

# Theory Testing in the Presence of Causal Heterogeneity

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## Motivation

- Causal relationships can change across units and over time
- Studying causal heterogeneity is one of the most important aims of social science research
- But dominant practices are to test whether a theory holds up uniformly across units and over time.**

## Current Approaches

- Employ finite mixture models or Dirichlet process mixture models to study heterogeneity across units
- Employ Hidden Markov Model to study heterogeneity over time

## Object

Study how causal relationships vary across units and over time **simultaneously** with panel data.

## An Empirical Example

We replicate Dunning (2004) on the relationship between Western aid and democracy in African.

Dunning argues:

- During the Cold War, Western aid failed to promote democracy.** Western countries and the Soviet Union vied for an influence in Africa, so Western aid was not provided conditioned on implementing democratic reforms.
- After the Cold War, Western aid promoted democracy.** The threat from the Soviet Union disappeared.

Dunning (2004) only considered **heterogeneity over time, not across units.**

## Proposed Methodology

- A non-parametric Bayesian approach: impose a **discrete-time discrete-state Markov process model on top of a Dirichlet process mixture model**

- The model:

$$y_{it} = X_{it}\beta_{g^{p[t]}[i]} + \epsilon_{it}$$

$$\epsilon_{it} \sim \mathcal{N}(0, \sigma_{g^{p[t]}[i]}^2)$$

$p[t]$ : which period time  $t$  belongs to;  
 $g^{p[t]}[i]$ : within period  $p[t]$ , which group unit  $i$  belongs to.

- Priors:

$p[t]$  for time transition

A Markov process defined by the transition probability matrix  $\mathcal{K}$ :

$$\mathcal{K} = \begin{bmatrix} k_{11} & k_{12} & 0 & \dots & 0 \\ 0 & k_{22} & k_{23} & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \dots & \vdots & 0 & k_{S,S} & k_{S,S+1} \\ 0 & 0 & \dots & 0 & 1 \end{bmatrix}$$

$$k_{p,p+1} \sim \text{Beta}(a, b)$$

$$k_{p,p} = 1 - k_{p,p+1}$$

$g^p[i]$  for grouping units

A stick-breaking process to generate group assignments:

$$g^p[i] \sim \text{Discrete}(\{q_j\}_{j=1}^{\infty})$$

$$q_j = \theta_j \prod_{l=1}^{j-1} (1 - \theta_l)$$

$$\theta_j \sim \text{Beta}(1, \alpha)$$

$\beta_{g^p}$  and  $\sigma_{g^p}^2$

$$\beta_{g^p} \sim \mathcal{N}(m, M)$$

$$\sigma_{g^p}^2 \sim \text{Inv-Gamma}(\frac{c}{2}, \frac{d}{2})$$

- Estimation: Blocked Gibbs Sampling

## Empirical Results

Compare the new approach and the original results

	Transition Point (Cold War Ended)	The Coefficient for Aid on Democracy	
		<i>before Cold War</i>	<i>after Cold War</i>
Dunning (2004)	1987	$\beta \approx 0$	$\beta > 0$ (slightly)
New Approach	1990	$\beta_{g_1} \approx 0$	$\beta_{g_1} < 0$ $\beta_{g_2} \approx 0$ $\beta_{g_3} >> 0$

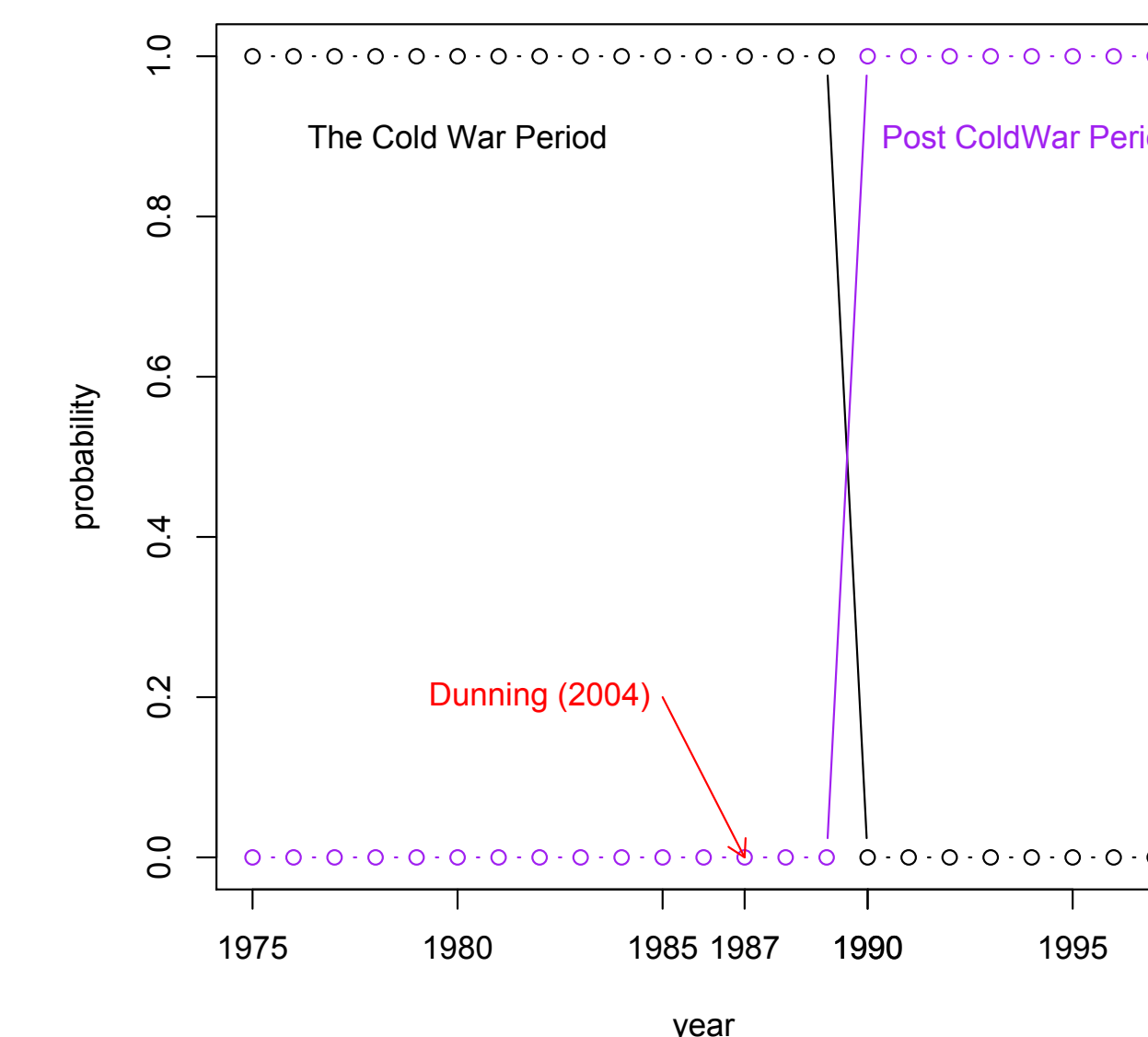


Figure 1: Probabilities that a certain year is in the period of the Cold War and the period after the Cold War respectively

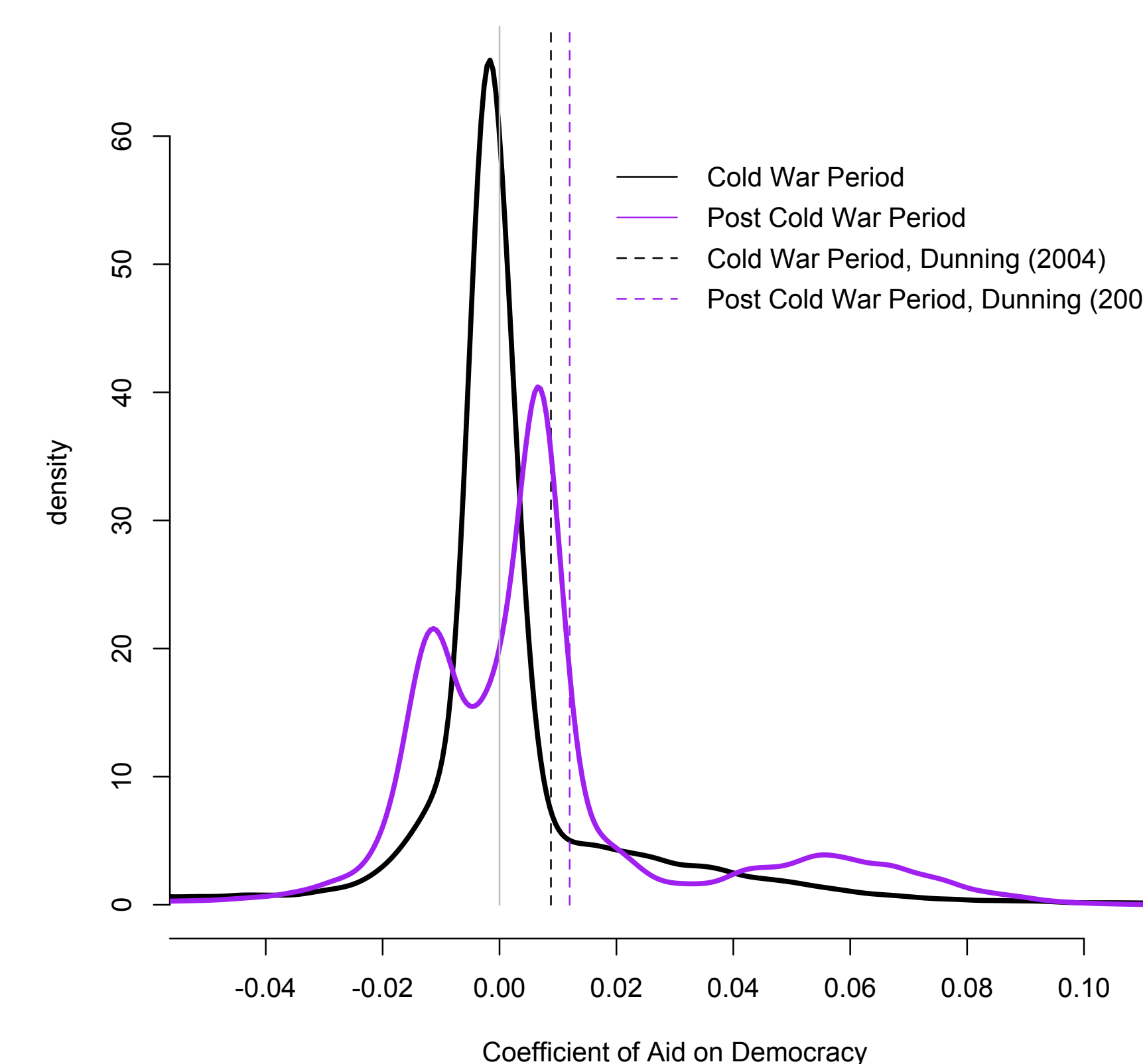


Figure 2: Distributions of  $\beta$ , the coefficient for aid on democracy

## Evaluate Existing Theories

- During the Cold War, Western aid failed to promote democracy ✓
- After the Cold War, Western aid promoted democracy ✗

## Explore New Theories

After the Cold War:

- Countries with large **positive** coefficient for aid  $\leadsto$  most are **former "Soviet clients"**
- Countries with large **negative** coefficient for aid  $\leadsto$  most are **old "Western friends"**

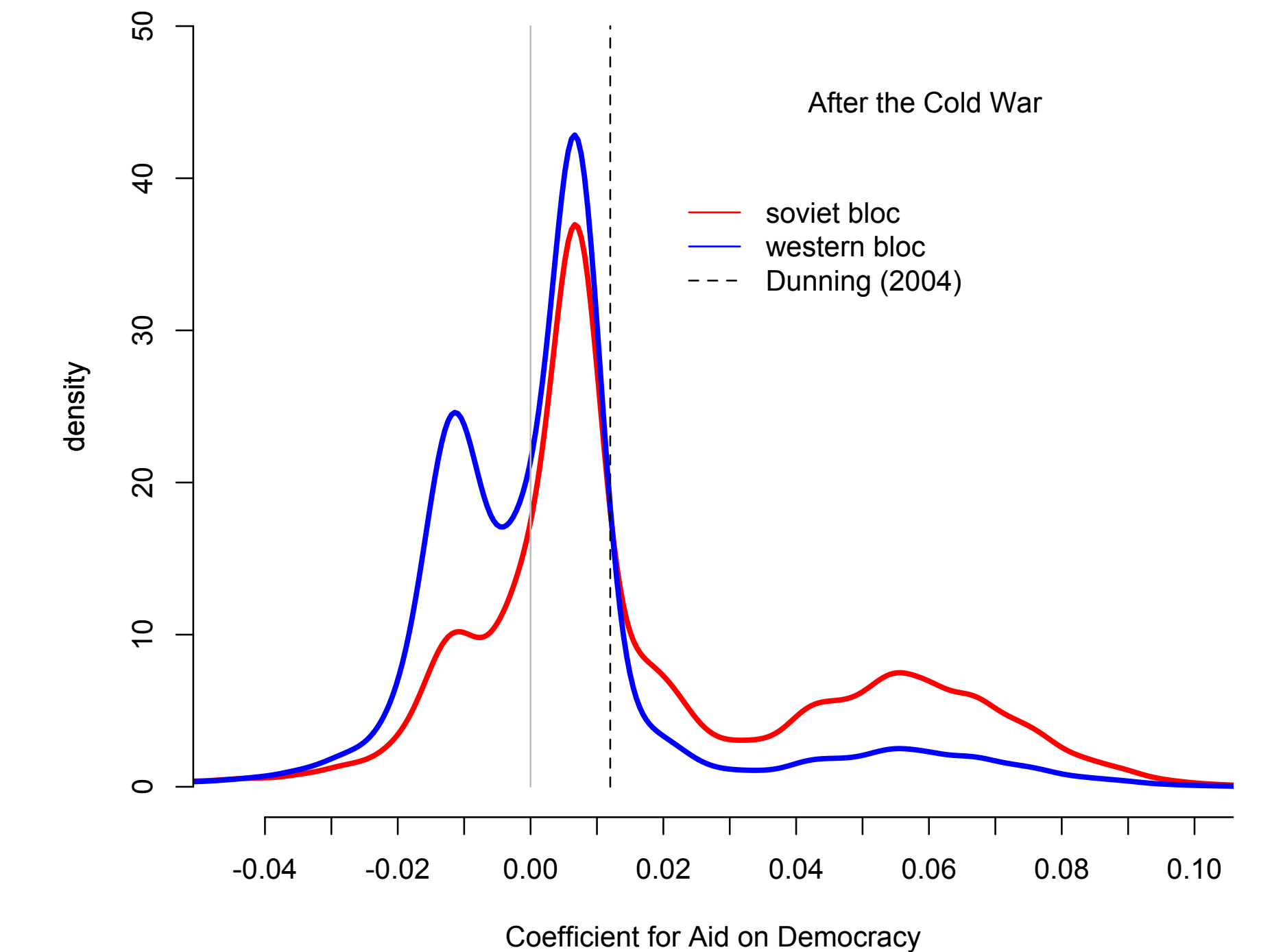


Figure 3: Distribution of  $\beta$ , the coefficient for aid on democracy, by blocs

Table 1: A list of countries with extremely large/small coefficients for aid on democracy

$\beta >> 0$	$\beta << 0$
The Gambia	Rwanda
Malawi	Djibouti
Madagascar	Burundi
Benin	Swaziland
Cape Verde	Togo
Mali	Guinea
Seychelles	