Center for European, Governance and Economic Development Research
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Discussion Papers

Number 247 – June 2015

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ISSN: 1439-2305

The Effect of Income on Democracy Revisited
A Flexible Distributional Approach

May 30, 2015

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Abstract

We reexamine the effect of economic development on the level of democracy based on the data sets of Acemoglu et al. (2008) with a novel regression specification utilizing a zero-one-inflated beta distribution for the response variable democracy. The zero-one-inflated beta distribution is more appropriate for continuous but bounded responses with non-zero probabilities for the boundaries of the support than the other frequently used distributions such as the normal. Contrary to the results of Acemoglu et al. (2008), some support of causality is found particularly when explaining the variance of the democracy variables. Since our analysis highlights that the distribution of democracy is bimodal, we approximate the modes using two separate samples of OECD and non-OECD countries. Our results indicate that there are differences not only in the mean but also in other features of the response distribution between the two groups. For instance, higher incomes are associated with higher democracy levels in the OECD sub-sample, however for non-OECD the association is insignificant.

KEYWORDS AND PHRASES: income; democracy; beta distribution; bimodal; OECD.

JEL: O1; C16

1 Introduction

The relationship between income and democracy has been widely investigated since the beginning of the twentieth century. While Aristotle (1932) already argued that there is a positive association between both factors more than twenty centuries ago, Lipset's law formalized it by stating that higher economic growth leads to a higher democracy level (Lipset, 1959). This law is (likely) the foundation of the modernization theory that asserts economic development as the

[1] This project has been funded with support from the European Commission. This publication reflects the views of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

major factor influencing the political environment. A number of authors, including Barro (1999), Dahl (1971), Huntington (1991) or Rueschemeyer and Stephens & Stephens (1992), additionally contributed to the findings showing that higher incomes are associated with higher levels of democracy.

Nevertheless, recent empirical findings show a less clear story. Some support for a positive association between income and democracy is indeed found by Londregan & Poole (1996) when using panel data to estimate a causal relationship as stated by Lipset (1959) but only after considering leadership type and political context as control factors. Murtin & Warcziag (2014) observe that the transition to democracy is linked to a fractional shift of illiterate to primary school graduates and, to a lesser extent, to income per capita. Moral-Benitto & Bartulocci (2011) show instead a non-linear effect between income and democracy. Fayad, Bates & Hoffler (2012) specifically distinguish between income from natural resources and other income. By applying heterogeneous panel techniques, the authors find that only when income comes from non resource sources is it significant in explaining democracy. Meanwhile, evidence of no causal relation has also been found by other authors. Przeworski et al. (2000) do not find any significant relationships between income per capita and transition to democracy when using a Markov transition model. This lack of evidence challenging Lipset's law is supported by Acemoglu et al. (2008) who use a panel data approach. Their study concludes that a causal effect from income to democracy cannot be found.

One of the reasons why findings are inconclusive could be that the assumptions underlying the theoretical developments are inadequate. In this paper we assume that causality goes from economic performance to democracy. In this setting, an important issue is the choice of distributional assumption to approximate democracy when modelling its mean in a regression specification. In particular, most quantitative research assumes that the democracy variable is an unbounded continuous variable that has a homogenous variance which fits with the normal distribution implicitly assumed in least squares estimation. Nevertheless, democracy measurements are in general finite with the upper limit stated as "democratic" and the lower limit as "autocratic". Hence, the main novelty of this paper is to focus on the distributional assumption of democracy, which has not yet been investigated in the related literature.

We focus on the framework of Acemoglu et al. (2008) and contribute to the understanding of this topic by evaluating the distributional assumption of democracy and its influence on the estimates. The main results indicate that when democracy is modeled with a zero-one-inflated beta regression (Ferrari & Cribari-Neto, 2004) partial support for income causing democracy is found. This is in contrast to Acemoglu et al. (2008), where no causal effect was found. More specifically, income causes democracy only when income data from the Penn World Table are used, but not when using income data from Maddison. We also find that higher incomes in the past increase the probability of a country being democratic. The second finding is somewhat robust to changes in the data sources.

The paper is organized as follows. In Section 2 we briefly discuss why the

research in this field generally comes to different conclusions and how this could be related to our primary concern, namely distributional assumptions that are questionable. Zero-one inflated beta distribution and regression are outlined in Section 3. We present our methodology in Section 4. The main results are presented in Section 5. Concluding remarks are given in Section 6.

2 Distributional issue

The recent empirical literature on the income democracy nexus has dealt with causality identification and omitted variable bias by using lags of the explanatory variables instead of levels in the right hand side. Additionally, country fixed effects are used to control for time-invariant unobserved heterogeneity (see for example Acemoglu et. al. 2008, 2014). However, there are other issues, namely other sources of endogeneity, incomplete data, measurement error and the distributional assumption for the variable democracy, all of which have not been fully addressed or even ignored. In the related literature, some attention has been given to endogeneity, incomplete data and measurement error (Acemoglu et. al., 2008; Moral-Benitto & Bartulocci, 2011; Treier & Jackman, 2008). Conversely, in this paper we focus on the latter to explore the zero-one inflated beta distribution as an alternative distributional assumption for democracy.

A parametric regression model relies on a specific distribution to derive the results. Assuming the normal distribution for the response variable given the explanatory variables is a handy approximation to fulfill the parametric assumption in the class of linear models. However, violations of this assumption makes any results questionable. Moreover, a bounded variable is by definition not normally distributed particularly when most observations are close to the boundaries. If this is the case, the variable of interest should not be used as a dependent variable in an ordinary least squares regression, which (at least implicitly) assumes normality for inference.

For illustration purposes, Table 1 reports summary statistics of the variables representing the level of democracy from the Freedom House Political Right Index and Polity IV data set as proxies for the level of democracy in a particular country[2]. The arithmetic mean is a natural characterization of the central tendency of a data set in particular for normally distributed variables.

Having the normality assumption in mind, the usual interpretation of a mean around 0.5 is that most of the countries are half democratic. The next step is to plot a histogram and a density estimate to examine whether these approximate

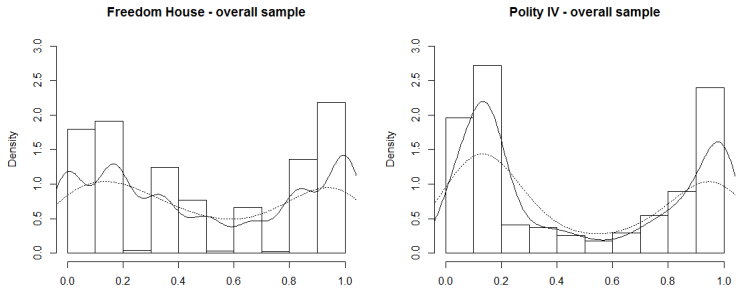
[2]Freedom House and Polity4 democracy variables are from Acemoglu et al. (2008). Among the various proxies of democracy that are available, we stick to Acemoglu et al. (2008) perspective by using their standardized indices from Freedom House and Polity IV for comparison purposes. The Freedom House index is based on a rating system ranging from 1 to 7 where smaller numbers represent a higher Freedom Rating. Polity IV is a multidimensional measure of political environment that is compressed into a scalar ranging from -10 to 10. Positive numbers are in favor of democracy while negative numbers symbolize autocracy. Standardization transforms both scales into the identical range between zero and one.

Table 1: Summary statistics of standardized democracy indices between 1960-2000, 211 countries

Variable	Observation	Trimmed mean (5%)	St. Dev.	Min.	Max.
Freedom House	4732	0.49	0.38	0	1
Polity IV	5173	0.47	0.39	0	1

Note: The trimmed mean is an aritmetic mean that discards sample at both tails of the distribution. Table 1 discards the lowest 5% and the highest 5% values.

Figure 1: Histogram and density plot of democracy between 1960-2000, 211 countries



Note: The solid density lines have a smoothing bandwitdth of 1 and the dotted ones double the bandwidth.

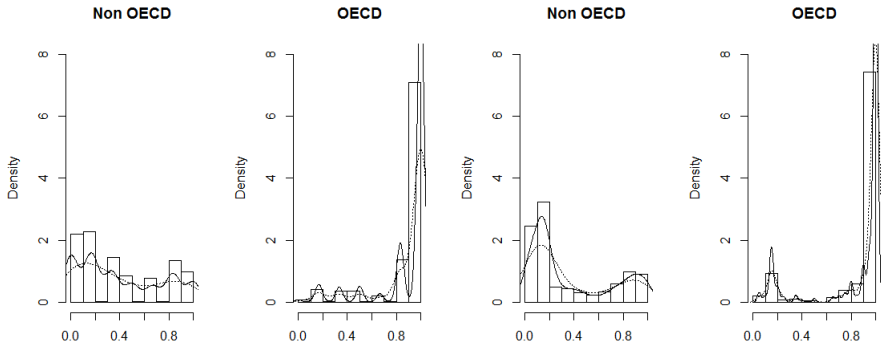
something close to a bell-shape, which would indicate a normal distribution for the democracy variables.

Figure 1 illustrates that neither Freedom House nor Polity IV show such a bell-shaped curve. Instead, their distributions are closer to a U-shaped curve with two peaks. As a consequence the unimodal interpretation no longer holds and the arithmetic mean does not represent the true central tendency, because it is a product of a compromise between two modes that center around zero and one. Therefore, it is the shape of the distributions and not the means that tell us something well-known, which is that most of the countries are either highly democratic or highly autocratic. A few data points are in between, and some of them could be the countries in transition to democracy or to authoritarian regimes. If the conclusion is misleading for the arithmetic mean with the misspecified distribution, it will also be potentially misleading for the parameters of a regression model based on the misspecified distributional assumption.

An additional issue is that the values of democracy are bounded. Without considering this aspect when modeling the distribution of the data, the fitted values could lay outside the interval [0,1]. In this case, we should consider nonlinear models that take care of the nonlinearity and the bounded characteristics of the response variable

It is important to take note of another prominent feature shown in Figure 2.

Figure 2: Histogram and density plot of subsamples between 1960-2000, Freedom House (left) and Polity IV (right)



Note: The solid density lines have a smoothing bandwitdth of 1 and the dotted ones double the bandwidth.

In particular, the plot of the distributions indicates that the world is polarized into two clear political regimes. We visually tested whether the lower mode comes from non-OECD countries and the higher one depicts OECD countries by plotting the subset of OECD and non-OECD according to Freedom House and Polity IV in Figure 2. [3]

The visual examination of Figure 2 suggests that the OECD group approximates the upper mode of the distribution, while the non-OECD subsample represents the lower mode. Moreover, the OECD group shows more variability. We anticipate that the high variation within the OECD sub-sample comes from the earlier period of the sample, seeing how nowadays all OECD countries are democratic. We will incorporate these features into the model to assess the statistical differences between both groups in the following parts.

3 Zero-one-inflated beta distribution and regression

A number of issues related to the suitable modeling strategy for bounded response variables have been discussed by Papke & Wooldridge (1996) under the heading of fractional response models. Possible extensions have also been recently summarized by Ramalho, Ramalho & Murteira (2011). The authors find that it is not reasonable to assume that the effect of explanatory variables is constant throughout the entire range of the response variable when the latter is bounded. They also argue that a beta distribution is not suitable for modelling

[3] OECD refers to all members of OECD in 2014. Therefore, OECD is a loose term referring to the members of OECD during the sample period as well as its future members.

bounded responses if values on the boundaries are observed with non-zero probability. However, while allowing for values on the boundaries, fractional response models only restrict the expectation of the response to the interval (0,1) and not the complete distribution. Rather than using a fractional response specification, we therefore inflate the beta distribution with point masses in zero and one to account for the non-zero probability of observing these boundary values.

The mixed discrete-continuous density of a zero-one-inflated beta random variable is given by

$$p(y) = \begin{cases} p_0 & \text{if } y = 0 \\ p_1 & \text{if } y = 1 \\ \frac{1}{B(a,b)} y^{a-1}(1-y)^{b-1} & \text{if } y \in (0,1) \end{cases} \tag{1}$$

where $B(a,b)$ is the beta function with parameters a and b given by

$$B(a,b) = \int_0^1 y^{a-1}(1-y)^{b-1}$$

where $a > 0$, $b > 0$.

The zero-one-inflated beta regression where the zero-one-inflated beta distribution is considered as the conditional distribution of the response was introduced by Ospina & Ferrari (2010). For the sake of interpretability, they propose a parameterization based on the expectation $\mu = \frac{a}{a+b}$ and the scale parameter vector $\sigma = \frac{1}{a+b+1}$ with $\mu \in (0,1)$ and $\sigma \in (0,1)$. We also replace the probabilities for zero and one by the parameters $\nu = p_0/p_2$ and $\tau = p_1/p_2$ where $p_2 = 1 - p_0 - p_1$ is the probability observing a response from the continuous part of the zero-one-inflated beta distribution. This parameterisation ensures that the probabilities for zero, one and the continuous part add up to one.

Furthermore, we let y_{it} be independent random variables where each y_{it} follows the density in (1) with mean μ_{it}, unknown scale parameter σ_{it} and zero/one inflation parameters ν_{it} and τ_{it}, while $t = 1, \ldots, T$ and $i = 1, \ldots, N$ index the time dimension and the individuals, respectively. To relate the parameters of the zero one inflated beta distribution to regression predictors, we apply suitable link functions, i.e.

$$\mu_{it} = \frac{\exp(\eta_{it}^{\mu})}{1+\exp(\eta_{it}^{\mu})} \qquad \sigma_{it} = \frac{\exp(\eta_{it}^{\sigma})}{1+\exp(\eta_{it}^{\sigma})} \qquad \nu_{it} = \exp(\eta_{it}^{\nu}) \qquad \tau_{it} = \exp(\eta_{it}^{\tau})$$

where η_{it}^{μ}, η_{it}^{σ}, η_{it}^{ν} and η_{it}^{τ} are regression predictors constructed from a set of covariates. The logit transformation applied to the mean and scale parameter enables a log odds ratio interpretation for two observations that only differ by one unit in the variable of interest. In contrast, the natural log transformation for the zero/one inflation parameters is directly interpretable since it is approximately proportional to differences.

Note that the model allows us to account for heteroscedasticity due to the regression effects on σ_{it} and μ_{it} since the variance of y_{it}

$$\mathrm{Var}(y_{it}) = \frac{\mu_{it}(1-\mu_{it})}{1+a_{it}+b_{it}}$$

is also a function of the mean μ_{it} and proportional to the scale parameter $\sigma_{it} = 1/(1+a_{it}+b_{it})$.

Even though the approach by Papke & Wooldridge (1996) also does not exclude the boundary values, it is more suitable when the truly fractional component of the response is dominant. Conversely, the inflated beta regression better matches our data sets because we observe a large fraction of zeros and ones. Furthermore, the fully parametric approach used by assuming a beta distribution for the fractional response variable leads to more efficient ML estimators (Ospina & Ferrari, 2010).

4 Model specification

Our study estimates a similar model to Acemoglu et al. (2008)[4]. We use Maddison historical GDP per capita[5] for a robustness check of measurement error and missing values. Hence, we have the combination of two democracy variables and two income per capita variables. We add a dummy variable for OECD membership, which acts as an additional regressor in each model. We implement a linear model structure with fixed-effects under the assumption that the response follows the zero-one inflated beta distribution where the basic predictor structure is given by

$$\eta_{it} = \beta_1 y_{it-s} + \beta_2 x_{1it-s} + \beta_3 x_{2it} + \vartheta_i + \delta_t \tag{2}$$

where x_{1it-s} is log income per capita of country i at time $t-s$, x_{2it} is the OECD dummy of country i at time t, ϑ_i is a country-specific fixed effect, δ_t is a time-specific fixed effect, and the predictor is linked to the parameters of the response distribution via the link functions discussed above. For the lagged part in the predictor, we used $s = 1$ for yearly data[6], $s = 5$ for five year, $s = 10$ for ten year and $s = 20$ for twenty year data, respectively. We use five year averages of data $t = \bar{x_5}$ and their first lag in equation (2) to mitigate endogeneity. We also employ the lagged values of explanatory variables for the same purpose as well as to design the causality relationship. To fit zero-one-inflated beta regression models, we used the R-package gamlss (Rigby & Stasinopoulos, 2005; Stasinopoulos, Rigby & Akantziliotou, 2008).

Because the zero-one-inflated beta regression allows us to estimate not only the mean as a function of the explanatory variables but also the scale parameter,

[4]Linear model with country fixed-effects

[5] Maddison GDP per capita is from Bolt & van Zanden (2013) with authors' adjustment.

[6]For $s = 1$, we jointly estimate the coefficients of mean and scale parameters with the previous four lags.

which is proportional to the variance, and the two probabilities for zero and one inflation, we can infer the causes of potential non-constant variance, as well as other distributional features of democracy at time t. Despite having a relatively suitable distributional assumption and some treatment for other statistical challenges, we do not claim that our estimation has a rigorous causal interpretation. Instead, our intention is to provide a benchmark for future related research.

5 Results

The main results of our model for different time intervals are presented in Table 2. The first column shows the model estimated with yearly data (model M1), the second to fourth column with five (M2), ten (M3), and twenty year (M4) intervals data and the last column is for five-year average data (M5). In each model, estimated coefficients are presented for the equation for μ which represents the mean of the beta distribution, the equation for σ which relates to the scale parameter of the beta distribution and the equations for ν and τ which relate to the probabilities for zero and one inflation, respectively.

The estimated coefficients for income per capita in the equation for μ are only significant in model (M3), in which a ten year interval and a ten year lag structure is used. In the equation for σ income is significant in model (M1), model (M2) and model (M5), suggesting that for annual, five year and twenty year data income influences the variance of democracy. The negative and significant income coefficient found for the ten year lag in the equation for ν indicates that a higher income per capita level leads to a lower probability of a country having a value of zero (autocracy) than a value between zero and one in the next ten years. The stronger evidence comes from the equation for τ. The positive and significant coefficient of income (for five, ten and twenty year lags) suggests that a higher income induces a higher probability of a country having a value of one (democracy outcome) than a value between zero and one.

The OECD dummy is also significant in the equations for μ and σ in some cases. The positive sign in the equation for μ reflects the higher level of democracy on average for OECD members relative to non-OECDs. Meanwhile, the positive sign in the equation for σ indicates that the OECD group has a higher variance. This confirms the findings in Figure 2. The diagnostic plots for ten year intervals are provided in Figure 3. Our estimation for the OECD versus non-OECD subsamples (see Appendix 3) shows that the effect of income on democracy is only statistically significant in the OECD countries.

As a comparison, we provide results for the Polity IV data using income from Maddison in Table 3 (see the Appendix for the results obtained using other data set combinations).

Table 2. Freedom House and Penn World Table GDP per capita

Dependent variable: democracy	Annual (M1)	5 year (M2)	10 year (M3)	20 year (M4)	5 year average (M5)
Mean equation (μ)					
Lag democracy	3.829***	0.139***	-0.982***	-0.772***	2.552***
	(0.088)	(0.163)	(0.263)	(0.255)	(0.181)
Lag log income per capita	0.032	-0.038	0.568**	-0.175	-0.137
	(0.183)	(0.147)	(0.270)	(0.265)	(0.147)
OECD(D)	0.356	2.543*	2.339***	-0.809	1.880
	(0.360)	(1.308)	(0.632)	(1.462)	(1.186)
Country fe	Yes	Yes	Yes	Yes	Yes
Year fe	Yes	Yes	Yes	Yes	Yes
Scale equation (σ)					
Lag Democracy	(2) +***	-***	+	No	-***
Lag log income per capita	(2) -***	+*	-	+***	+
OECD(D)	+	+	+**	No	+***
Country fe	No	No	No	No	No
Year fe	Yes	Yes	Yes	Yes	Yes
Zero inflation equation (ν)					
Lag democracy	-14.137***	-1.700**	-1.977**	-1.325	-5.690
	(1.546)	(0.852)	(0.859)	(1.715)	(1.305)
Lag log income per capita	-1.201	0.307	-0.375**	-1.162	0.391
	(1.372)	(0.786)	(0.319)	(0.780)	(0.879)
OECD(D)	-20.090	-33.197	-18.645	-25.954	-19.579
	(1.963e+7)	(1.381e+7)	(5.092e+3)	(4.640e+5)	(3.625e+4)
Country fe	Yes	Yes	No	No	Yes
Year fe	Yes	Yes	No	No	No
One inflation equation (τ)					
Lag democracy	28.584***	9.484***	5.024***	1.150	27.357***
	(3.931)	(2.392)	(1.068)	(1.119)	(6.065)
Lag log income per capita	-2.733	5.289***	3.179***	4.245***	5.677
	(4.884)	(1.988)	(0.551)	(0.937)	(3.223)
OECD(D)	5.743	17.800	-0.404	0.795	-11.058
	(3.355e+7)	(1.383e+7)	(0.543)	(0.721)	(4.306e+4)
Country fe	Yes	Yes	No	No	Yes
Year fe	Yes	Yes	No	No	Yes
Observation	2743	808	348	125	820
Country	131	131	115	75	134
Global deviance	-3004.814	-203.706	34.381	-149.026	-399.097
AIC	-1938.814	670.291	302.381	30.974	479.903
SBC	1214.844	2721.814	818.576	285.523	2546.287

The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance levels are 0.1 (*), 0.05 (**) and 0.01 (***). Standard errors are in parentheses with "qr" type, which assumes there is no correlation among the parameters. The number inside the bracket before the annual coefficients indicates the respective lag. If there is no bracket, the coefficient shown is for the first lag. Models M2-M4 are estimated using 5, 10 and 20 year intervals, respectively. Country fixed-effects and year fixed-effects are used only when the algorithms converge.

Figure 3: Diagnostic plots for ten year intervals: overall sample (top panel) and OECD (bottom panel)

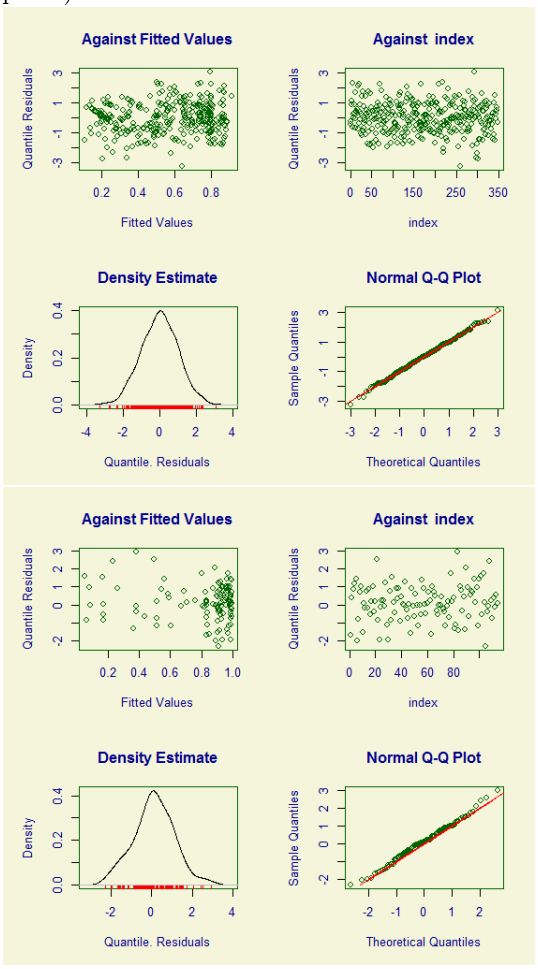


Table 3 suggests that our findings are not robust for the equations for μ , ν and τ, yet it is more robust for the equations for σ. Past income explains the non-constant variance of democracy through the equation for σ. The difference between the OECD and non-OECD groups is more apparent here. The dummy for OECD countries is significant and positive in the equation for μ in three cases, suggesting that OECD countries have higher democracy indices. The OECD dummy is also positive and statistically significant in the equation for τ in two cases, signaling that OECD membership increases the probability of being completely democratic. However, there is no evidence that OECD membership causes democracy (see Appendix 4).

Results for the overall sample from the two alternative data sets generally indicate a similar effect of lag income for the equations for σ. Additionally, the sets were and to a large extent robust for τ, as well as for our results for the OECD dummy in the equations for μ and σ. Nevertheless, a detailed examination suggests that there is a sort of selection bias. The differences in results mainly depend on which income variable is used in the model. On the one hand, when using income data from the Penn World Table, a positive effect of income on democracy is found more often than when using income data from Maddison. On the other hand, Maddison GDP favors significance for the OECD dummy. Hence, we conclude that even though the democracy indices are subject to measurement error, in our model specification they are more robust than the income per capita variables.

Table 3. Polity IV and Maddison GDP per capita

Dependent variable: democracy	Annual (M1)	5 year (M2)	10 year (M3)	20 year (M4)	5 year average (M5)
Mean equation (μ)					
Lag democracy	(3) -0.281***	1.750***	-0.304	-2.253***	2.965***
	(0.101)	(0.164)	(0.287)	(0.459)	(0.153)
Lag log income per capita	(3) 0.016	0.160	0.192	-0.521	0.137
	(0.144)	(0.136)	(0.261)	(0.436)	(0.110)
OECD (D)	0.418***	1.199**	2.085	4.842***	0.786
	(0.137)	(0.587)	(1.054)	(1.258)	(0.509)
Country fe	Yes	Yes	Yes	Yes	Yes
Year fe	Yes	Yes	Yes	Yes	Yes
Scale equation (σ)					
Lag democracy	-***	+***	+**	+**	+***
Lag log income per capita	-***	+***	+	+**	+
OECD (D)	+***	-	+***	-***	+
Country fe	No	No	No	No	No
Year fe	Yes	Yes	Yes	Yes	Yes
Zero inflation equation (ν)					
Lag democracy	-184.400***	-17.981	-85.161***	-534.129	-144.686***
	(0.340)	(0.141)	(23.077)	(3.243e+6	(0.340)
Lag log income per capita	-4.077	-3.971	0.128	0.215	0.318
	(4.439)	(1.914)	(0.305)	(0.526)	(0.298)
OECD (D)	79.300	40.098	-14.449	-1.328	-20.624
	(5.417e+7)	(5.650e+7)	(3.461e+6)	(1.264e+6)	(1.846e+5)
Country fe	Yes	No	No	No	No
Year fe	No	No	No	No	No
One inflation equation (τ)					
Lag democracy	187.795***	23.405***	9.568***	5.761***	28.038***
	(37.193)	(2.318)	(2.148)	(1.227)	(2.540)
Lag log income per capita	18.906	-0.666	-0.217	-0.554**	10.831***
	(13.866)	(2.029)	(0.150)	(0.280)	(3.733)
OECD (D)	2.734	27.905	2.936***	4.052***	-40.509
	(1.128)	(9.811e+5)	(0.573)	(1.012)	(2.131e+7)
Country fe	No	Yes	No	No	Yes
Year fe	Yes	Yes	No	No	Yes
Observation	3769	864	368	142	892
Country	136	136	127	89	136
Global deviance	-8495.498	-850.319	-212.372	-221.576	-1179.173
AIC	-7645.498	39.681	79.629	-9.576	-561.173
SBC	-4995.808	2158.581	657.181	303.741	920.009

The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance levels are 0.1 (*), 0.05 (**) and 0.01 (***). Standard errors are in parentheses with "qr" type, which assumes there is no correlation among the parameters. The number inside the bracket before the annual coefficients indicates the respective lag. If there is no bracket, the coefficient shown is for the first lag. Models M2-M4 are estimated using 5, 10 and 20 year intervals, respectively. Country fixed-effects and year fixed-effects are used only when the algorithms converge.

6 Concluding remarks

Which comes first, income or democracy? The chicken and egg causality dilemma reflects the existence of opposite theoretical perspectives in which empirical evidence has been found to support each side. Inconclusive findings together with statistical challenges have converted the study of the relationship into a far more complex issue than what Aristotle proposed a long time ago. Among the acknowledged statistical issues, we claim that the usual distributional assumption for democracy as a response variable could be inappropriate. In particular, the use of an unbounded distribution - such as a normal distribution - for a bounded variable that has dominant observations around the boundaries of its domain could cause problems. Furthermore, the conclusions derived from an analysis that rely on the wrong underlying assumptions could be misleading.

Our approach accounts for this fact by assuming a zero-one-inflated beta distribution for democracy and implementing the corresponding regression models with the appropriate link functions to model democracy. As the baseline evidence shows, we find partial support for income causing democracy when modeling the mean of democracy. This evidence is obtained only when using income from the Penn World Table, while the use of income from the Maddison data set does not always show significant outcomes. The findings also indicate that heteroscedasticity is an issue and that a higher lag income increases the probability of a country being democratic. The causality interpretation in terms of the values probabilities for values being exactly equal to zero or one is more plausible than in terms of the mean, since income might not be the only factor that has an impact on democracy and the other factors could diminish the degree of the potential relationship over time.

We also find systematic differences between OECD and non-OECD samples in the mean, variance and probabilities of zero and one inflation. OECD countries are on average more democratic and evidence that higher income causes higher levels of democracy is found for this group. Furthermore, this difference draws to some extent a line of political regimes between richer countries, with OECD representing high income countries that are democratic, and poorer countries which are less democratic. Using Maddison GDP, we find that being an OECD member increases the probability of being completely democratic while this is not the case when using Penn World Table data for income. The differences encountered when using Penn World Table and Maddison data indicate that economic measurement seems to matter and can influence the outcomes.

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Appendix 1. Freedom House and Maddison GDP per capita

Dependent variable: democracy	Annual (M1)	5 year (M2)	10 year (M3)	20 year (M4)	5 year average (M5)
Mean equation (μ)					
Lag democracy	(2) 0.180*	1.113***	-0.369	-3.186***	2.391***
	(0.108)	(0.158)	(0.249)	(0.227)	(0.145)
Lag log income per capita	(2) -0.346	-0.098	0.097	-0.356	-0.168
	(0.264)	(0.136)	(0.252)	(0.290)	(0.114)
OECD (D)	-0.034	1.946	0.232	-0.308	2.878***
	(0.501)	(1.309)	(0.896)	(0.407)	(1.205)
Country fe	Yes	Yes	Yes	Yes	Yes
Year fe	Yes	Yes	Yes	Yes	Yes
Scale equation (σ)					
Lag Democracy	-***	-**	+***	No	-
Lag Log income per capita	-***	+***	+	+***	+
OECD (D)	-	+**	+***	-***	+
Country fe	No	No	No	No	No
Year fe	Yes	Yes	No	No	Yes
Zero inflation equation (ν)					
Lag democracy	-15.398***	-2.323***	-3.206***	-3.677	-4.602***
	(1.312)	(0.711)	(0.676)	(1.327)	(1.085)
Lag log income per capita	0.522	-0.516	-0.044	0.239	0.433
	(1.347)	(0.619)	(0.008)	(0.164)	(0.704)
OECD (D)	-10.675	-21.138	-22.784***	-19.167	-29.430
	(1.537e+7)	(1.478e+5)	(2.196e+4)	(5.009e+3)	(2.347e+6)
Country fe	Yes	Yes	No	No	Yes
Year fe	Yes	Yes	No	No	Yes
One inflation equation (τ)					
Lag democracy	27.624***	10.276***	6.329***	2.791***	24.261***
	(0.042)	(2.509)	(0.990)	(0.845)	(6.799)
Lag log income per capita	-7.869	4.877**	0.027	0.291	4.452
	(0.065)	(2.170)	(0.130)	(0.196)	(3.427)
OECD (D)	-5.770	-12.087	1.900***	2.023***	-15.899
	(1.489e+7)	(2.605e+4)	(0.445)	(0.557)	(3.611e+5)
Country fe	Yes	Yes	No	No	Yes
Year fe	Yes	Yes	No	No	Yes
Observation	3102	935	422	157	940
Country	138	139	132	97	139
Global deviance	-3291.897	-160.667	179.863	-79.516	-626.181
AIC	-2183.897	747.333	481.863	146.484	295.819
SBC	1162.154	2944.942	1092.659	491.840	2529.770

The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance levels are 0.1 (*), 0.05 (**) and 0.01 (***). Standard errors are in parentheses with "qr" type, which assumes there is no correlation among the parameters. The number inside the bracket before the annual coefficients indicates the respective lag. If there is no bracket, the coefficient shown is for the first lag. Models M2-M4 are estimated using 5, 10 and 20 year intervals, respectively. Country fixed-effects and year fixed-effects are used only when the algorithms converge.

Appendix 2. Polity IV and Penn World Table GDP per capita

Dependent variable: democracy	Annual (M1)	5 year (M2)	10 year (M3)	20 year (M4)	5 year average (M5)
Mean equation (μ)					
Lag democracy	(4) 0.341***	1.357***	-0.651**	-3.826***	-3.612***
	(0.087)	(0.186)	(0.321)	(0.477)	(0.187)
Lag log income per capita	(4) 0.308**	0.092	0.087	-0.261	0.002
	(0.125)	(0.160)	(0.308)	(0.684)	(0.150)
OECD (D)	0.515***	2.085***	1.151	0.061	0.915
	(0.145)	(0.706)	(0.727)	(0.693)	(0.649)
Country fe	Yes	Yes	Yes	Yes	Yes
Year fe	Yes	Yes	Yes	Yes	Yes
Scale equation (σ)					
Lag Democracy	-***	+	+*	+***	-***
Lag Income per capita	-***	+	-	-***	-
OECD (D)	+***	-	+**	-	+*
Country fe	No	No	No	No	No
Year fe	Yes	Yes	No	No	No
Zero inflation equation (ν)					
Lag democracy	-414.706	-12.508	-57.075*	5.647e+7	-715.163
	(1.261e+3)	(6.257e+4)	(29.429)	(1.607e+6)	(2.757e+5)
Lag log income per capita	66.790	-23.139	0.472	1.119e-7	-51.077
	(177.900)	(85.170)	(1.051)	(7.855e+5)	(3.772e+4)
OECD (D)	466.487	39.649	-13.058	3.935e-7	704.595
	(4.478e+7)	(1.358e+7)	(1363.399)	(1.506e+6)	(1.408e+8)
Country fe	Yes	Yes	No	No	Yes
Year fe	Yes	Yes	No	No	Yes
One inflation equation (τ)					
Lag democracy	171.103*	30.500***	7.100***	4.541***	25.482***
	(24.788)	(2.104)	(2.075)	(1.509)	(1.858)
Lag log income per capita	12.165***	1.450	2.280***	2.335**	3.884**
	(6.898)	(2.963)	(0.574)	(1.009)	(1.709)
OECD (D)	-1.057	8.953	0.808	1.907	19.147
	(1.031)	(9.187e+4)	(0.583)	(0.924)	(4.745e+7)
Country fe	No	Yes	No	No	Yes
Year fe	Yes	Yes	No	No	No
Observation	3188	731	318	112	758
Country	119	118	106	69	120
Global deviance	-6492.482	-634.644	-150.392	-195.667	-890.045
AIC	-5642.482	161.356	99.068	23.667	-110.045
SBC	-3063.944	1989.932	569.324	210.124	1695.921

The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance levels are 0.1 (*), 0.05 (**) and 0.01 (***). Standard errors are in parentheses with "qr" type, which assumes there is no correlation among the parameters. The number inside the bracket before the annual coefficients indicates the respective lag. If there is no bracket, the coefficient shown is for the first lag. Models M2-M4 are estimated using 5, 10 and 20 year intervals, respectively. Country fixed-effects and year fixed-effects are used only when the algorithms converge.

Appendix 3. Freedom House and Penn World Table GDP per capita for sub samples

Dependent	5 year		10 year		5 year average	
variable:	OECD	non-OECD	OECD	non-OECD	OECD	non-OECD
democracy	(M1)	(M2)	(M3)	(M4)	(M5)	(M6)
Mean equation (μ)						
Lag democracy	1.187*	1.014***	-7.406***	-0.711**	3.094***	2.457***
	(0.713)	(0.171)	(0.495)	(0.279)	(0.588)	(0.189)
Lag log income per capita	1.002*	-0.189	2.859***	0.242	0.559	-0.245
	(0.587)	(0.164)	(0.444)	(0.295)	(0.512)	(0.158)
Country fe	Yes	Yes	Yes	Yes	Yes	Yes
Year fe	Yes	Yes	Yes	Yes	Yes	Yes
Scale equation (σ)						
Lag democracy	-***	-**	-***	+	-***	-***
Lag log income per capita	-***	+*	-	-*	No	+
Country fe	No	No	No	No	No	No
Year fe	No	Yes	No	No	No	No
Zero inflation equation (ν)						
Lag democracy	42.913	-2.239**	4.917e-7	1.899	-49.188	-5.981***
	(1.207e+7)	(0.924)	(8.748e+6)	(2.208)	(2.258e+5)	(1.358)
Lag log income per capita	-10.302	0.333	-3.062e-7	1.525	38.304	0.350
	(2.269e+7)	(0.674)	(8.518e+6)	(1.662)	(4.953e+5)	(0.881)
Country fe	Yes	Yes	Yes	Yes	Yes	Yes
Year fe	Yes	Yes	Yes	Yes	Yes	Yes
One inflation equation (τ)						
Lag democracy	44.020***	7.777***	14.450	9.421**	68.419***	26.437***
	(15.870)	(2.586)	(9.651)	(3.976)	(8.845)	(8.412)
Lag log income per capita	-2.225	7.293***	9.523**	31.863***	-3.627	12.323**
	(4.302)	(2.708)	(3.901)	11.800	(2.963)	(0.047)
Country fe	Yes	Yes	Yes	Yes	Yes	Yes
Year fe	Yes	Yes	No	Yes	Yes	Yes
Observation	229	579	114	234	231	589
Country	29	101	28	86	29	104
Global deviance	-89.181	-187.327	-74.626	-158.414	-107.998	-352.375
AIC	154.819	498.673	133.374	399.586	134.002	337.625
SBC	573.733	1994.6	417.939	1363.621	550.535	1848.182

The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance levels are 0.1 (*), 0.05 (**) and 0.01 (***). Standard errors are in parentheses with "qr" type, which assumes there is no correlation among the parameters. Models M1-M4 are estimated using 5 and 10 year intervals, respectively. Country fixed-effects and year fixed-effects are used only when the algorithms converge.

Appendix 4. Modeling OECD membership as the causal factor of higher democracy

Dependent variable: democracy	5 year (M1)	5 year (M2)	10 year (M3)	10 year (M4)	5 year average (M5)	5 year average
Mean equation (μ)						
Lag democracy	1.187*	0.851*	-7.418***	-1.202	3.181***	3.500***
	(0.713)	(0.471)	(0.491)	(0.898)	(0.567)	(0.430)
Lag log income per capita	1.002*	-0.217	2.873***	-0.006	0.482	-0.112
	(0.587)	(0.407)	(0.438)	(0.661)	(0.564)	(0.382)
Lag OECD (D)	-	0.587	-	-	-0.485**	0.491
		(0.439)			(0.218)	(0.379)
Country fe	Yes	Yes	Yes	Yes	Yes	Yes
Year fe	Yes	Yes	Yes	Yes	Yes	Yes
Scale equation (σ)						
Lag democracy	-***	+***	-***	-**	-***	-**
Lag log income per capita	-***	-***	-	-***	-***	-***
Country fe	No	No	No	No	No	No
Year fe	No	No	No	No	No	No
Zero inflation equation (ν)						
Lag democracy	42.928	-2.911e-8	8.839e+7	3.517e-8	-55.467	8.240e-8
	(1.208e+7)	(4.595e+4)	(9.870e+5)	(1.436e+5)	(2.665e+6)	(3.538e+5)
Lag log income per capita	-10.321	2.391	5.906e-7	2.379e-9	43.102	-5.106e-9
	(2.271e+7)	(5.274e+4)	(1.246e+6)	(1.161e+5)	(5.777e+6)	(3.355e+5
Country fe	Yes	Yes	Yes	Yes	Yes	Yes
Year fe	Yes	Yes	Yes	Yes	Yes	Yes
One inflation equation (τ)						
Lag democracy	43.327***	12.370	21.419**	12.530	48.702***	24.155***
	(16.220)	(4.396)	(9.190)	(9.920)	(11.786	(6.367)
Lag log income per capita	-2.549	-6.580	3.524**	5.184	1.230	6.390
	(4.256)	(4.057)	(1.345)	(1.869)	(1.012)	(8.467)
Lag OECD (D)	1.103	4.083	2.101	-4.302	1.244	-6.119
	(3.322)	(3.701)	(1.296)	(15.070)	(1.002)	(0.224)
Country fe	Yes	Yes	No	Yes	No	Yes
Year fe	Yes	Yes	Yes	Yes	Yes	Yes
Observation	229	214	114	108	231	218
Country	30	28	29	27	30	28
Global deviance	-89.279	-115.581	-50.651	-50.774	-80.685	-142.817
AIC	156.721	120.419	107.50	153.226	107.315	93.183
SBC	579.069	517.604	323.509	426.803	430.903	492.554

The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance levels are 0.1 (*), 0.05 (**) and 0.01 (***). Standard errors are in parentheses with "qr" type, which assumes there is no correlation among the parameters. Models with odds number are from Freedom House-Penn World Table variables, models with even numbers are from Polity4-Maddison variables. Country fixed-effects, year fixed-effects and the lag of OECD are used only when the algorithms converge.