Interest Rate Determination & the Taylor Rule

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Monetary Policy Rules

- Policy rules form part of the "modern" approach to monetary policy where the goal is to stabilize the economy
- Definition: systematic decision process using information consistently and predictably
- Desirable properties
  - Rule must recognize that individuals anticipate decisions by the Central Bank
  - Rule must be explicit about how information is used
  - Rule should not be changed without a lot of forethought
  - Rule must be easily understood: complicated rules come across as capricious

Taylor Rule

- The Taylor rule determines a benchmark for the short-term policy rate:

$$i = r + \pi + \beta \cdot (\pi - \pi^*) + (1 - \beta) \cdot (y - y^*)$$

- Where
  - i is the federal funds rate predicted by the Taylor rule
  - r is the real interest rate
  - π is the current value of inflation
  - π^* is the target inflation rate
  - y is the measure of economic activity
  - y^* is the measure of "full employment" economic activity
  - $\beta > 0$ importance of inflation for monetary policy

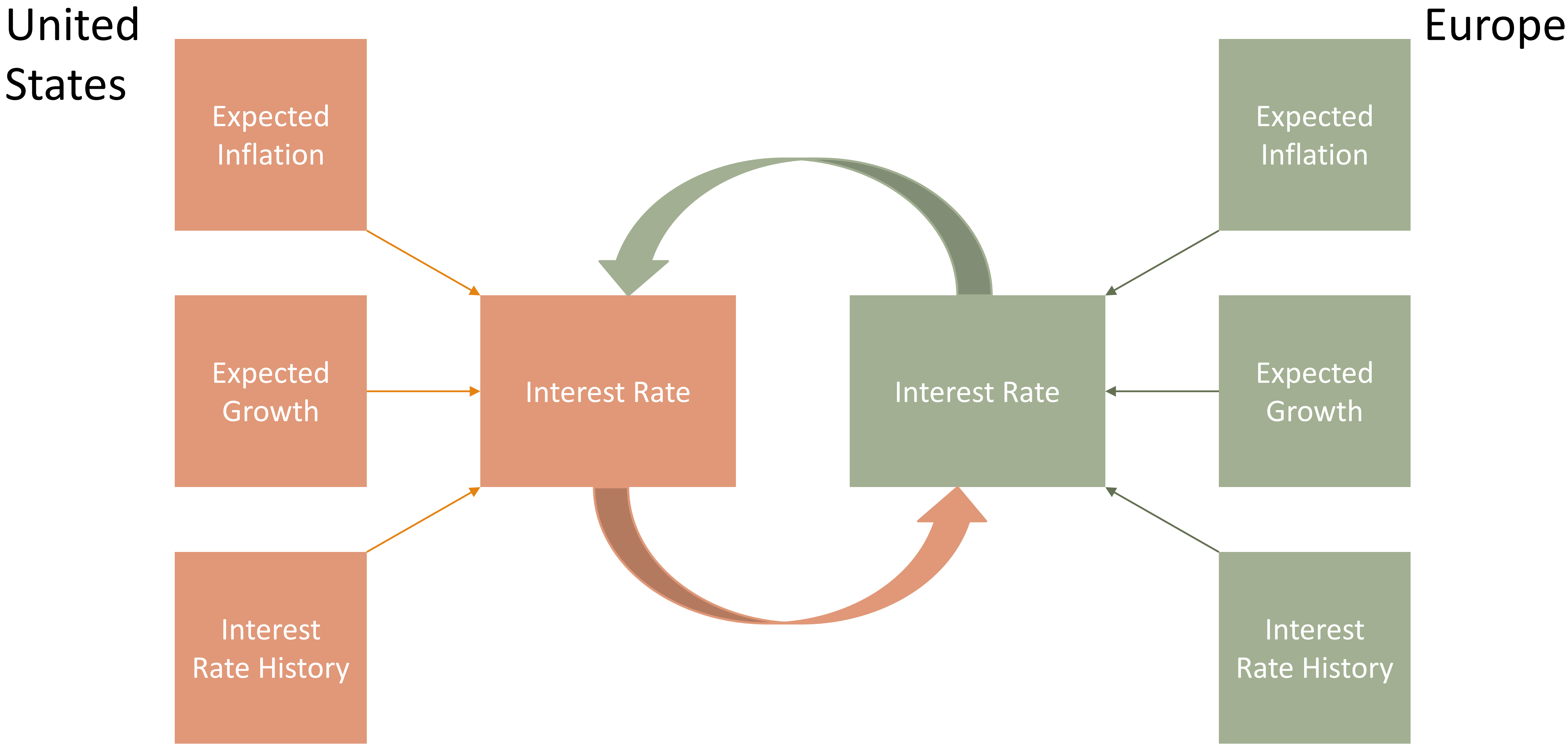
Source: http://www.brookings.edu/~/media/Events/2015/10/15-fed-crossroads/Taylor_remarks.pdf?la=en

Properties of the Taylor Rule

- If $\pi > \pi^*$ then $i \uparrow$: If the inflation rate exceeds the target rate, then monetary policy raises the short term rate
- If $y > y^*$ then $i \uparrow$: If the economic activity exceeds its full employment level, then monetary policy should raise the short-term rate
- If $\pi > \pi^*$ and $y > y^*$, then $i = r + \pi$, which is the Fisher equation
- The “money” of monetary policy follows the interest rate

Extensions of the Taylor Rule

- Persistence:
  - Monetary policy seeks to avoid large swings in policy rates
  - History of recent rates plays a role in setting monetary policy
- Expectations:
  - Changes in monetary policy do not materialize instantaneously: there is a lag
  - What matters are expectations of inflation and economic activity
  - If authorities anticipate an event that will disrupt the economy, they must act now to offset the expected disruption
- Interdependencies:
  - Interest rates are not determined in a vacuum
  - Domestic monetary policy potentially depends on foreign monetary policy and vice versa


United States
Europe
Expected Inflation
Expected Growth
Interest Rate History
Interest Rate
Interest Rate
Expected Inflation
Expected Growth
Interest Rate History

Generic Taylor Rule

$i_t \leftarrow$

↙	*neutral rate*	$r + \pi_{t+1}$
↙	*future inflation*	$\beta \cdot (\pi_{t+1} - \pi^*)$
←	*future growth*	$(1 - \beta) \cdot (y_{t+1} - y_t^*)$
↖	*history*	$\delta \cdot i_{t-1}$
↖	*interdependence*	$\lambda \cdot i_t^e$

Implementation of the Taylor Rule

- Parameters of the Taylor rule are generally unknown
- Practitioners typically assume values for the unknown parameters
- For example:
  - $\beta = 0.5$: Monetary policy is equally concerned with inflation and economic activity
  - $(y_{t+1} - y_t^*)$: output gap from the International Monetary Fund's *World Economic Outlook*
  - Target inflation rate $\pi^* = 2$ set and announced by the Central Bank
  - Real interest rate $r = 2$
- Values for unknown parameters can be estimated from data
- Real interest rate and output gap can be modelled with Monte Carlo analysis

Estimating Parameters: Rationale

- Rather than assuming parameters, estimate them based on past performance
  - United States and Euro Area data from 1995-2015
  - Inflation and output gap from the International Monetary Fund's *World Economic Outlook*
  - Federal funds rate from St. Louis Federal Reserve's *Federal Reserve Economic Data* (FRED)
  - Eonia rate from European Central Bank
- How are the determinants of the interest rate actually weighted?

Empirical Methodology

- The structural model is:

$$i_t^{US} = \varphi_0 + \varphi_1 \cdot (y_t - y_t^*) + \varphi_2 \cdot \pi_t + \varphi_3 \cdot i_{t-1} + \varphi_4 \cdot i_t^{EU}$$

$$i_t^{EU} = \varphi_0^{EU} + \varphi_1^{EU} \cdot (y_t^{EU} - y_t^{EU*}) + \varphi_2^{EU} \cdot \pi_t^{EU} + \varphi_3^{EU} \cdot i_{t-1}^{EU} + \varphi_4^{EU} \cdot i_t^{US}$$

- Estimate using Full Information Maximum Likelihood (FIML) method

Estimating Parameters: Results

Independent Variable	Estimated Parameters for the US	Estimated Parameters for the EU
Economic Activity	$\varphi_1 = 0.3428^{**}$	$\varphi_1^{EU} = 0.1425$
Inflation	$\varphi_2 = 0.1709$	$\varphi_2^{EU} = 0.3951^{**}$
Interest Rate History	$\varphi_3 = 0.6430^{***}$	$\varphi_3^{EU} = 0.5009^{***}$
Foreign Interest Rate (EU/US)	$\varphi_4 = 0.0000$^	$\varphi_4^{EU} = 0.3055^{***}$
*** p<0.01, ** p<0.05, * p<0.1		
^We constrain with respect to the EONIA rate because it is statistically insignificant and negative in the unconstrained FIML estimation procedure		

Estimating Parameters: Implications

- For the United States:
  - Interest rate history and economic activity are most important for US rates
  - Inflation is less significant for the US
  - The US interest rate is not impacted by Euro Area rates

- For the Euro Area:
  - Interest rate history and inflation are most important for Euro Area rates
  - Economic activity is less significant for the Euro Area
  - The US interest rate factors heavily in the determination of Euro Area rates

Sensitivity of Results to Changes in Exogenous Variables

- Rather than assuming values for the real interest rate, r, and potential output, y^*, model them with Monte Carlo analysis
  - Federal funds rate from St. Louis Federal Reserve's Federal Reserve Economic Data (FRED)
  - Potential output figures from Congressional Budget Office
  - Determine standard deviation from historic rates and potential output
- Create random drawings for r and y^* to incorporate in Taylor rule
- Incorporate similarly random "shocks" to these drawings
- Generate an empirically robust range of Taylor rules

Empirical Methodology

- Recall the simple Taylor rule,

$$i = r + \pi + \beta \cdot (\pi - \pi^*) + (1 - \beta) \cdot (y - y^*)$$

- Where $r = 2 + \varepsilon_1$ and $y^* = 2 + \varepsilon_2$ such that,
  - $\varepsilon_1 = \sigma_r \cdot \mu_1 + \sigma_{ry} \cdot \mu_2$ and $\varepsilon_2 = \sigma_{ry} \cdot \mu_1 + \sigma_y \cdot \mu_2$
  - σ_r is the historic standard deviation of the federal funds rate
  - σ_y is the historic standard deviation of potential output
  - σ_{ry} is the covariance between the two, chosen exogenously
  - μ_1 and μ_2 are random “shocks” normally distributed with a mean of 0 and standard deviation of 1

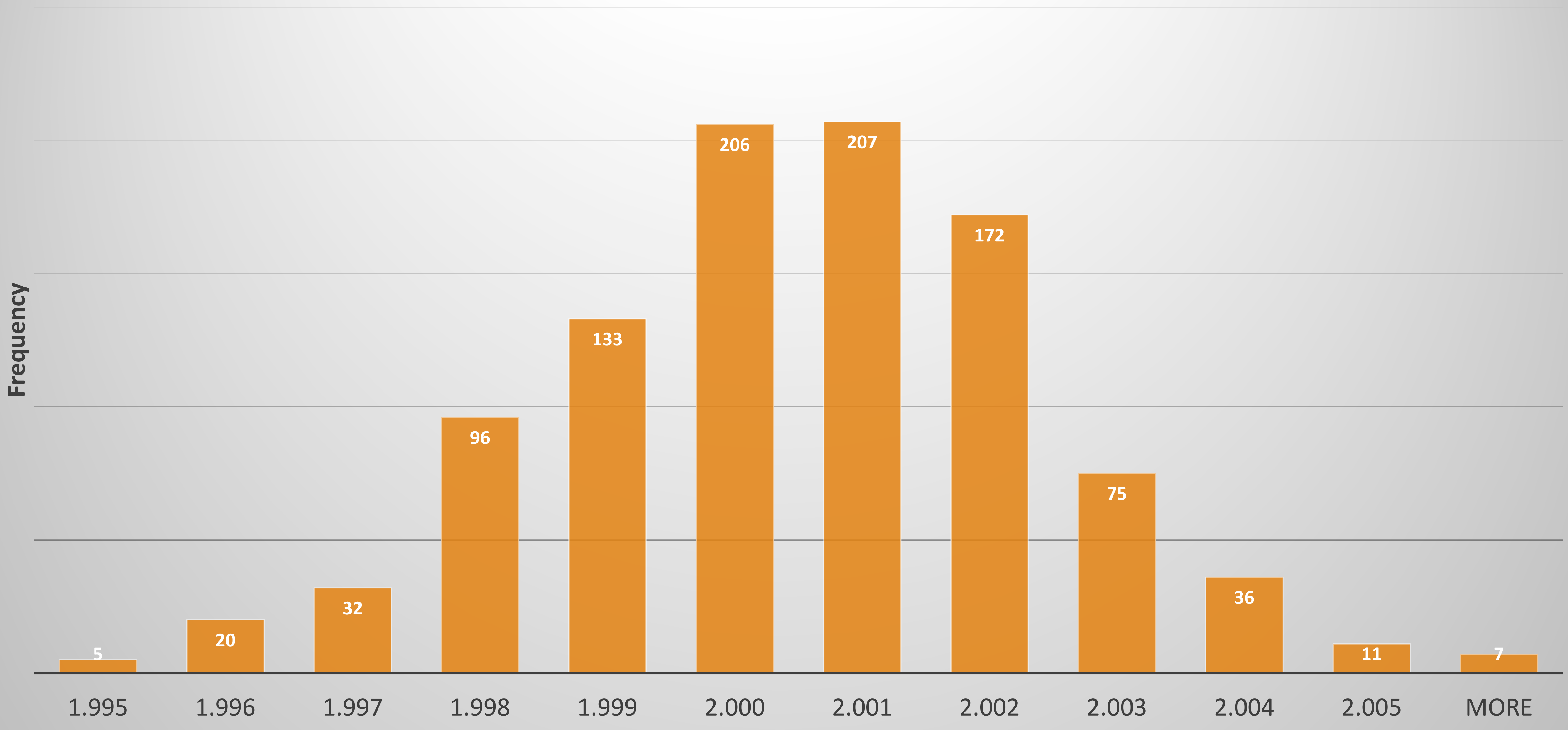
Empirical Methodology

- So, real interest rate and potential output are drawn such that,

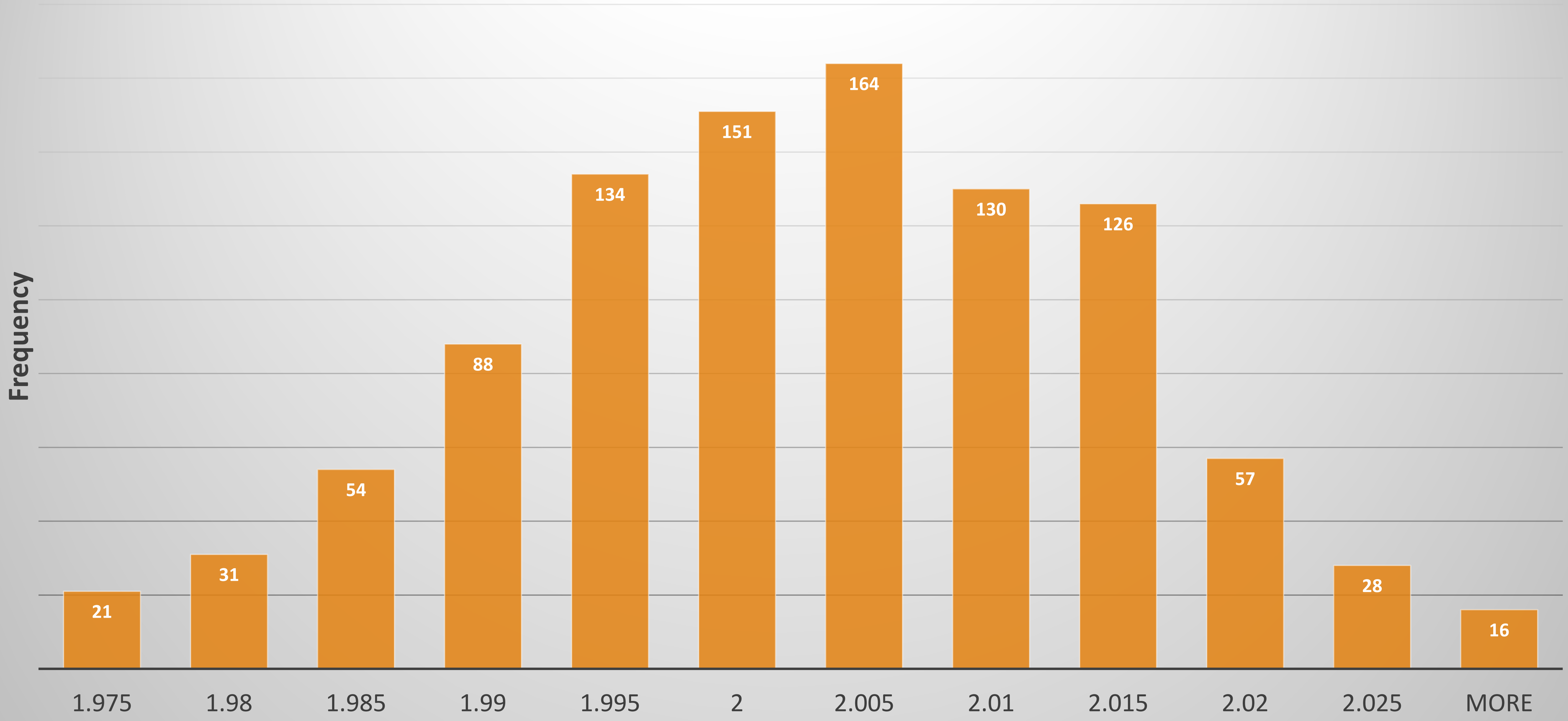
$$\begin{bmatrix} r \\ y \end{bmatrix} = \begin{bmatrix} 2 \\ 2 \end{bmatrix} + \begin{bmatrix} \sigma_r & 0 \\ \sigma_{ry} & \sigma_y \end{bmatrix} \cdot \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}$$

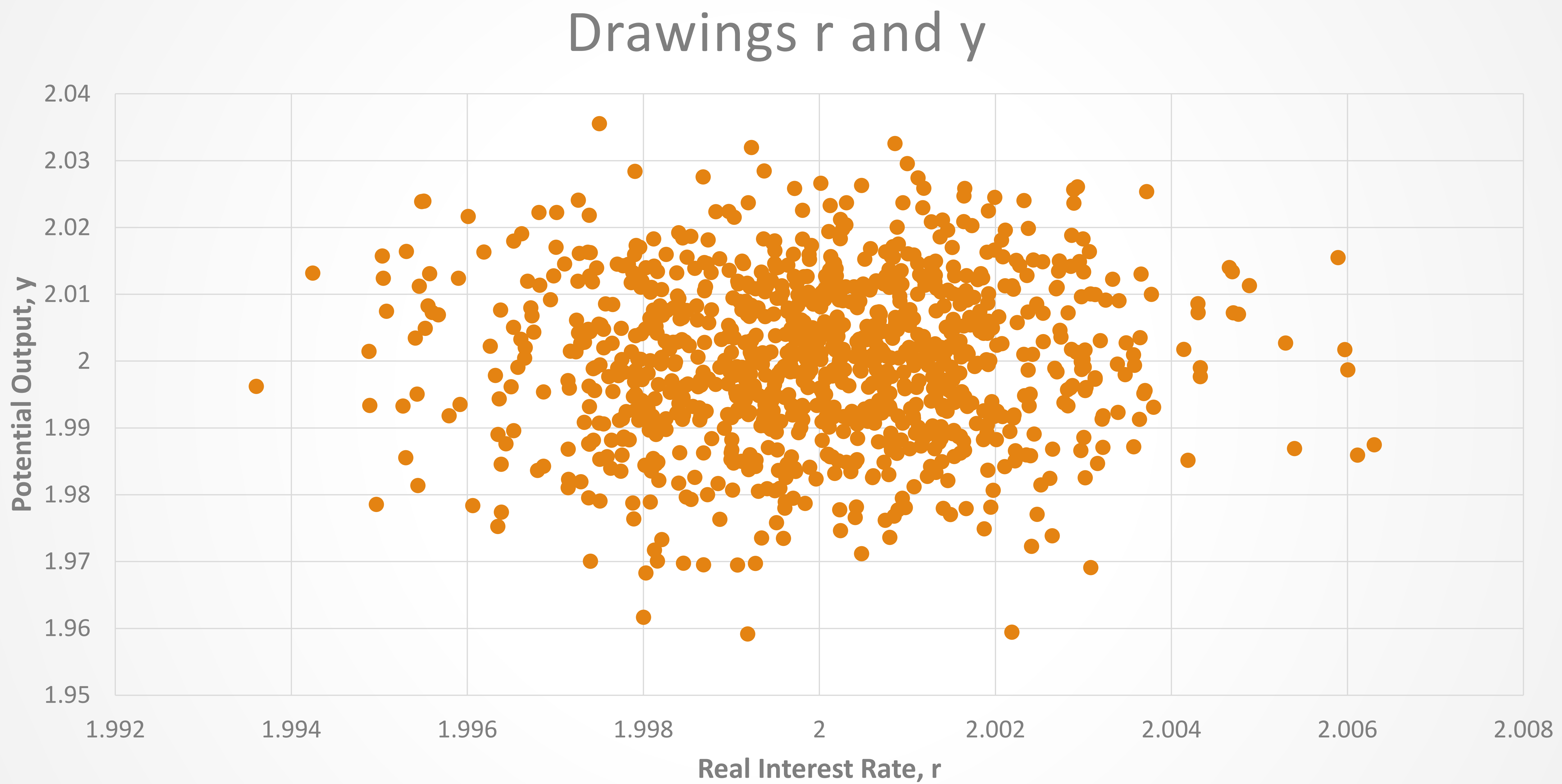
- Draw 1,000 iterations each of μ_1 and μ_2
- Draw 1,000 subsequent iterations of r and y according to the equation above
- Assume $\sigma_{ry} = 0$

Distribution of Real Interest Rate Drawings



Distribution of Potential Output Drawings

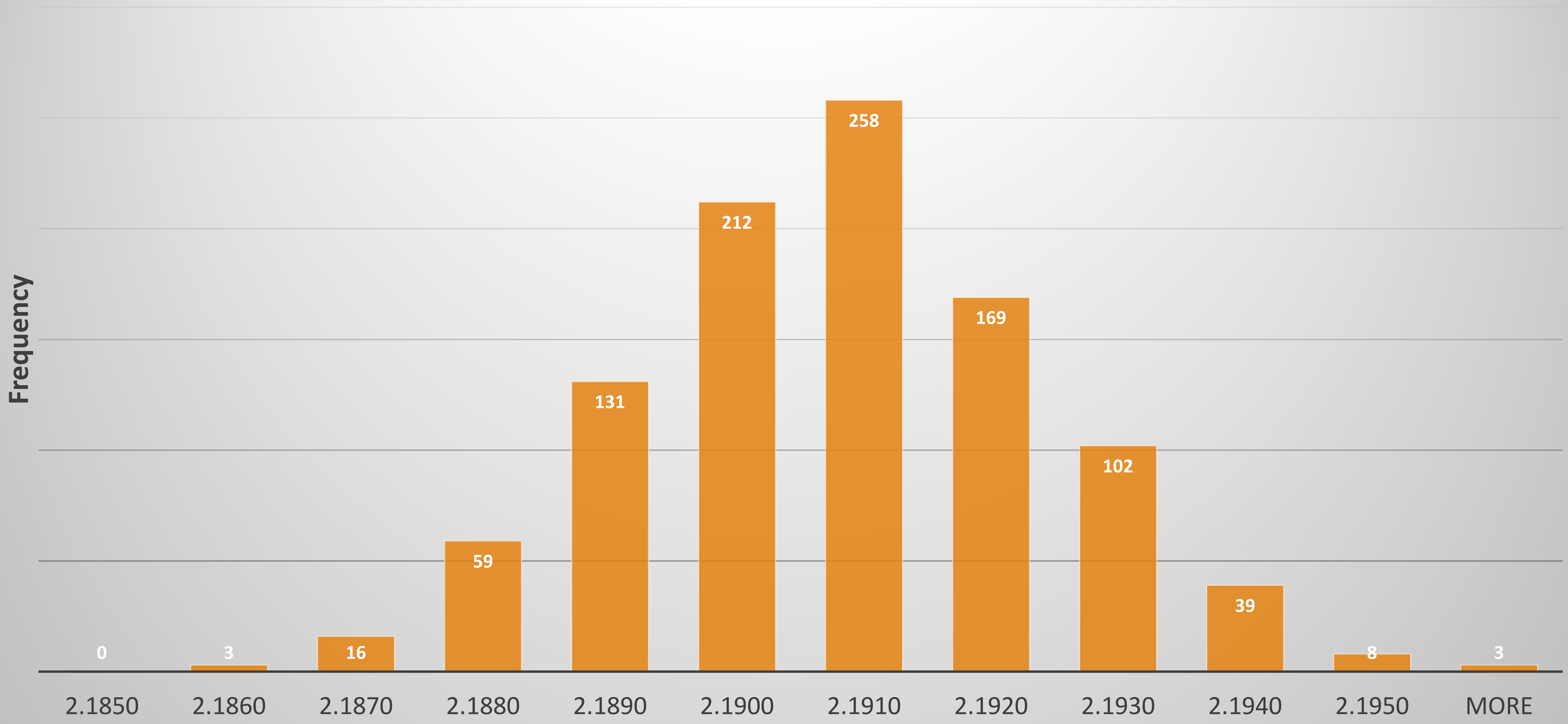



Drawings r and y
2.04
2.03
2.02
2.01
2
1.99
1.98
1.97
1.96
1.95
Potential Output, y
1.992
1.994
1.996
1.998
2
2.002
2.004
2.006
2.008
Real Interest Rate, r

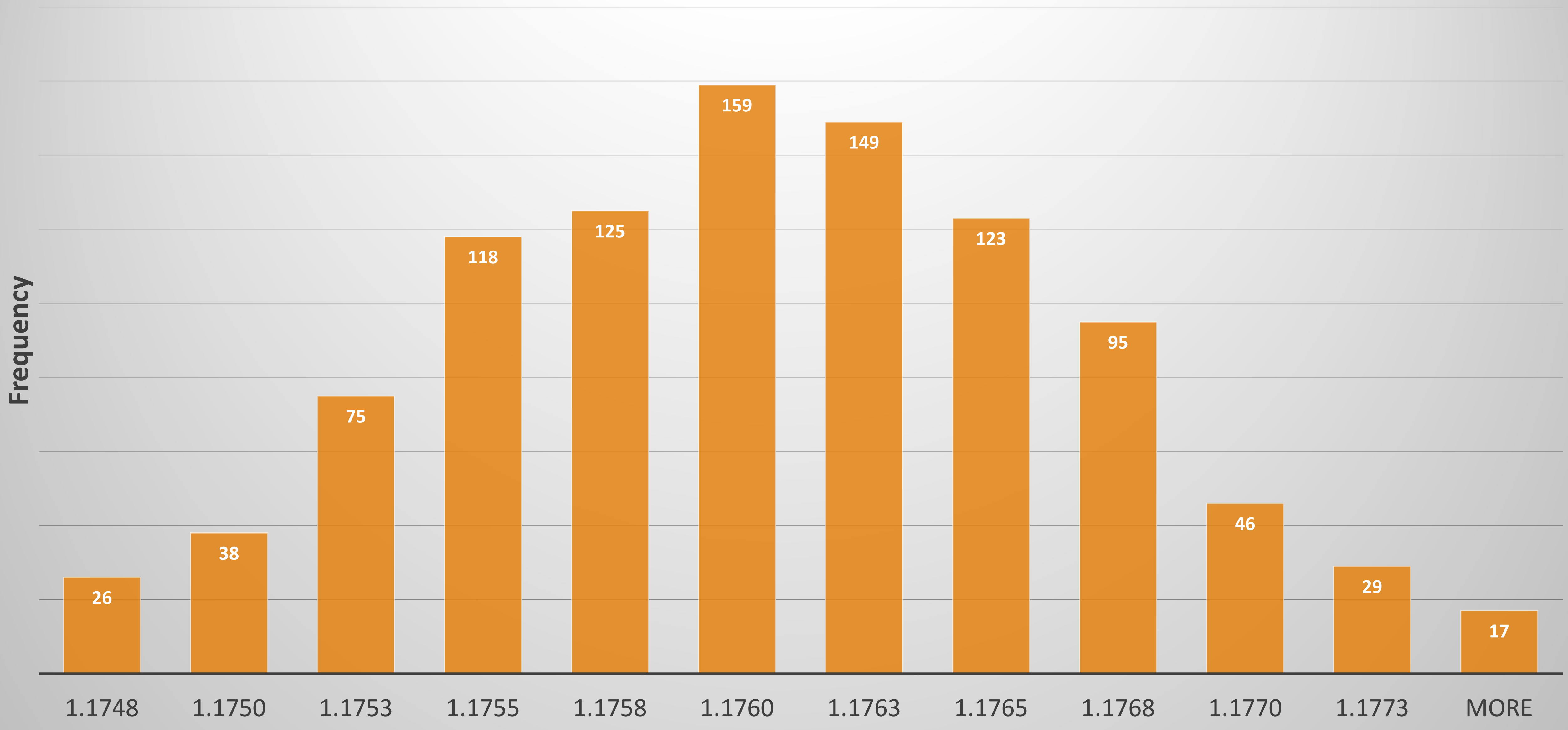
Monte Carlo Taylor Rule: Results

- Using drawings for r and y, establish similar distributions of US Taylor rules
- Forward looking, using estimated parameters
- Forward-looking, using chosen parameters
  - Weight the importance of inflation and growth equally ($\beta = \theta = 0.5$)
  - Weight persistence heavily ($\delta = 0.9$), implying “slow” adjustment of the interest rate
  - No interdependency ($\lambda = 0.0$)

Taylor Rule Distribution (Estimated Parameters)



Taylor Rule Distribution (High Persistence)



Monte Carlo Taylor Rule: Implications

- Should the assumptions of the Taylor rule and projections hold, we can confidently estimate a range of possible interest rates for 2017
- Overall distribution is a reasonably tight range
- Choice parameters can be adjusted accordingly given different assumptions
  - “Slowness” of adjustments (persistence parameter)
  - Expectations vs. current data (forward-looking)
  - Initial value for potential growth and real interest rate
- Changes in parameters more drastically alter the distribution