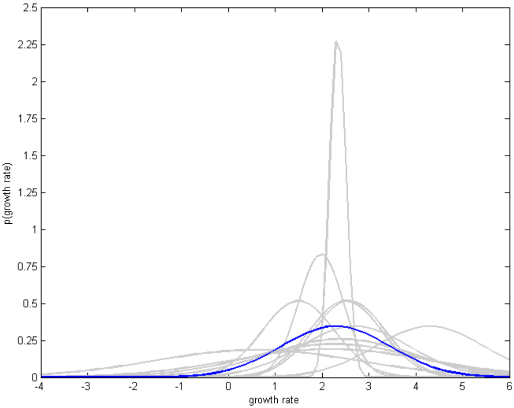
Expert Survey on Long-Run Economic Growth

Modeling Uncertainty Project

EMF, Snowmass 2015

July 27, 2015

PDF: GDP Growth Rates (2010-2100)



$$\hat{\mu} = 2.29;\ \hat{\sigma} = 1.15$$

Uncertainty in Long-Run Productivity Growth

- Climate models generally draw estimates of emissions pathways from background models of economic growth
  - EMF-22 or SRES scenarios (IAWG 2010)
- Literature on long-run productivity growth involves active and ongoing debates
  - role of new technologies and inventions (Brynjolfsson and McAfee 2012, Gordon 2012)
  - research intensity and educational attainment in emerging economies (Fernald and Jones 2014, Freeman 2010)
  - institutional reform (Acemoglu et al. 2005)

Obtaining a PDF

- Processes underlying productivity growth is non-stationary
  - simulations using historical data may not be sufficiently informative (Webster and Cho, 2006)
  - limited historical data and measurement error
- The role of expert surveys
  - experts can add value to forecasts based on historical observations
  - combining expert estimates has been shown to reduce error in short-run forecasts (Batchelor and Dua 1995).
  - very little systematic survey work (Nordhaus 1991 (unpublished), Webster et al 2002)

Expert Survey: Design

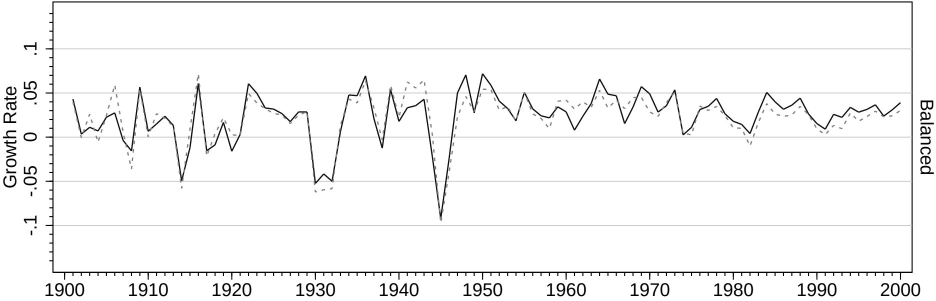
- GDP per capita, average annual rates
- 10th, 25th, 50th, 75th, 90th percentiles
- World and major regions
- Self-reported expertise

Survey Design

Q2. Please provide estimates for the 10th, 25th, 50th, 75th, and 90th percentile rates of growth of per capita real GDP (average percent per year) for the following regions...

	2010-2050					2010-2100				
	10th	25th	50th	75th	90th	10th	25th	50th	75th	90th
World										
United States										
China										
High Income (Includes US)										
Middle Income										
Low Income (includes China and India)										

Data Provided: Historical Growth Rates (1900-2000)



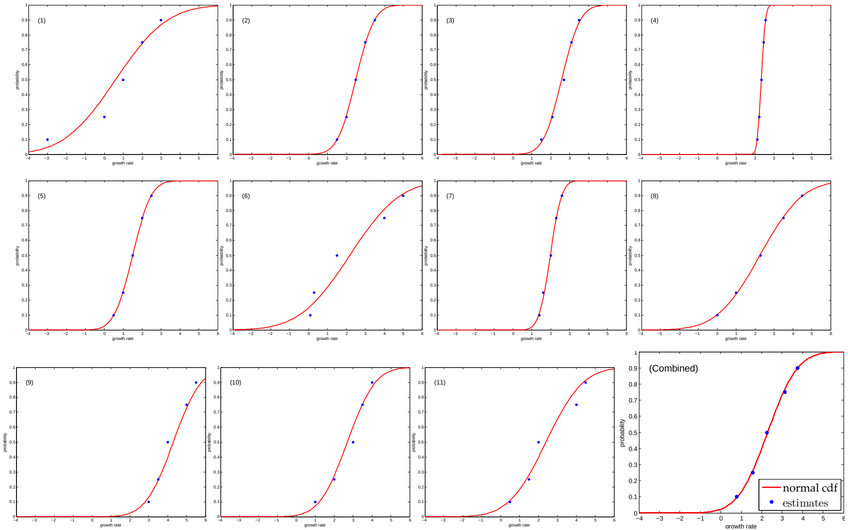
Solid Line - Barro-Ursua (2010)
Dashed Line - Maddison (2003)

Self-Reported Expertise

7.4.
Please rank your own expertise on the different regions by checking a box on the following scale of 1-10. A rating of 1 indicates little expertise, a 5 indicates the expertise of someone who has studied the subject but is not a specialist, and 10 indicates an expertise that is among the leading experts.

	Expertise on Economic Growth									
	1	2	3	4	5	6	7	8	9	10
World	○	○	○	○	○	○	○	●	○	○
United States	○	○	○	○	○	●	○	○	○	○
China	○	○	○	○	○	●	○	○	○	○
High Income	○	○	○	○	○	●	○	○	○	○
Middle Income	○	○	○	○	○	●	○	○	○	○
Low Income	○	○	○	○	○	○	●	○	○	○

Expert Estimates Fit to Normal CDF

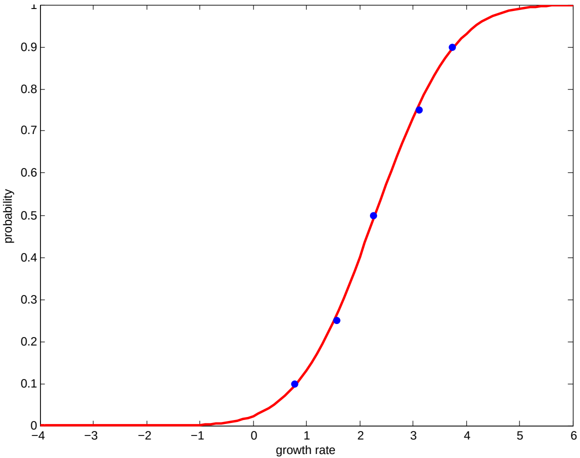


Estimated Parameters and Kolmogorov-Smirnov Test

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	combined
μ	0.60	2.50	2.58	2.34	1.50	2.18	1.98	2.26	4.30	2.70	2.40	2.29
σ	2.16	0.77	0.77	0.17	0.77	2.09	0.48	1.78	1.16	1.16	1.54	1.15
K-S	0.441	0.933	0.933	0.983	0.692	0.540	0.919	0.641	0.999	0.841	0.733	0.784
K-S(p)	0.212	0.000	0.000	0.000	0.007	0.068	0.000	0.016	0.000	0.000	0.003	0.001

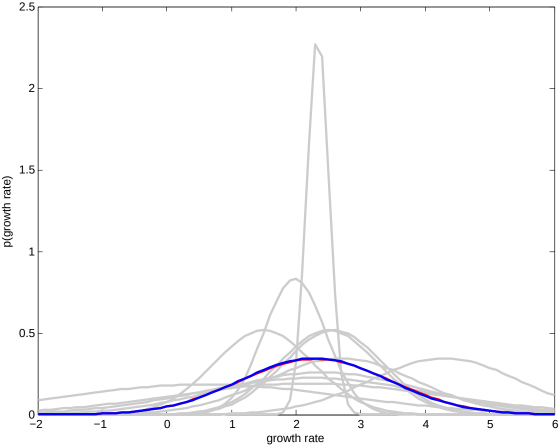
Notes: The one sample K-S test compares empirical distribution function for each expert to the cdf of the normal distribution; H(0): the empirical cdf is drawn from the normal cdf.

Combined (Normal) CDF: 2010-2100
$\hat{\mu} = 2.29$; $\hat{\sigma} = 1.15$



Notes:
(i) Combined normal distribution: $X \sim \mathcal{N}(\hat{\mu}, \hat{\sigma})$ that minimizes the sum of squared differences between $F(x)$ and $F(x; \hat{\theta}_{i,p=10}, \hat{\theta}_{i,p=25}, \hat{\theta}_{i,p=50}, \hat{\theta}_{i,p=75}, \hat{\theta}_{i,90})$, where $\hat{\theta}_{i,p} = \frac{1}{n}\sum_{i=1}^{n} \theta_{i,p}$. This d.f. assumes that experts possess iid estimates of quantiles for the distribution of long-run growth rates, $F(x; \theta_{i,p=10}, \theta_{i,p=25}, \theta_{i,p=50}, \theta_{i,p=75}, \theta_{i,90})$.

Marginal and Combined (Normal) PDFs 2010-2100



Notes:
(i) Alternate Method: Combined normal distribution is $X \sim \mathcal{N}(\hat{\mu}, \hat{\sigma})$, where $\hat{\mu} = \frac{1}{n}\sum_{i=1}^{n} \mu_i$ and $\hat{\sigma} = \frac{1}{n}\sum_{i=1}^{n} \sigma_i$. This d.f. assumes that each expert possesses estimates of μ and σ. Each individual set of parameters (μ_i, σ_i) is defined by the normal distribution that minimizes the sum of squared differences between the df and the quantile distribution $F(x; \theta_{i,p=10}, \theta_{i,p=25}, \theta_{i,p=50}, \theta_{i,p=75}, \theta_{i,90})$ reported by each expert.
(ii) Method 1: $\hat{\mu} = 2.29$; $\hat{\sigma} = 1.15$ Method 2: $\hat{\mu} = 2.30$; $\hat{\sigma} = 1.17$
(iii) Median: $\hat{\mu} = 2.34$; $\hat{\sigma} = 1.16$ Trimmed Mean: $\hat{\mu} = 2.30$; $\hat{\sigma} = 1.17$

Comparison with Historical Data

- Standard deviation in 100-year rates from 1000 AD to 2000 AD is 1.5%
- Standard deviation in annual rates from 1900-2000 AD is 2.70%
- Standard deviation in annual rates from 1950-1975 is 1.34% and from 1975-2000 AD is 1.09%

Table 1: MADDISON UNBALANCED PANEL

	WORLD					
	Growth Rate	SD (100,1)	SD (25,1)	SD (25,4)	N	Income Share
1900-1925	0.016	0.0270	0.0275	0.0122	34	0.67
1925-1950	0.015	0.0270	0.0412	0.0122	39	0.66
1950-1975	0.033	0.0270	0.0134	0.0122	122	0.93
1975-2000	0.025	0.0270	0.0109	0.0122	128	0.93

Notes:
(i) Data reference: Maddison (2003) and Barro-Ursua (2010)

Concluding Remarks

- Uncertainty in productivity growth will be modeled using expert projections
- We have a sample of 11 pdfs to date
- Experts estimates express divergent views but distributions are overlapping
- All but 2 distributions are approximately normal and combined distribution is a close fit to normal
- Combined expert projections closer to recent than distant history (lower growth rates)

Thank You