The Effect of Income on Democracy Revisited A Flexible Distributional Approach

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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)[1] with a novel regression specification utilizing a zero-one-inflated beta distribution for the response variable democracy. The zero-one-inflated beta distribution for democracy is more appropriate for continuous and bounded responses with non-zero probabilities for the boundaries of the support than the other most frequently used distributions such as the normal. Contrary to the results of Acemoglu et al. (2008)[1], some support of causality is found in particular when explaining heteroscedasticity. Since our analysis indicates that the distribution of democracy is bimodal, we approximate the modes by 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. Only for the OECD sub-sample higher incomes are associated with higher democracy levels, whereas 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 at least since the beginning of the twentieth century. While Aristotle (1932)[3] has already argued about a positive association between both factors more than

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twenty centuries ago, Lipset's law formalized it by stating that higher economic growth in a nation leads to a higher democracy level (Lipset, 1959)[14]. This law is (likely) the foundation of modernization theory that places economic development as the major factor influencing the political environment. A number of authors, including Barro (1999)[5], Dahl (1971)[8], Huntington (1991)[13], Rusechemeyer, Stephens & Stephens (1992)[30], additionally contributed to the view that higher incomes are associated with higher levels of democracy.

Still, recent empirical findings show a less clear story. Indeed, some support for a positive association of income and democracy is found by Londregan & Poole (1996)[18] using panel data for a causality relationship as stated by Lipset (1959)[14] but only after considering leadership type and political context as control factors. Murtin & Warcziag (2014)[20] observe that 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)[19] show instead a non-linear effect between income and democracy. Fayad, Bates & Hoffler (2012)[10] specifically distinguish between income from natural resources and other income and, by applying heterogeneous panel techniques, find that only when income comes from non resource sources it is significant in explaining democracy. Meanwhile, evidence of no causal relation has also been found by other authors. Przeworski et al. (2000)[24] do not find any significant relationship between income per capita and transition to democracy by using a Markov transition model. This lack of evidence challenging Lipset's law is supported by Acemoglu et al. (2008)[1] when using a panel data approach. Their study concludes that a causal effect from income to democracy cannot be found. Furthermore, Acemoglu et al. (2014)[2] recently found support indicating that the causality could go from democracy to economic growth. This reverse causation has been drawing a lot of attention in recently, as shown e.g. by Sirowy & Inkeles (1990)[31], Barro 1997 [4], Lizzeri & Persico (2004)[17], Rodrik et. al. (2004)[28], Gerring et. al. (2005)[12] and Bates et. al. (2012)[6].

One of the reasons why findings are inconclusive could be that the assumptions underlying the theoretical developments are inadequate. Assuming that causality goes from economic performance to democracy, 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 and has a homogenous variance to fit 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, in this paper the main focus is on the distributional assumption of democracy that has not yet been investigated in the related literature.

We focus on the framework of Acemoglu et al. (2008)[1] 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-Netto, 2004)[11] partial support for income causing democracy is found.

This is in contrast to Acemoglu et al. (2008)[1], 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 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 summarize our methodology in Section 4. The main results are presented in Section 5. Concluding remarks are given in Section 6.

2 Identification of critical issues

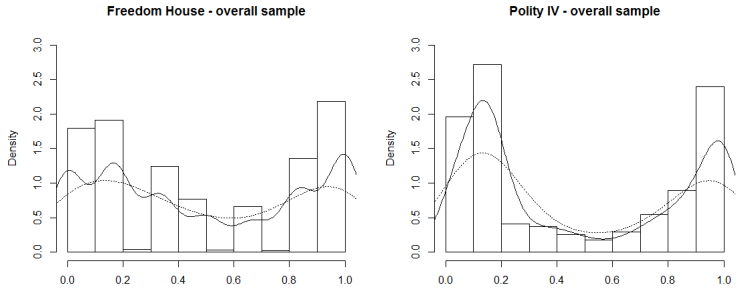
The recent empirical literature on the income democracy nexus has dealt with causality identification and omitted variable bias by using lags of the explanatory variables instead of levels in the right hand side and by using country fixed effects to control for time-invariant unobserved heterogeneity (see for example Acemoglu et. al. 2008[1], 2014[2]). However, there are other issues, namely other sources of endogeneity, incomplete data, measurement error and the distributional assumption for the variable democracy, that have not been fully addressed or even ignored. An instrumental variable approach is a partial solution for endogeneity, although it is debatable in cases of weak correlation of the instruments with the endogenous variable. Incomplete data is far less discussed in the literature but has a severe impact in terms of potentially biased estimates if it is neglected. According to Rubin (1976)[29], only if the missing values mechanism is completely at random (MCAR) the estimates are unbiased. However, due to the fact that economic data or democracy data are missing usually relates to other variables or even to the variable itself leads to the suspicion that estimations from previous studies are potentially biased. Conversely, measurement errors are an issue that has been partially investigated on two fronts. On the one hand, there is a large body of economic literature assessing each type of progress in economic measurement. On the other hand, Treier & Jackman (2008)[33] have shown that democracy is a latent variable. Therefore, research that includes democracy should also integrate its uncertainty measurement in the model. Regarding the last issue, to the best of our knowledge our study is the first to explore the zero-one inflated beta distribution as an alternative distributional assumption for democracy in deriving outcomes from the empirical model.

A parametric regression model relies on a specific distribution in deriving 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 result questionable. Moreover, a bounded variable is by definition not normally distributed particularly when most observations are close to the

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

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

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



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.

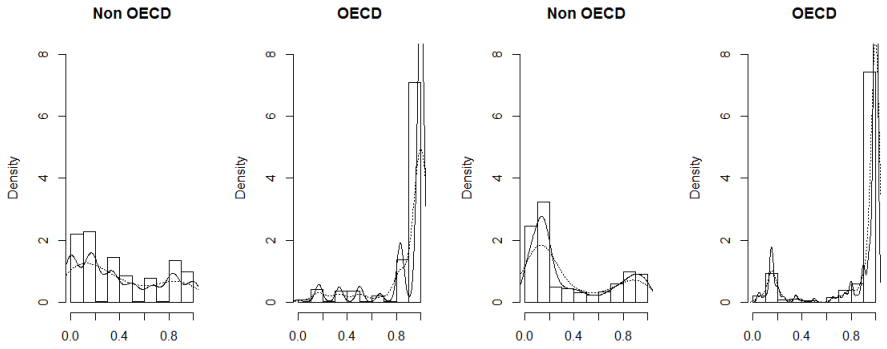
For illustration purposes, we report summary statistics of the variables representing the level of democracy from the Freedom House Political Right Index and Polity IV data set as a proxy for the level of democracy in a particular country.[2] The arithmetic mean is a natural characterisation of the central 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 something near bell-shaped that would indicate a normal distribution for the democracy variables.

Figure 1 shows 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 does no longer hold and the arithmetic mean does not represent the true central tendency, because

[2]Freedom House and Polity4 data set are from Acemoglu et al. (2008). Among the various proxies of democracy that are available, we stick to Acemoglu et al. (2008)[1] 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.

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



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 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 the graphics. 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 for Freedom House and Polity IV at 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 high variation within the OECD sub-sample comes from the earlier period of the sample, since nowadays all OECD countries are democratic. We will incorporate these features in the model to assess the statistical differences between both groups in the following.

[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.

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)[22] under the heading of fractional response models and possible extensions have been recently summarized by Ramalho, Ramalho & Murteira (2011)[26]. 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 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 $a > 0$, $b > 0$.

Zero-one-inflated beta regression where the zero-one-inflated beta distribution is considered as the conditional distribution of the response has been introduced by Ospina & Ferrari (2010)[21]. 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 to observe 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. As link functions, we employ the logit transformation for μ and σ and the log transformation for ν and τ. The logit transformation enables a log odds ratio interpretation for two observations that only differ by one unit in variable of interest, while the natural log transformation is directly interpretable since being approximate proportional to differences.

Furthermore, let $y_{it}, i = 1, ..., N$ and $t = 1, ..., T$, where i is the individual dimension and t is the time dimension, be independent random variables where

each y_{it} follows the density in (1) with mean μ_{it} and unknown scale parameter σ_{it}. To relate the beta parameters to regression predictors, we apply suitable link functions, i.e.

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

where η_{it}^{μ} and η_{it}^{σ} are regression predictors for the mean and the scale parameter, respectively, constructed from a set of covariates. Note that the model allows to account for heteroscedasticity due to the regression effects on σ_{it} and μ_{it} since the variance of y_{it}

$$Var(y_{it}) = \frac{\mu_{it}(1 - \mu_{it})}{1 + \phi_{it}}$$

[4]

is also a function of the mean μ_{it} and proportional to the scale parameter σ_{it}.

Even though the approach by Papke & Wooldridge (1996)[22] 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)[21]. To fit zero-one-inflated beta regression models, we used the R-package gamlss() by Rigby & Stasinopoulos (2005)[27] and Stasinopoulos, Rigby & Akantziliotou (2008)[32].

4 Model specification

Our study follows the identification strategy of Acemoglu et al. (2008)[1]. 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 also implemented a similar 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

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

for country i at time t, 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

[4] $\phi = a + b$ is the precision parameter so that $a = \mu\phi$, $b = (1 - \mu)/\phi$. The precision parameter ϕ reflects the inverse of the variance such that for a fixed μ, the variance of y gets larger when ϕ gets smaller.

[5] Maddison GDP per capita is from Bolt & van Zanden (2013)[7] with authors' adjustment.

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 5 year, $s = 10$ for 10 year and $s = 20$ for 20 year data, respectively. We use 5 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 that purpose and to design the causality relationship.

Because 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, which is proportional to the variance, and the two probabilities for zero and one, we can infer the causes of potential non-constant variance and 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 model is estimated for different time intervals and the main results are presented in Table 2. The first column shows the model estimated with yearly data, the second to fourth column with 5, 10, and 20 year intervals data and the last column is for five-year average data. 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 related 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 10 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 data, 5 year and 20 year data income influences the variance of democracy. Two additional sets of results are presented for the equations for ν and τ. The negative and significant income coefficient found for the 10 year lag in the equation for ν indicates that a higher income per capita level implies that there is a lower probability of a country getting 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 5, 10 and 20 year lags) suggests that a higher income induces a higher probability of a country getting 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. 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.

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

This confirms the findings in Figure 2. The diagnostic plots for ten year intervals are provided in Figure 3. Our estimation for the sub samples (see Appendix 3 for the result) 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 which uses income from Maddison in Table 3 (see the Appendix for the results obtained using other data set combinations).

Table 2. Freedom House and World Penn Table GDP per capita[a]

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	-***	-***	+	No	-***
Lag log income per capita	+	+*	-	+***	+
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

[a]The coefficients are in logit form for the equations for μ and σ, and in log form for the equations for ν and τ. The significance levels are 0.1 (***), 0.05 (**) and 0.01 (***). Standard errors are in parentheses with "qr" type, which assumes that 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.

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

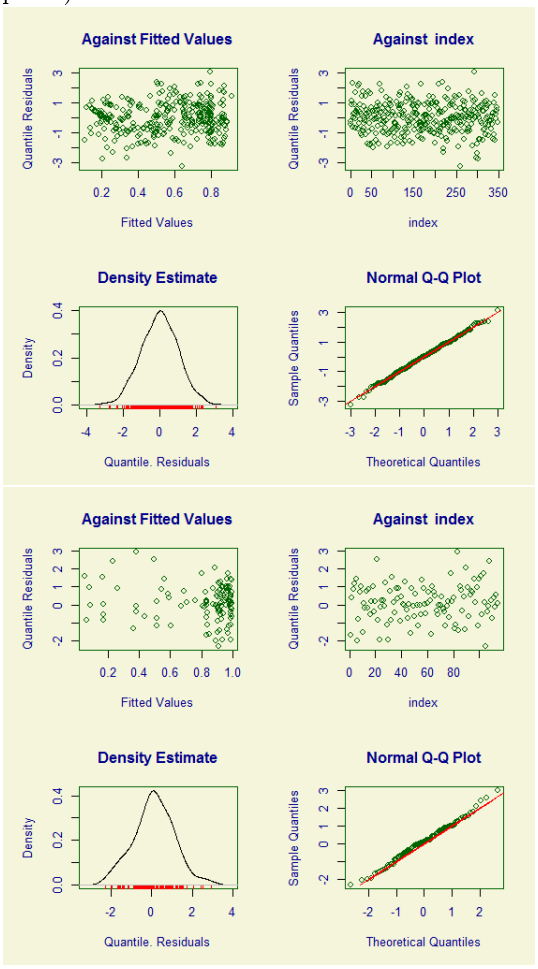


Table 3 suggests that our findings are not robust for the equations for μ and ν, yet it confirms the robustness for the equations for σ and τ. Past income explains the non-constant variance of democracy through the equation for σ. The difference between the OECD and non-OECD groups is more apparent here. The dummy for OECD countries is significant and positive in the equation for μ, suggesting that OECD countries have higher democracy indices. The OECD dummy is also positive and statistically significant in the equation for τ, signaling that OECD membership increases the probability to be completely democratic. Nevertheless, there is no evidence that OECD membership causes democracy (see Appendix 5).

Results for the overall sample from the two alternative data sets generally indicate a similar effect of lag income for the equations for σ and τ, as well as robustness of 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 Tables, an 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[a]

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	-21.576	-1179.173
AIC	-7645.498	39.681	79.629	-9.576	-561.173
SBC	-4995.808	2158.581	657.181	303.741	920.009

[a]The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance level 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.

6 Concluding remarks

Which comes first, income or democracy? The chicken and egg causality dilemma reflects the existence of opposite theoretical perspectives and empirical evidence has been found to support each side. Inconclusive findings together with statistical challenges have converted the study of the relationship in a far more complex issue than what Aristotle thought a long time ago. Moreover, among the acknowledged statistical issues, we claim that the usual distributional assumption for democracy as a response variable could be problematic. 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 takes care of this fact by assuming a zero-one-inflated beta distribution for democracy and implementing 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 Tables, while the use of income from the Maddison data set does not show significant outcomes. The fully robust findings are that heteroscedasticity is an issue and a higher lag income increases the probability of a country being democratic. The causality interpretation in terms of the 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 for 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 that are less demoncratic. 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 World Penn tables data for income. The differences encountered when using Penn World Tables and Maddison data indicate that economic measurement seems to matter and does indeed influence the outcomes.

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Appendix 1. Freedom House and Maddison GDP per capita[a]

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

[a]The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance level 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.

Appendix 2. Polity IV and Penn World Tables GDP per capita [a]

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

[a] The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance level 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.

Appendix 3. Freedom House and Penn World Tables GDP per capita for sub samples[a]

Dependent	5 year		10 year		5 year average	
variable:	OECD	non-OECD	OECD	non-OECD	OECD	non-OECD
democracy	(M1)	(M2)	(M3)	(M4)	(M5)	
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

[a]The coefficients arein logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance level 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.

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

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

[a]The coefficients are in logit form for the equations for μ and σ, in log form for the equations for ν and τ. Significance level 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 Tables data set, models with even numbers are from Polity4-Maddison data set. Some models do not provide the coefficient of OECD membership lag because the maximum likelihood estimation algorithm does not converge.