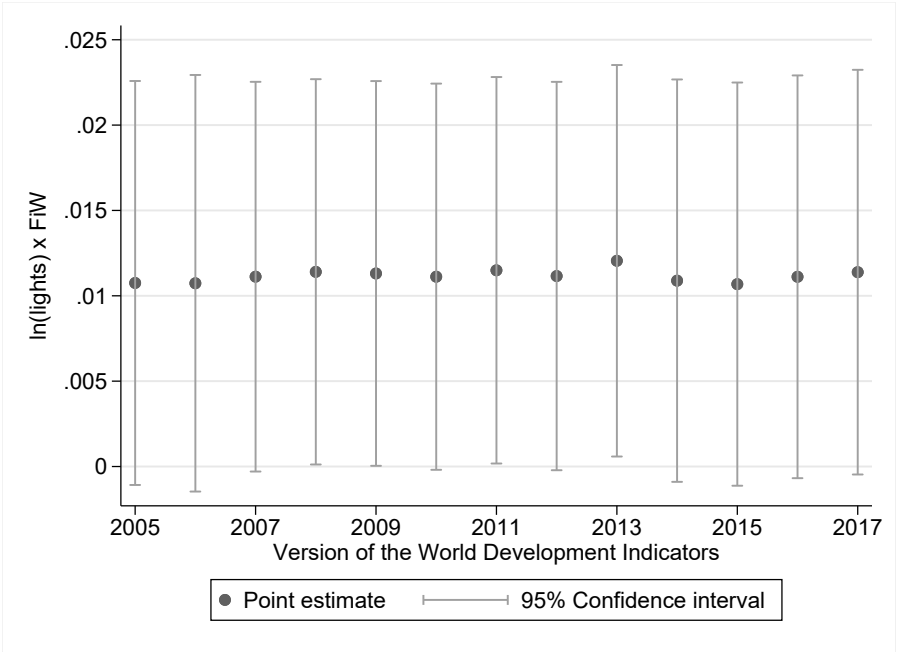
Note: Figure shows point estimates and 95% confidence intervals for a regression of ln(GDP) on a full set of triple interactions of year indicators, ln(lights) and the adjusted Freedom in the World (FiW) index. FiW ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Other regressors are ln(lights), FiW, FiW squared, and separate year interactions with ln(lights) and FiW. Regressions in both panels include country and year fixed effects. Standard errors clustered by country. Sample includes 2,914 observations from 179 countries. Sampler period: 1992-2008.

Figure A3: The effect of subregion exclusions on the autocracy gradient of the night-lights elasticity of GDP



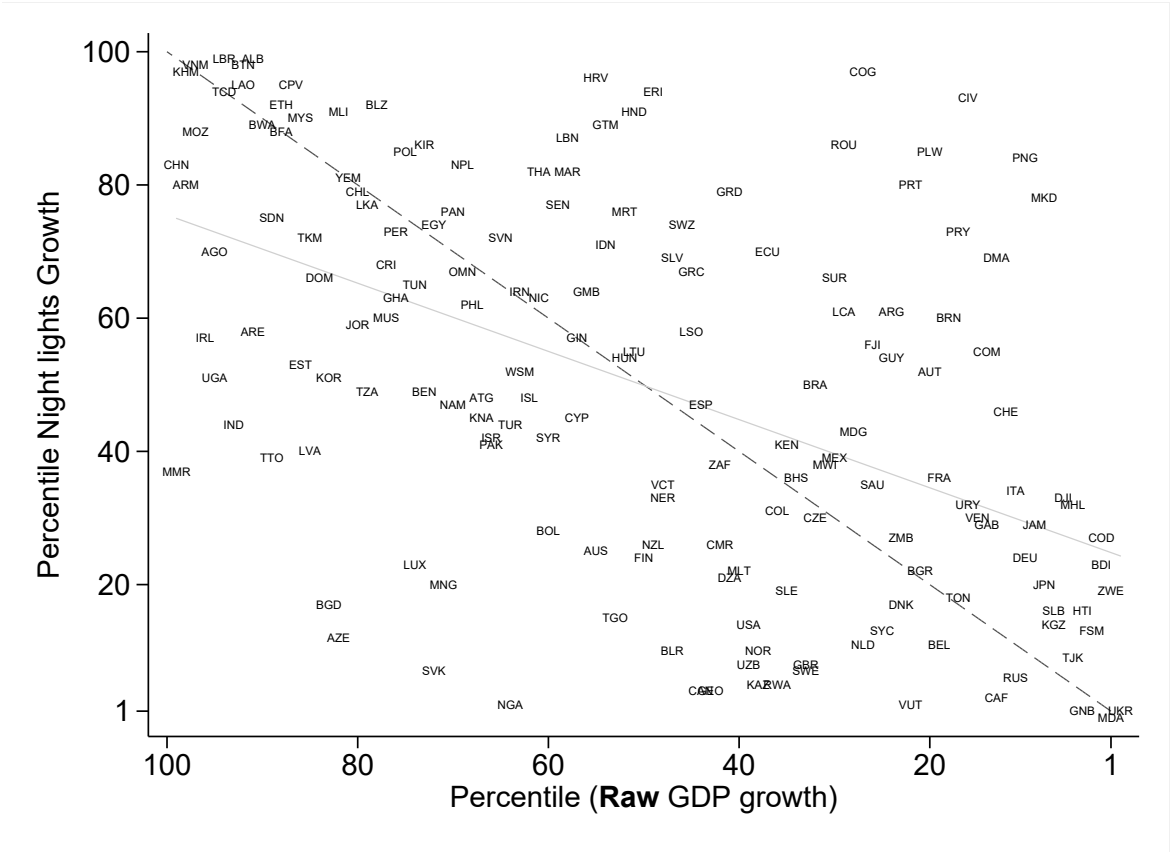
Note: Graph shows point estimates and 95% confidence intervals from regressions of ln(GDP) on the interaction of ln(lights) and FiW, in which the subregion indicated at the bottom has been excluded from the sample. The adjusted Freedom in the World (FiW) index ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Other regressors [estimates not shown] are ln(lights), FiW and FiW squared, as well as country and year fixed effects. Standard errors clustered by country. Subregional classification is based on the United Nations geoscheme. Sample period: 1992-2008.

Figure A4: Preventing GDP manipulation: WDI data revisions



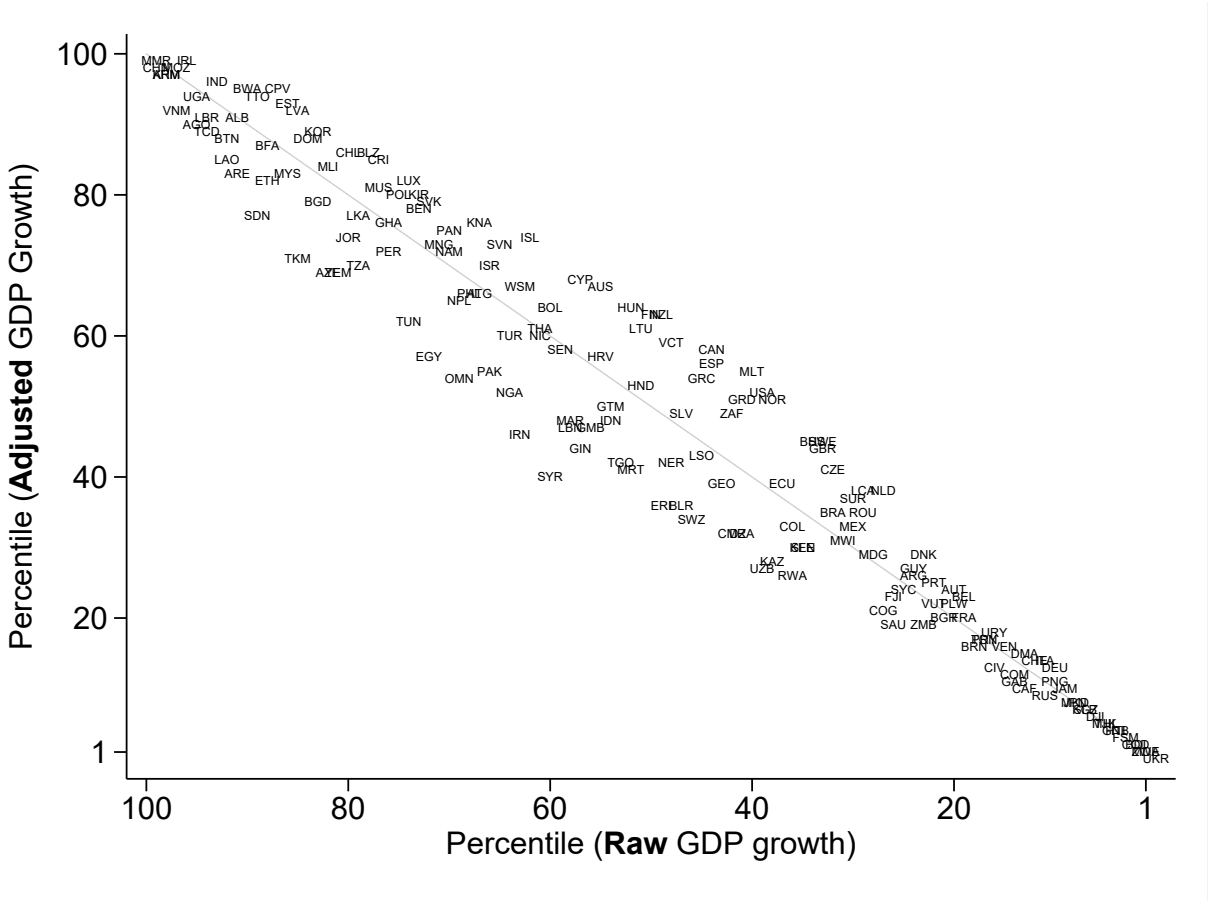
Note: The figure shows point estimates and 95% confidence intervals for a set of fixed-effects (country and year) regressions of ln(GDP) on the interaction of ln(lights) and the adjusted Freedom in the World (FiW) index. FiW ranges from 0 to 6, with lower values corresponding to greater enjoyment of civil liberties and political rights. Regressors also include FiW, FiW squared [estimates not reported]. The estimates shown correspond to separate regressions, each one using GDP figures from a different release year of the World Development Indicators (2005-2017). All regressions were estimated with a fixed sample of 1,970 observations from 173 countries between 1992 and 2003. Standard errors clustered by country.

Figure A5: Long-run growth percentiles of GDP and Nighttime Lights



Note: Graph shows a scatter of each country's percentile in the long-run GDP and nighttime lights growth distributions (1992-2006). Dashed line corresponds to the 45-degree line. Lighter solid line shows the line of best fit.

Figure A6: Correcting for manipulation in long-run GDP growth estimates



Note: Graph shows a scatterplot of raw and adjusted percentile of the change in ln(GDP) between 1992/3 and 2005/6 (two-year average in both cases). The x-axis shows the percentile corresponding to the raw data in the World Bank's World Development Indicators. The y-axis shows the adjusted percentile after the ln GDP series has been adjusted for manipulation. The adjustment is based on the estimate of the bias parameter σ implied by the results in column 6 of Table 2. See Section 3.2 for the underlying empirical model.