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Have we been Under-Estimating Inflation Persistence Before the First World War? International evidence, 1851-1913

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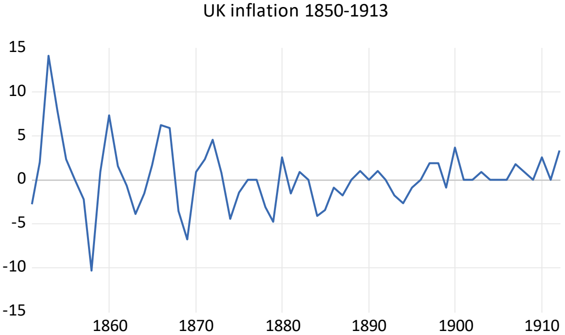
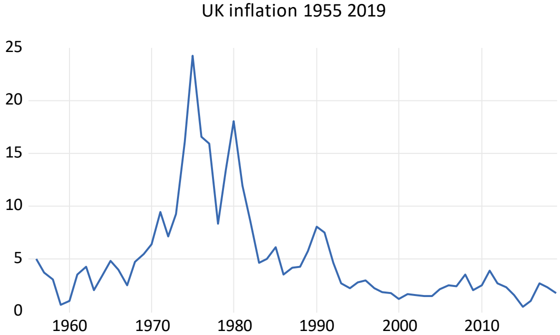
Background





- Generally accepted that inflation was not very persistent during the Gold Standard.
- Benati, QJE (2008) states that his results reassert:
  - *‘**the well-known absence of inflation persistence** in the United States, the United Kingdom, and Sweden under the gold standard’.*
- We use inflation in 17 countries during the 19th century to ask whether measurement error in inflation may be driving this result.

Background to lack of persistence

- Series of studies in the 1980s on US data during the classical gold standard.
- These papers focus on the lack of a Fisher relation between interest rates and inflation:
  - The Fisher hypothesis states that nominal interest rates should increase one-for-one with fully-anticipated inflation.
  - However, before the First World War, the correlation between nominal interest rates and inflation in the US is negative.
    - Instead, there is the Gibson Paradox: price LEVEL and interest rates are positively correlated.
- To explain this, the predictability of inflation was closely examined in several papers to understand how expectations around inflation were formed ex ante.
- Fisher argued that inflation expectations may be a weighted average of current and past inflation.
  - However, empirical estimates suggested that the number of lags required to generate expected inflation in a manner that the Fisher relation would hold, were improbably large (approximately 10 to 30 years, see Cagan (1965)).
  - Summers (1983) concludes that it is difficult to reconcile the data with standard economic models of full informed and rational agents.

Forecastability and persistence of inflation

- Barsky (1987) argues that it was basically impossible to forecast inflation pre-1914:
  - *'Inflation evolved from essentially a white noise process in the pre-World War I years, to a highly persistent, non-stationary ARIMA process in the post-1960 period'.*
  - As a result; the variance of anticipated inflation during the gold standard was very small relative to the variance of realized inflation.
- Schiller and Siegel (1977) at least in part attribute the Gibson Paradox to large unanticipated inflation shocks, again suggesting that inflation was not easily forecasted at the time.
- Benati (2008) finds that statistical persistence was entirely absent in inflation data for several countries in the period before 1914.
- Grytten and Hunnes (2009) draw similar conclusions studying data on Denmark, Norway and Sweden during the gold standard.

However…

- Series of papers studying the effect of monetary regime on inflation persistence directly measure inflation persistence using simple Philips curves or univariate AR processes often find some persistence during the gold standard (Alogoskoufis and Smith (1991), Alogoskoufis (1990), Burdekin and Siklos (1991), Siklos (1998)).
  - These papers generally focus on the US and UK.
- Meltzer and Robinson (1987) report first order serial correlation in inflation rates during the gold standard in five of the seven economies that they study. Their data are not a balanced panel but cover periods starting between the early-1860s and late-1880s and ending in 1913.

Quantity theory of money

- On a gold standard, gold discoveries increase the money supply and should lead to inflation.
- Barsky and DeLong (1991) show that gold production forecasted inflation during the gold standard.
- Flandreau (2004) details how gold finds in Australia and California in the 1850s led to fears of inflation, causing some countries – Belgium, Holland and Switzerland – to move to a silver standard in the belief that this would insulate them from price movements.
- *The Economist* was a strong believer in the quantity theory of money.
  - Although Barsky and DeLong (1991) argue that the *Economist* was uncertain about the exact model of the economy through which gold finds would pass-through to inflation.

We will consider the role of measurement error

- Kaufmann (2020) and Officer (2014) identify several sources of measurement error present in historical US price data:
  1. The number of price quotes used to construct historical price indices is usually much smaller than is used to construct modern series.
  2. The scarcity of price quotes means that data for small geographical areas are often used to represent countries as a whole. (London prices may be used for the UK, Vermont farm prices for the US.)
  3. Some price indices are only available at intervals and have to be interpolated. This is particularly true in the case of housing and rent for which data are scarce.
     - Long (1960) approximates the prices of rent by a linear interpolation over the entire 1880s, while Lebergott (1964) constructs a reproduction cost index by equally weighting the cost of construction materials and wages for low-skilled workers.
  4. Price quotes for services are particularly scarce.
  5. Wholesale prices are frequently used to proxy for missing retail prices. For instance, 20% of our UK price data in the years 1860-1870 is proxied using wholesale prices for flour, pork and bacon, potatoes and tallow.

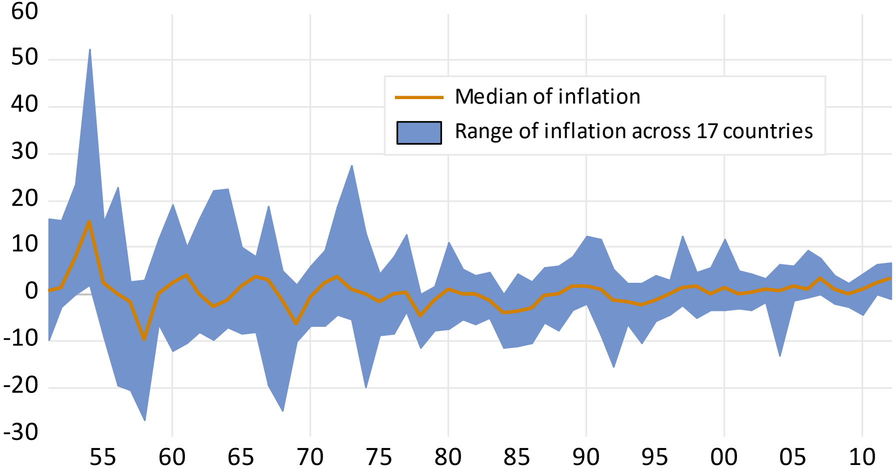
Importance of measurement error

- Benati (2008) states that although:
  - *'the problem [of measurement error] is potentially there, unfortunately it is not clear at all how to even gauge an idea of the likely extent of its impact, and in what follows I will therefore ignore it'.*
- Several studies had argued that deflation was not costly during the gold standard, and the only episode of costly deflation was the Great Depression (Bordo and Filardo (2005), Borio et al. (2015)).
- Kaufmann (2020) shows allowing for measurement error, the link is quite strong, with the shortfall of US industrial production growth ranging from -4.5 pp to -7.6pp during periods of deflation.
- Cogley and Sargent (2015) and Cogley, Sargent and Saurico (2015) estimated UCSV models of the price level in the US and UK, respectively, with an equation for unobserved measurement error.
  - Estimate a measurement error (but still find that the persistent component of inflation in both countries is centred around zero during the 19th century).

CPI Data, 17 countries, 1850-1913

	Median	Mean	Standard deviation	Source
Australia	1.29	1.31	4.91	McLean (1999), W6-series used
Austria	0.00	0.18	4.68	Mühlpeck, et al., (1979)
Belgium	0.00	0.33	1.40	Mitchell (2003)
Canada	0.00	0.19	2.64	Various, see text
Denmark	0.72	0.67	6.64	Abildgren (2009)
Finland	0.00	0.47	5.22	Heikkinen (1997)
France	0.54	0.67	4.25	Mitchell (2003)
Germany	0.80	0.55	3.23	Mitchell (2003)
Iceland	1.07	0.73	3.49	BIS , www.bis.org
Netherlands	1.07	0.73	3.49	Arthur van Riel, http://iisg.nl/hpw/brannex.php
Norway	0.56	0.55	5.83	Grytten (2004)
Portugal	0.00	0.93	8.52	Clio-infra.eu
Spain	-0.47	0.29	6.05	Clio-infra.eu
Sweden	0.72	0.20	2.37	Edvinsson and Söderberg (2010)
Switzerland	-0.08	0.12	3.19	Studer and Schuppli (2008), Historical Statistics of Switzerland (2012)
UK	0.12	-0.31	5.69	FRED, fred.stlouisfed.org
US	0.56	0.49	3.07	www.measuringworth.com

Median and range of inflation across 17 countries



One mis-measured regressor, one instrument

- We assume that the measurement errors are normally distributed and serially and mutually uncorrelated.
- We observe the inflation rate in economy i, $\pi_{i,t}$, subject to a measurement error, $\nu_{i,t}$:

  $\pi_{i,t} = \pi^*_{i,t} + \nu_{i,t}$, where $\pi^*_{i,t}$ denotes the true, unobserved, inflation rate.

- Consider next a first-order autoregressive model:

$$\pi^*_{i,t} = \beta_i \pi^*_{i,t-1} + \varepsilon_{i,t}$$

- Since data on $\pi^*_{i,t}$ are not available, must rewrite this equation in terms of the observed inflation rate, $\pi_{i,t}$:

$$\pi_{i,t} = \beta_i \pi_{i,t-1} + \left[\varepsilon_{i,t} - \beta_i \nu_{i,t-1} + \nu_{i,t}\right]$$

- where we assume that the regression error $\varepsilon_{i,t}$ is normally distributed and serially uncorrelated.
- Under the assumptions we have made $\varepsilon_{i,t} - \beta_i \nu_{i,t-1} + \nu_{i,t}$ is correlated with $\pi_{i,t-1}$.
- The resulting attenuation bias pushes the autoregressive parameter toward zero, and under-estimate persistence.

Instrumental variable

- Can estimate β_i using instrumental variables.
- Requires an instrument, z_{t-1}, that is, ideally perfectly, correlated with the unobserved true inflation rate, $\pi^*_{i,t-1}$, but uncorrelated with the measurement error, $\nu_{i,t-1}$.
- Under our assumption that the measurement errors are uncorrelated across economies, the cross-sectional mean and median of the lagged inflation rates in the 17 economies we study are likely to be unaffected by the measurement error in individual economies.
- Assume for simplicity that the measurement errors have the same variance in all countries and are mutually uncorrelated and consider the cross-sectional mean of inflation.
- The errors add a term to the variance of the mean equal to σ^2/N , where N is the number of economies.
- Thus, while measurement errors increase the variance of inflation in an individual economy by σ^2, they increase the variance of the mean of 17 countries by just 6% of that.
- The same argument applies to the cross-sectional median. We use this, since there are occasional large outliers in the inflation rate of individual economies that may potentially be due at least partly to measurement errors.

Median as an instrument

- Of course, an instrument must also be correlated with the unobserved, correctly measured national inflation rate.
- In Gerlach and Stuart (2021) we estimate reduced-form inflation equations of the form proposed by Ciccarelli and Mojon (2010) and demonstrate that the common component, defined as the cross-sectional median, is significant in 13 of the 15 economies we study.
- This suggests that it will be a good instrument for the purposes of this paper.

R^2 from the regression of the domestic inflation rate on the median inflation rate	
Australia	0.17
Austria	0.16
Belgium	0.45
Canada	0.35
Denmark	0.59
Finland	0.36
France	0.40
Germany	0.47
Iceland	0.27
Netherlands	0.64
Norway	0.58
Sweden	0.53
Switzerland	0.50
UK	0.77
US	0.02

What might measurement error look like?

- We never observe the ‘true’ inflation rate over the sample period.
- The series that we use for the US is a composite series compiled by Officer (2014).
- We collect eight alternative price series considered and rejected by Officer. These series cover various sub-samples over the period 1850-1913.
- Assume that all nine series (Officer’s series plus the eight alternatives) provide measures of the true rate of inflation plus an error term.
- Use the median to capture a common component of inflation, which as per our arguments above, should contain little measurement error.
  - We therefore calculate measurement error as the difference between each series and the median of the nine series.
  - The measurement error is regressed on a constant and a lagged dependent variable.
  - The constant is never statistically significant, and the lagged dependent variable is only significant in one out of the nine regressions.

OLS results

$$\pi_{i,t} = \alpha_i + \beta_i \pi_{i,t-1} + \zeta_{i,t}$$

1852-1913, 62 observations

Dep. Var:	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Iceland	Nether-lands	Norway	Portugal	Spain	Sweden	Switzer-land	UK	US
C	0.211	0.467	0.168	-0.100	0.165	0.456	0.357	0.693	0.774	0.082	0.445	1.268	0.242	0.439	0.418	0.201	0.188
	(1.151)	(0.450)	(0.654)	(0.896)	(0.368)	(0.819)	(0.214)	(0.760)	(0.529)	(0.464)	(0.480)	(1.072)	(0.774)	(0.623)	(1.032)	(0.426)	(0.509)
	[0.183]	[1.038]	[0.256]	[-0.112]	[0.449]	[0.557]	[1.671]	[0.912]	[1.462]	[0.176]	[0.927]	[1.182]	[0.312]	[0.704]	[0.405]	[0.471]	[0.369]
Lagged inflation	0.190	0.241	0.200	0.247	0.462	0.208	0.129	0.417	-0.009	0.415	0.335	-0.143	-0.036	0.319	0.179	0.349	0.659
	(0.126)	(0.124)	(0.127)	(0.124)	(0.115)	(0.126)	(0.128)	(0.112)	(0.129)	(0.117)	(0.122)	(0.126)	(0.129)	(0.122)	(0.127)	(0.120)	(0.097)
	[1.508]	[1.938]	[1.571]	[1.988]	[4.033]**	[1.651]	[1.007]	[3.730]**	[-0.073]	[3.531]**	[2.740]**	[-1.137]	[-0.278]	[2.615]*	[1.412]	[2.910]**	[6.792]**
Observations:	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
R-squared:	0.037	0.059	0.039	0.062	0.213	0.043	0.017	0.188	0.000	0.172	0.111	0.021	0.001	0.102	0.032	0.124	0.435
F-statistic:	2.274	3.757	2.467	3.952	16.265	2.727	1.013	13.913	0.005	12.468	7.506	1.292	0.078	6.840	1.995	8.466	46.129
Prob(F-stat):	0.137	0.057	0.122	0.051	0.000	0.104	0.318	0.000	0.942	0.001	0.008	0.260	0.782	0.011	0.163	0.005	0.000

standard errors in parenthesis, (); t-statistics in brackets, []. */** denotes significance at the 5%/1% level.

AR parameter much smaller than in recent data

Dep. Var:	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Iceland	Nether-lands	Norway	Portugal	Spain	Sweden	Switzer-land	UK	US
Lagged	0.190	0.241	0.200	0.247	0.462	0.208	0.129	0.417	-0.009	0.415	0.335	-0.143	-0.036	0.319	0.179	0.349	0.659
inflation	(0.126)	(0.124)	(0.127)	(0.124)	(0.115)	(0.126)	(0.128)	(0.112)	(0.129)	(0.117)	(0.122)	(0.126)	(0.129)	(0.122)	(0.127)	(0.120)	(0.097)
	[1.508]	[1.938]	[1.571]	[1.988]	[4.033]**	[1.651]	[1.007]	[3.730]**	[-0.073]	[3.531]**	[2.740]**	[-1.137]	[-0.278]	[2.615]*	[1.412]	[2.910]**	[6.792]**
Observations:	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
R-squared:	0.037	0.059	0.039	0.062	0.213	0.043	0.017	0.188	0.000	0.172	0.111	0.021	0.001	0.102	0.032	0.124	0.435

OLS results, same countries, 1957-1969; 1986-2020

Lagged	0.704	0.461	0.311	0.660	0.761	0.607	0.433	0.663	0.719	0.523	0.600	0.792	0.695	0.636	0.739	0.697	0.596
inflation	(0.097)	(0.131)	(0.136)	(0.116)	(0.093)	(0.099)	(0.135)	(0.113)	(0.086)	(0.148)	(0.115)	(0.054)	(0.106)	(0.106)	(0.102)	(0.102)	(0.130)
	[7.267]**	[3.504]**	[2.292]*	[5.685]**	[8.172]**	[6.124]**	[3.214]**	[5.887]**	[8.336]**	[3.523]**	[5.236]**	[14.791]**	[6.537]**	[5.970]**	[7.284]**	[6.809]**	[4.593]**
Observations:	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
R-squared:	0.534	0.211	0.102	0.413	0.592	0.449	0.183	0.430	0.602	0.212	0.373	0.826	0.482	0.437	0.536	0.502	0.314

IV estimates

$$\pi_{i,t} = \alpha_i + \beta_i \pi_{i,t-1} + \zeta_{i,t}$$

1852-1913, n= 62, instrument: cross-section median

Dep. Var:	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Iceland	Nether-lands	Norway	Portugal	Spain	Sweden	Switzer-land	UK	US
C	0.183	0.494	0.037	-0.100	0.115	0.184	0.252	0.469	0.607	0.059	0.217	0.730	0.095	0.062	0.506	0.194	0.199
	(1.184)	(0.493)	(0.723)	(0.896)	(0.375)	(0.916)	(0.233)	(0.796)	(0.563)	(0.474)	(0.523)	(1.272)	(0.872)	(0.726)	(1.047)	(0.426)	(0.539)
	[0.155]	[1.001]	[0.051]	[-0.112]	[0.306]	[0.201]	[1.083]	[0.589]	[1.078]	[0.125]	[0.416]	[0.574]	[0.109]	[0.086]	[0.484]	[0.455]	[0.369]
Lagged inflation	0.426	0.203	0.659	0.235	0.627	0.683	0.386	0.554	0.216	0.596	0.718	0.433	0.474	0.859	0.033	0.377	0.626
	(0.250)	(0.316)	(0.212)	(0.187)	(0.146)	(0.227)	(0.222)	(0.169)	(0.244)	(0.158)	(0.177)	(0.314)	(0.291)	(0.215)	(0.186)	(0.144)	(0.518)
	[1.705]	[0.643]	[3.112]*	[1.262]	[4.287]*	[3.011]*	[1.737]	[3.274]*	[0.887]	[3.765]*	[4.055]*	[1.378]	[1.631]	[4.001]*	[0.178]	[2.613]*	[1.209]
Lee et al., critical values	2.54	3.29	2.16	2.16	1.96	2.26	3.31	2.16	2.46	2.02	2.03	2.75	2.63	2.19	2.12	1.96	NA
Observations:	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
R-squared:	-0.020	0.057	-0.168	0.062	0.186	-0.182	-0.049	0.168	-0.051	0.139	-0.034	-0.320	-0.260	-0.190	0.011	0.123	0.434
F-statistic:	2.908	0.413	9.682	1.592	18.381	9.065	3.017	10.720	0.786	14.178	16.439	1.899	2.660	16.010	0.032	6.826	1.463
Prob(F-stat):	0.093	0.523	0.003	0.212	0.000	0.004	0.088	0.002	0.379	0.000	0.000	0.173	0.108	0.000	0.860	0.011	0.231

standard errors in parenthesis, (); t-statistics in brackets, []. * denotes significance at the 5% level based on critical values from Lee et al., (2020), Table 3.

AR half-life

- The AR parameter is of crucial interest as it captures the persistence of a shock to inflation.
- The half-life of a shock is given by $\frac{ln(0.5)}{ln(\beta_i)}$.
- This function is nonlinear and steepens as β_i rises.
- As the AR parameter approaches unity, the slope approaches infinity.

	OLS		IV	
	AR	Half-life	AR	Half-life
Australia	0.19	0.42	0.43	0.81
Austria	0.24	0.49	0.20	0.43
Belgium	0.20	0.43	0.66*	1.66
Canada	0.25	0.50	0.24	0.48
Denmark	0.46*	0.90	0.63*	1.48
Finland	0.21	0.44	0.68*	1.82
France	0.13	0.34	0.39	0.73
Germany	0.42*	0.79	0.55*	1.17
Iceland	-0.01		0.22	0.45
Netherlands	0.41*	0.79	0.60*	1.34
Norway	0.34*	0.63	0.72*	2.09
Portugal	-0.14		0.43	0.83
Spain	-0.04		0.47	0.93
Sweden	0.32*	0.61	0.86*	4.55
Switzerland	0.18	0.40	0.03	0.20
UK	0.35*	0.66	0.38*	0.71
US	0.66*	1.66	0.63	1.48
Mean	0.24	0.65	0.48	1.25

Discussion

- The parameter is only significant in 8 cases when IV is used.
  - Thus, we cannot reject the hypothesis of no persistence in most cases.
- However, this impression stems from looking at the results equation-by-equation.
  - In the presence of measurement errors, the OLS estimates will be biased towards zero, reducing the likelihood that we can reject the hypothesis that the coefficient is zero.
  - Furthermore, the IV estimates are generally inefficient.
- Since we have 17 equations, we test the joint restriction that all the β_i parameters are zero.
  - Using both the OLS estimates and the IV estimates yields a p-value of 0.000.
- But are the AR parameters estimated with OLS and IV, are they the same?
  - If there are no measurement error, then the OLS and IV estimates are both consistent and we would expect them to differ randomly.
  - But, in 12 of 17 cases the IV estimates are larger than the OLS estimates, the probability of which is 4.7% if they had the same expected value. This suggests that measurement errors are present.

Are the OLS and IV estimates of persistence the same?

- The test is constructed by performing the first-stage regression implicit in IV estimation process, that is, by regressing the national inflation rates, $\pi_{i,t}$, on the cross-sectional median of inflation, π_t^M:

$$\pi_{i,t} = \delta_i + \gamma_i \pi_t^M + u_{i,t}$$

- The estimated residuals are added to the equation:

$$\pi_{i,t} = \alpha_i + \beta_i \pi_{i,t-1} + \lambda_i \hat{u}_{i,t-1} + \zeta_{i,t}^*$$

- We then test the joint hypothesis that the parameters on the residuals λ_i from the first-stage regressions are all zero: p-value is 0.000.
- Overall, considering the results for the 17 economies together, the lagged dependent variables are significant in both the OLS and IV regressions, and the parameter is larger when IV is used.
- Taken together, these findings are compatible with inflation being measured subject to errors.

Robustness (1): 1802-1913

IV estimates of inflation equation $\pi_{i,t} = \alpha_i + \beta_i \pi_{i,t-1} + \zeta_{i,t}$

1802-1913, n =112, instrument: cross-section median

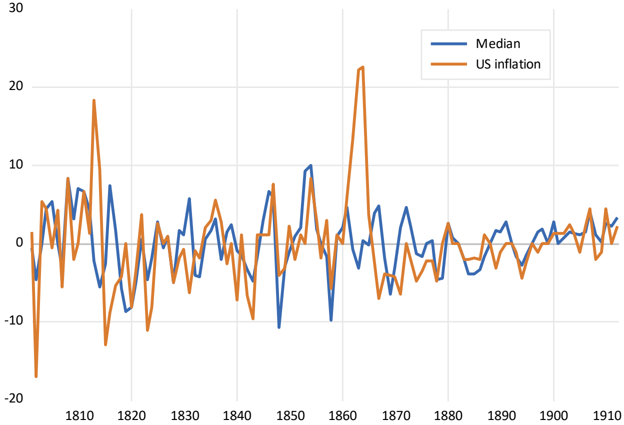
Dep. Var:	Austria	Canada	Denmark	Finland	Netherlands	Norway	Portugal	Sweden	Switzerland	UK	US
C	0.454	-0.241	0.208	0.122	-0.236	0.320	0.046	0.546	-0.053	-0.102	-0.070
	(0.548)	(0.746)	(1.996)	(0.924)	(0.472)	(1.797)	(1.034)	(0.627)	(0.871)	(0.516)	(0.538)
	[0.829]	[-0.323]	[0.104]	[0.132]	[-0.501]	[0.178]	[0.044]	[0.871]	[-0.060]	[-0.197]	[-0.131]
Lagged	-0.026	0.470	1.019	0.694	0.362	0.857	0.216	0.533	0.162	0.435	0.664
inflation	(0.197)	(0.245)	(0.313)	(0.278)	(0.124)	(0.241)	(0.191)	(0.154)	(0.150)	(0.129)	(0.338)
	[-0.130]	[1.919]	[3.252]**	[2.498]*	[2.910]**	[3.561]**	[1.134]	[3.466]**	[1.081]	[3.379]**	[1.961]
Observations:	112	112	112	112	112	112	112	112	112	112	112
R-squared:	-0.003	-0.054	-0.260	-0.439	0.048	-0.025	-0.007	-0.071	0.009	0.034	0.043
F-statistic:	0.017	3.682	10.576	6.238	8.468	12.679	1.287	12.014	1.169	11.421	3.846
Prob(F-stat):	0.897	0.058	0.002	0.014	0.004	0.001	0.259	0.001	0.282	0.001	0.052

Robustness (1): 1802-1913

- Repeat the analysis for 11 countries for which we have CPI data starting in 1800.
- Increases our n from 62 to 112, which is helpful since the IV estimates are valid only asymptotically.
- The average slope parameters using OLS and IV are virtually the same as for the shorter sample.
    - DWH tests rejects the null with a p-value of 0.000.
- Overall, the results for the 1802-1913 sample period are very similar to those for the 1852-1913 sample period.

Robustness (2): US estimates

- Results for US disappointing.
- The US civil war was a country-specific shock that would not affect the cross-sectional median.
- We drop the years 1861-1865 and re-estimate the equations over the years 1802 1913.
- The OLS AR parameter is 0.13 and insignificant.
- Using IV, the AR parameter is 0.64 and significant at the 5% level.
- DWH test indicates that the OLS and IV parameters are significantly different at the 5% level.



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Thank you

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