A P P E N D I X

No Direct Taxation Without New Elite Representation

Industrialization and the Domestic Politics of Taxation*

Forthcoming in *European Journal of Political Research*

Patrick Emmenegger†, Lucas Leemann‡, André Walter§

Contents

1 A: Agricultural Inequality Measure

The available historic data on agricultural structure that is available is not as detailed as it might be hoped. We rely here on the number of farms with a specific count of cows to derive an agricultural inequality measure. The number of cows owned by a farmer is not directly reported but rather how many farms have one to five cows, six to ten, eleven to 20, and more than twenty cows. We know, for example, that in Zurich in 1866 there are 16,695 farmers who have between one and four cows, 4355 farmers who have between five and ten cows, 266 farmers who have between eleven and 20 cows, and 16 farmers with more than twenty cows.

1.1 Derivation of Estimator

Because we only observe censored data (i.e. how many farmers fall into which bracket, for example, one to four cows) we cannot calculate the Gini coefficient directly. But by imposing a distributional assumption on the underlying number of cows, we can derive an inequality measure. The strategy is as follows; we first impose a distributional assumption with parameters $\boldsymbol{\theta}$, we then estimate a customized maximum likelihood model for the censured data to retrieve $\hat{\boldsymbol{\theta}}$, after that we simulate random draws from the assumed distribution governed by $\hat{\boldsymbol{\theta}}$ which will produce actual number of cows for a hypothetical society with the same structure (i.e. $\hat{\boldsymbol{\theta}}$), and can then eventually compute the Gini coefficient on that data.

To begin we need a distributional assumption. The negative binomial distribution is flexible for count data. Since there are no records on farmers with no cows at all ($Y = 0$) we need a truncated negative binomial distribution for $Y = 1, 2, 3, ...$ which has two parameters θ_1 and θ_2 (Sampford, 1955). If we were to observe the true count data we could now just estimate the parameters from that data but we only observe censored data and know how many farms had between one and four cows, five and ten cows, and so on. Recognizing that this is a form of censoring makes it possible to derive a maximum likelihood model that takes this specific form of censoring into account.

We derive the likelihood function and to do so first derive the probabilities as a function of parameters and observed data. The observed data is X, whereas the true number of cows is Y:

$$X = \begin{cases} 1 & \text{if } 0 < Y < 5, \\ 2 & \text{if } 4 < Y < 11, \\ 3 & \text{if } 10 < Y < 21, \\ 4 & \text{if } 20 < Y. \end{cases} \tag{1}$$

Given the distributional assumption we can derive the probability of observing a specific value for Y - the truncated negative binomial distribution has two parameters θ_1 and θ_2

$$B = \frac{1}{1 + e^{-\theta_2}} \tag{2}$$

$$P(Y = j) = P_j = \; = \frac{\frac{\Gamma(\theta_1 + j)}{\Gamma(j+1)\cdot\Gamma(\theta_1)} \cdot \Big(1 - B\Big)^j \cdot B^{\theta_1}}{1 - B^{\theta_1}} \tag{3}$$

The maximum likelihood estimator needs to take into account the nesting structure (Equation 1) and is based on the following probabilities:

$$P(X=1) = \sum_{j=1}^{4} P_j \quad (4)$$

$$P(X=2) = \sum_{j=5}^{10} P_j \quad (5)$$

$$P(X=3) = \sum_{j=11}^{20} P_j \quad (6)$$

$$P(X=4) = 1-\sum_{j=1}^{20} P_j \quad (7)$$

And this allows us to define the likelihood function for the observed data:

$$\mathcal{L} = \prod P(X=1)^{I(X=1)} \cdot P(X=2)^{I(X=2)} \cdot P(X=3)^{I(X=3)} \cdot P(X=4)^{I(X=4)} \quad (8)$$

Taken altogether, we can build a maximum likelihood estimator that takes the censoring into account and adds for a given observation the probability of one cow, two cows, three cows, and four cows into a sum in case a specific observation is in the first category. Here is the code:

```
negbin.animal.size <- function(theta,y){
  a <- (theta[1])
  b <- theta[2]
  B <- 1/(1+exp(-b))
  Pr <- rep(NA,21)
  for (i in 1:21){
    # G(x+n)/(G(n) x!) p^n (1-p)^x
    # i = x
    # B = p
    # a = n
    Pr[i] <- gamma(a+i)/(gamma(i+1)*gamma(a))*(1-B)^i*B^(a) / (1-(B)^a)
    # truncated negative binomial distribution, Sampford (1958)
  }
  p1 <- sum(Pr[1:4])      # corresponds to 1-4 animals
  p2 <- sum(Pr[5:10])     # corresponds to 5 to 10
  p3 <- sum(Pr[11:20])    # corresponds to 11 to 20
  p4 <- 1-sum(Pr[1:20])   # corresponds to 21 and more
  p <- cbind(p1,p2,p3,p4)
  P <- p[y]
  ll <- sum(log(P))
  return(ll)
}
```

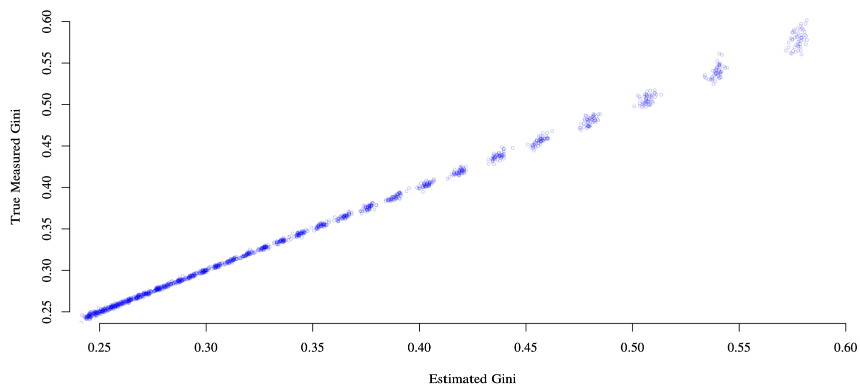
With the historical data and with this estimator we can retrieve $\hat{\theta_1}$ and $\hat{\theta_2}$ for a specific canton and year. We can then turn to simulation and generate e.g. 1 million random draws of a truncated negative binomial model with parameters $\hat{\theta_1}$ and $\hat{\theta_2}$. The simulated data is not censored and we can compute the Gini coefficient on it.

1.2 Monte Carlo Tests of Estimator

In addition, we also carry out a Monte Carlo Analysis to see if we can uncover the true underlying Gini coefficient in this way. We start by setting the parameters in such a way, that we cover Gini coefficients from roughly 0.25 up to 0.6 by setting $\theta_1 = 0.1, 0.3, 0.5, ...6.7, 6.9$ and $\theta_2 = -1$. We pick these values because in the Swiss data we find the smallest Gini coefficient over all cantons and years to be 0.27 and the largest to be 0.58.

In each iteration we sample a hypothetical population of $N = 20,000$ and determine the true Gini coefficient for that population. We then discard all measures of '0' and censure the data into observable groups (1-4, 5-10, 11-20, more than 20) and use our approach to estimate the Gini coefficient. We run 50 simulations per individual setting (i.e. specific value for θ_1).

Figure A3: Monte Carlo Analysis



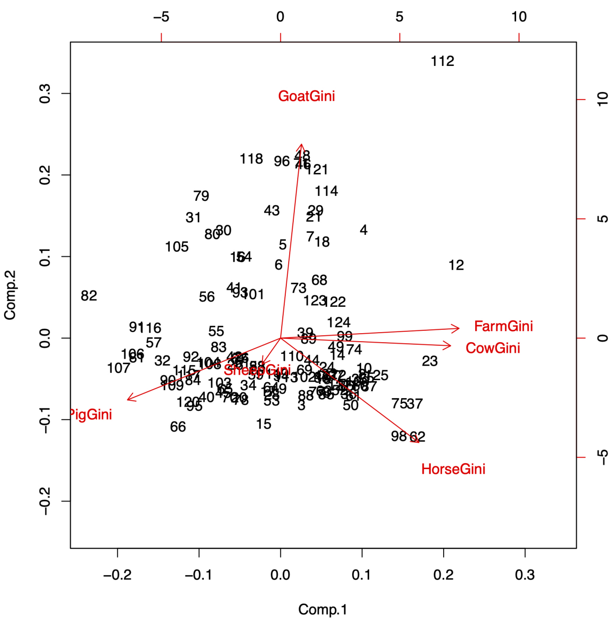
Note: Plot shows estimated and true values for the Gini coefficient. 50 simulations for each setting.

In Figure A4 the true measured Gini can be observed on the y axis and the estimated Gini coefficient on the x axis. As can be seen from this visualization, the estimates are very good in uncovering the true underlying value despite the censuring of the data into groups (1-4, 5-10, 11-20, more than 20).

1.3 Measuring Agricultural INequality

Finally, for the period where there is also data on farm sizes, we can inspect how closely these two measures correlate. We run a principal component analysis to see how the various animal-based measures correlate with each other and with farm sizes. Figure A4 shows the bi-plot of the principal component analysis. The Gini coefficient based on farm size and the Gini coefficient based on number of cows are strongly associated, but fairly uncorrelated with the inequality in the number of goats, pigs, and horses.

Figure A4: Various Measures for Agricultural Inequality



Note: Plot shows location of various cantons and also how individual Gini measures are closer or further away from each other.

2 Robustness of Empirical Results

This section presents additional model estimates based on different samples, further control variables, and alternative operationalizations of the parliamentary competition variable.

2.1 Alternative Measure for Competition

	Model 10	Model 11	Model 12
Political Representation (REP)	-71.03^{**}		
	(29.99)		
One Party Majority (MAJ)		38.44	
		(27.03)	
Party Dominance (DOM)			47.00^{**}
			(22.87)
Direct Democracy (HDDI)	-17.18^{***}	-21.13^{***}	-15.83^{**}
	(6.53)	(8.01)	(6.60)
Industrialization (IND)	16.24	−63.81	−21.26
	(61.64)	(67.06)	(60.56)
REP x IND	137.49^{***}		
	(52.59)		
MAJ x IND		-61.32^{*}	
		(34.30)	
DOM x IND			-92.73^{**}
			(41.13)
HDDI x IND	32.95^{***}	39.79^{***}	30.60^{***}
	(10.85)	(13.31)	(11.04)
Lagged Dependent Variable	0.82^{***}	0.85^{***}	0.83^{***}
	(0.03)	(0.04)	(0.03)
Deficit	−0.03	−0.03	−0.03
	(0.04)	(0.04)	(0.04)
Suffrage Restrictions	-17.59^{*}	-20.60^{*}	-17.57^{*}
	(9.72)	(11.20)	(9.38)
Seat Share Political Left	−2.67	−3.50	−4.01
	(6.57)	(6.36)	(6.52)
Rural Inequality	143.57^{**}	99.89	130.31^{*}
	(72.10)	(73.53)	(70.99)
Federal Payments	-0.27^{*}	-0.33^{**}	-0.27^{*}
	(0.15)	(0.16)	(0.14)
Printed Documents	1.73	−0.12	1.78
	(6.16)	(6.80)	(6.21)
R^2	0.979	0.978	0.979
Num. obs.	234	234	234
Cantonal FE	✓	✓	✓
Annual FE	✓	✓	✓

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A3: Alternative Measures for Parliamentary Competition

2.2 Domestic Determinants

	Model 6	Model 7	Model 8	Model 9
Political Representation (REP)	20.14*	14.47	−83.30**	−73.43**
	(10.77)	(10.05)	(37.36)	(31.13)
Direct Democracy (HDDI)	1.49	−19.99**	1.76	−16.99**
	(1.78)	(8.16)	(1.70)	(6.87)
Industrialization (IND)	3.69	−60.26	130.65*	56.76
	(57.53)	(67.13)	(67.92)	(70.12)
REP x IND			165.15**	141.49***
			(64.73)	(53.96)
HDDI x IND		36.95***		32.19***
		(13.73)		(11.64)
Lagged Dependent Variable	0.90***	0.87***	0.85***	0.83***
	(0.04)	(0.04)	(0.03)	(0.03)
Deficit	−0.01	−0.03	−0.03	−0.05
	(0.08)	(0.08)	(0.08)	(0.08)
Suffrage Restrictions	−9.74	−14.45	−11.33	−15.21*
	(10.11)	(10.10)	(9.26)	(9.10)
Seat Share Political Left	−7.31	0.37	−9.39	−2.41
	(6.58)	(7.59)	(7.24)	(7.21)
Rural Inequality	105.94	128.60	201.04*	207.15*
	(98.15)	(105.92)	(104.62)	(112.48)
Federal Payments	−0.43**	−0.36**	−0.34*	−0.30*
	(0.21)	(0.18)	(0.18)	(0.16)
Printed Documents	12.07	−7.63	13.21*	−4.12
	(7.99)	(11.21)	(7.71)	(9.70)
R^2	0.98	0.98	0.98	0.98
Num. obs.	200	200	200	200
RMSE	19.69	19.15	19.20	18.81

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A4: The Domestic Determinants of Direct Taxation

2.3 Earlier Time Period

	Model 13	Model 14	Model 15	Model 16
Political Representation (REP)	22.45^{**}	-80.29^{**}	14.24	-51.38^{**}
	(10.56)	(35.24)	(10.30)	(24.99)
Direct Democracy (HDDI)	2.34	2.24	-33.97^{***}	-29.24^{***}
	(2.22)	(2.41)	(9.77)	(9.21)
Industrialization (IND)	13.23	123.83	-62.62	19.19
	(61.52)	(76.90)	(71.85)	(83.32)
REP x IND		167.05^{***}		108.46^{**}
		(61.59)		(44.18)
HDDI x IND			63.62^{***}	55.24^{***}
			(17.12)	(16.37)
Lagged Dependent Variable	0.84^{***}	0.85^{***}	0.77^{***}	0.78^{***}
	(0.18)	(0.18)	(0.16)	(0.17)
Deficit	0.05	0.02	0.05	0.03
	(0.11)	(0.10)	(0.10)	(0.10)
Suffrage Restrictions	-13.76	-13.56	-29.80^{**}	-27.55^{**}
	(11.71)	(9.38)	(12.95)	(11.59)
Seat Share Political Left	1.17	1.71	0.06	0.56
	(8.80)	(8.76)	(8.76)	(8.64)
Rural Inequality	166.10	164.75	181.89	178.93
	(167.50)	(159.23)	(167.94)	(152.79)
Federal Payments	-0.92^{*}	-0.67	-0.53	-0.42
	(0.51)	(0.43)	(0.34)	(0.33)
Printed Documents	-1.97	0.63	-19.80	-15.76
	(11.01)	(9.78)	(12.48)	(11.43)
R^2	0.956	0.960	0.964	0.965
Num. obs.	115	115	115	115
Cantonal FE	✓	✓	✓	✓
Annual FE	✓	✓	✓	✓

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A5: Models For Early Period (1850-1885)

2.4 Adding Poverty Measure

	Model 17	Model 18	Model 19	Model 20
Political Representation (REP)	17.44^{**}	-72.14^{**}	13.10	-69.17^{**}
	(8.43)	(32.65)	(8.31)	(27.78)
Direct Democracy (HDDI)	2.08	2.17	-17.97^{**}	-16.60^{**}
	(1.65)	(1.62)	(7.52)	(6.71)
Industrialization (IND)	-32.92	84.31	-95.45	16.61
	(50.86)	(56.06)	(60.80)	(61.78)
REP x IND		145.48^{***}		134.05^{***}
		(55.85)		(48.08)
HDDI x IND			34.18^{***}	31.97^{***}
			(12.45)	(11.18)
Lagged Dependent Variable	0.88^{***}	0.84^{***}	0.85^{***}	0.82^{***}
	(0.04)	(0.03)	(0.03)	(0.03)
Deficit	-0.01	-0.02	-0.02	-0.03
	(0.04)	(0.04)	(0.04)	(0.04)
Suffrage Restrictions	-14.55	-15.06	-17.71	-17.98^{*}
	(11.91)	(10.57)	(11.48)	(10.14)
Seat Share Political Left	-5.88	-7.85	-0.53	-2.69
	(6.56)	(6.74)	(6.86)	(6.57)
Rural Inequality	102.45	131.84^{*}	123.79^{*}	149.49^{**}
	(74.65)	(75.79)	(72.83)	(74.35)
Federal Payments	-0.36^{**}	-0.32^{*}	-0.31^{**}	-0.27^{*}
	(0.17)	(0.16)	(0.15)	(0.15)
Printed Documents	14.86^{**}	14.19^{**}	1.75	1.98
	(6.12)	(5.73)	(6.80)	(6.39)
Poverty	-93.07	-59.48	-46.13	-18.22
	(57.20)	(44.58)	(52.47)	(44.49)
R^2	0.977	0.978	0.978	0.979
Num. obs.	234	234	234	234
Cantonal FE	✓	✓	✓	✓
Annual FE	✓	✓	✓	✓

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A6: Models Including Poverty

2.5 Adding a Spatial Lag

	Model 21	Model 22	Model 23	Model 24
Political Representation (REP)	18.54**	12.31	−78.35**	−69.64**
	(8.78)	(8.14)	(36.42)	(29.75)
Direct Democracy (HDDI)	1.90	−19.97**	2.10	−17.41***
	(1.79)	(8.01)	(1.68)	(6.64)
Industrialization (IND)	−44.74	−109.62*	87.92	10.60
	(52.19)	(62.27)	(58.23)	(61.06)
REP x IND			157.25**	134.11**
			(63.31)	(51.89)
HDDI x IND		37.31***		33.24***
		(13.09)		(11.01)
Lagged Dependent Variable	0.88***	0.85***	0.85***	0.82***
	(0.04)	(0.04)	(0.03)	(0.03)
Deficit	−0.00	−0.02	−0.02	−0.03
	(0.04)	(0.04)	(0.04)	(0.04)
Suffrage Restrictions	−11.64	−16.63	−13.36	−17.55*
	(11.15)	(10.94)	(10.18)	(9.80)
Seat Share Political Left	−5.27	1.09	−8.01	−1.93
	(6.88)	(7.54)	(6.95)	(6.86)
Rural Inequality	32.87	73.03	100.91	126.68
	(92.17)	(87.71)	(85.84)	(87.03)
Federal Payments	−0.38**	−0.31**	−0.32**	−0.27*
	(0.18)	(0.15)	(0.16)	(0.15)
Printed Documents	13.63**	−1.62	14.07**	0.42
	(6.58)	(7.57)	(6.30)	(6.97)
Spatial Lag	−0.07	−0.08	−0.02	−0.04
	(0.08)	(0.09)	(0.07)	(0.08)
R^2	0.98	0.98	0.98	0.98
Num. obs.	234	234	234	234
Cantonal FE	✓	✓	✓	✓
Annual FE	✓	✓	✓	✓

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A7: Including a Spatial Lag

2.6 Effects on Total Taxation

	Model 25	Model 26	Model 27	Model 28
Political Representation (REP)	41.41**	−114.92**	35.34*	−107.84**
	(17.93)	(47.98)	(18.17)	(49.24)
Direct Democracy (HDDI)	3.33*	3.64*	−17.48*	−12.95*
	(1.97)	(1.85)	(9.02)	(7.73)
Industrialization (IND)	−49.16	153.85*	−115.32	85.75
	(63.25)	(90.32)	(75.78)	(106.48)
REP x IND		250.13***		231.08**
		(90.00)		(94.50)
HDDI x IND			35.62**	28.34**
			(14.56)	(12.76)
Lagged Dependent Variable	0.86***	0.81***	0.83***	0.79***
	(0.04)	(0.04)	(0.04)	(0.04)
Deficit	0.06	0.03	0.05	0.02
	(0.07)	(0.07)	(0.07)	(0.06)
Suffrage Restrictions	−6.71	−8.56	−11.15	−11.95
	(12.52)	(10.22)	(13.05)	(10.76)
Seat Share Political Left	−6.79	−10.60	−0.98	−5.68
	(9.54)	(9.47)	(10.57)	(9.90)
Rural Inequality	101.76	162.96	142.82	190.97
	(115.55)	(120.71)	(111.14)	(118.89)
Federal Payments	−0.52**	−0.41**	−0.45**	−0.37**
	(0.21)	(0.19)	(0.19)	(0.18)
Printed Documents	22.27***	20.24***	8.03	9.06
	(7.57)	(6.88)	(8.63)	(7.96)
R^2	0.978	0.978	0.979	0.980
Num. obs.	234	234	234	234
Cantonal FE	✓	✓	✓	✓
Annual FE	✓	✓	✓	✓

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A8: The Domestic Determinants of Total Taxation

2.7 Education Spending

	Model 29
Total Taxation	0.21
	(0.13)
Federal Payments	−0.08
	(0.09)
Poverty	1.03
	(73.32)
Deficit	−0.02
	(0.05)
Lagged Dependent Variable	0.22
	(0.17)
R^2	0.986
Num. obs.	100
Cantonal FE	✓
Annual FE	✓

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A9: Total Taxation and Public Spending on Education at Cantonal Level

References

Sampford, M.R. 1955. "The truncated negative binomial distribution." *Biometrika* 42(1/2): 58–69.