

Two-Part Random Effects Models for Longitudinal Cost Data

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Outline of Talk

- Motivation and Purpose
- Cost-sharing studies
- VA System
- Policy change and sample
- Outcome: VA Specialty Expenditures
- Longitudinal two-part modeling
- Results
- Summary

Motivation of the Talk

- Opportunity to apply innovative two-part model to re-examine a VA policy question
 - Previously applied uncorrelated longitudinal two-part model
- Demonstrate a successful collaboration between biostatistician & health economist

Purpose of Analysis

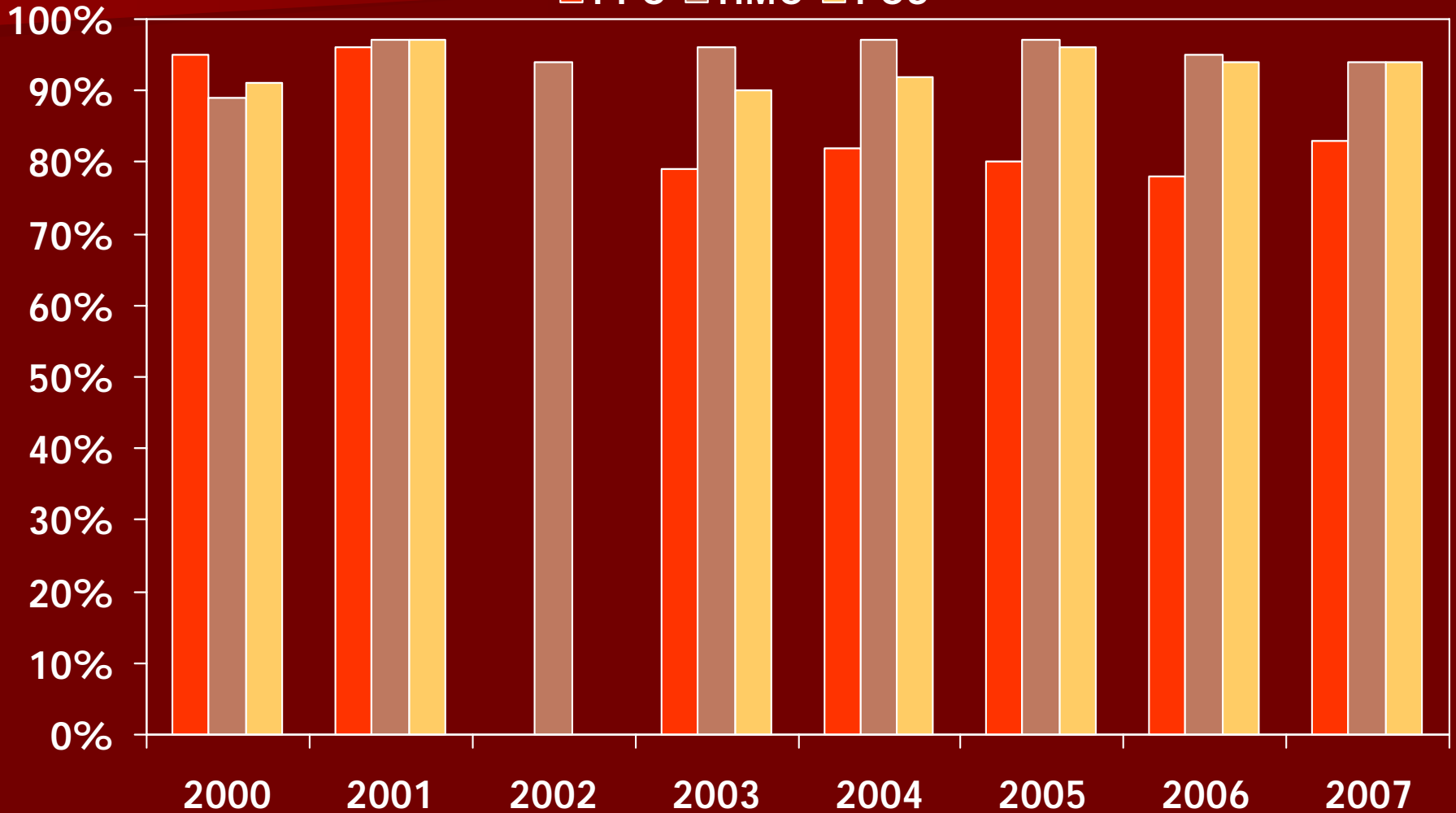
- Policy question: Were specialty expenditures impacted by a specialty visit copay increase from \$15 to \$50?
 - Copay increased in November 2001
- Methods question: Is the probability of positive specialty expenditures related to the level of expenditures over time?
 - Does “naïve” longitudinal two-part model generate different results than correlated two-part model?

RAND HIE: Coinsurance Effects & Outpatient Use and Expenditures

- Compared to free plan, individuals in plans with coinsurance had lower likelihood of use
 - Mental health & medical care
 - Emergency care
 - Preventive care
- Compared to free plan, users in plans with coinsurance had lower expenditures
 - Mental health care (per episode)
 - Medical care (annual)

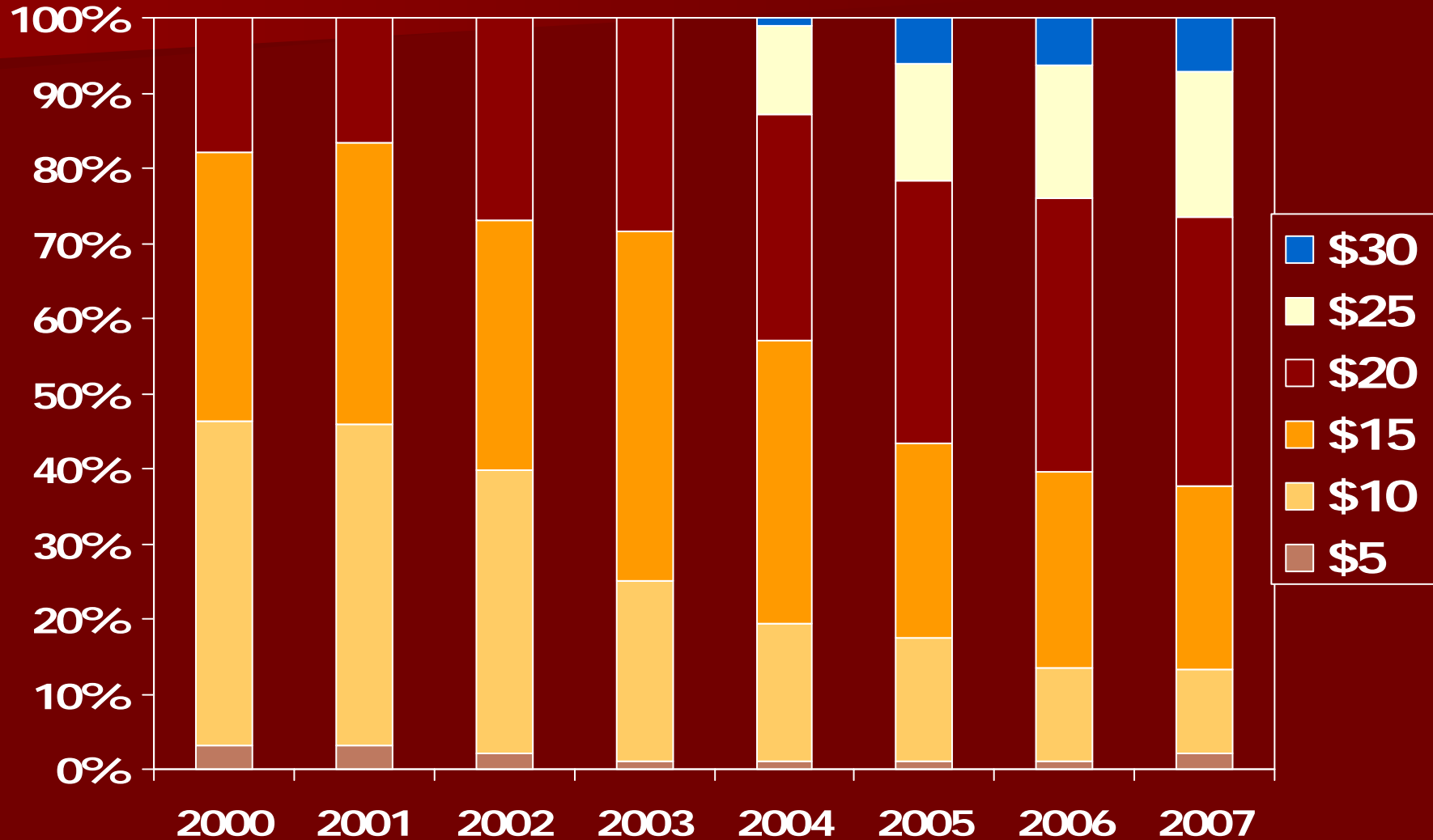
PPO, HMO & POS Enrollees with Outpatient Visit Copays

■ PPO ■ HMO ■ POS



2000-2007 Kaiser/HRET Survey of Employer-Sponsored Health Benefits

Primary Care Visit Copays of PPO Enrollees with Copays



Copay Association w/ Outpatient Services, Visits & Expenditures

- Emergency department: Negative
 - Selby, 1996; Magid, 1997; Reed, 2005; Hsu, 2006
- Primary care: Negative (Cherkin, 1989)
- Mental health/Substance abuse
 - Pr(use): NS (Simon, 1996), negative (Stein, 2000)
 - Level: Negative (Simon, 1996; Lo Sasso, 2004,06)
- Preventive services: NS or negative
 - Cherkin, 1990; Solanki, 1999 & 2000
- Specialty care: NS (Cherkin, 1989)

Veterans Health Administration

- Largest vertically and horizontally integrated health care system in US (2006)
 - 155 hospitals in 50 states, DC and Puerto Rico
 - 800+ outpatient clinics & 135 nursing homes
 - 46 residential rehabilitation treatment centers
 - Over 200 readjustment counseling centers
 - 5 million users & 54 million outpatient visits
- Annual budget of \$35 billion in 2007
- Divided into 21 regional networks



DEPARTMENT OF VETERANS AFFAIRS Veterans Health Administration Facilities

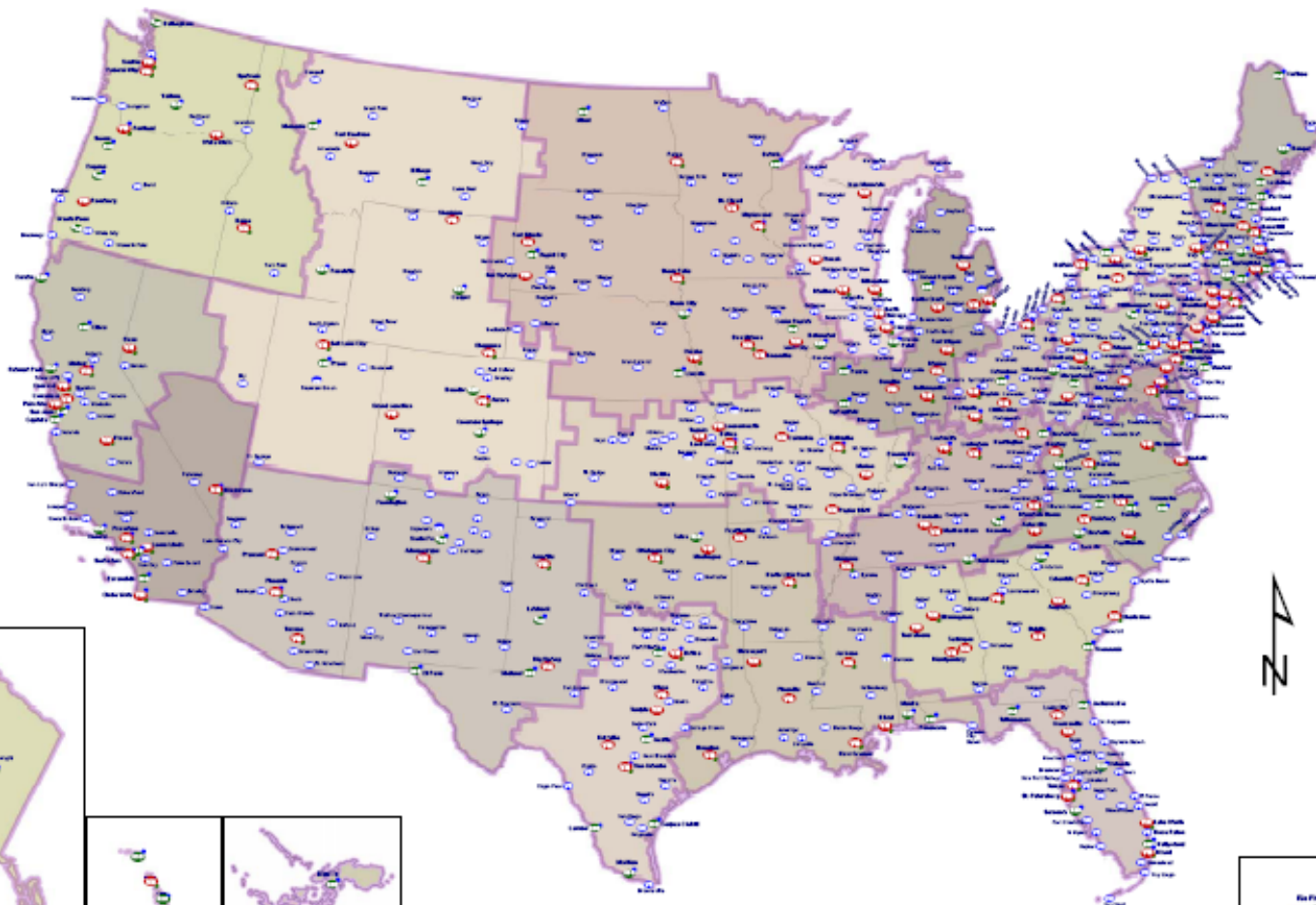
VA VISN INDEX



LEGEND

Composite symbols such as represent facilities that have one or more additional remote site(s).

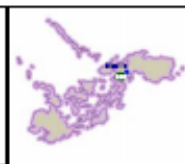
- Hospital w/ Remote Clinic(s)
- Hospital w/ Vet Center
- Hospital w/ Remote Clinic(s)
- Hospital
- Vet Center w/ Remote Clinic(s)
- Vet Center
- Clinic(s)
- VISN Boundary
- State



ALASKA



HAWAII



PHILIPPINES



PUERTO RICO

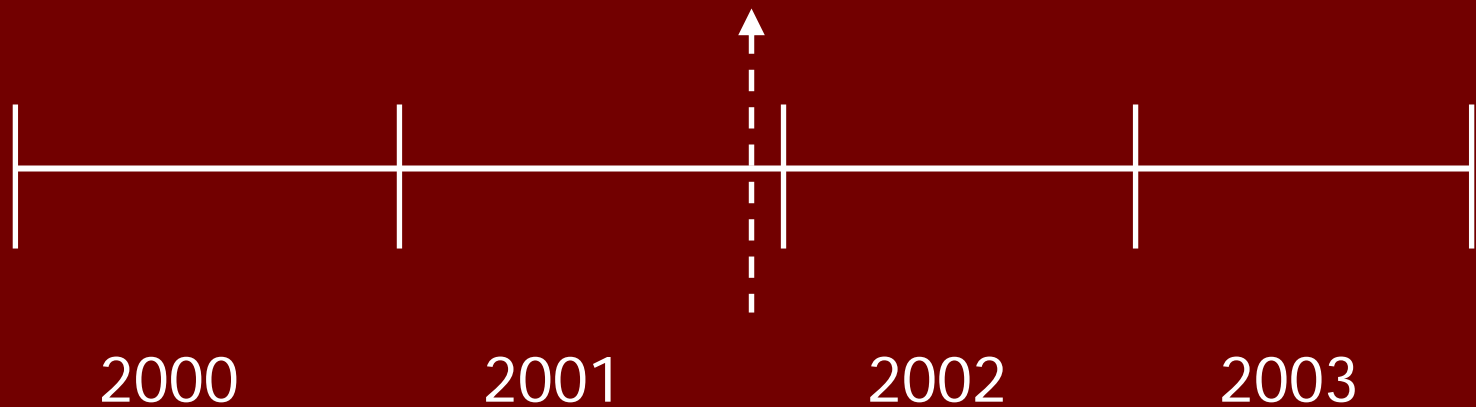
NOTE: Information contained in this graphic presentation was prepared for the sole purpose and use of the Department of Veterans Affairs and this information may not be suitable for other purposes. Further documentation of this data can be obtained by contacting Planning Systems Support Group, Part 110 of the Assistant Deputy Under Secretary for Health Policy and Planning, Department of Veterans Affairs, 330 E. University Avenue, Suite 400, Gainesville, Florida 32601 tel: (352) 314-6000.

Timeline of Copay Change

December 6, 2001

Specialty Care up from \$15 to \$50

Primary Care copay (\$15) introduced



Study Design and Data

■ Study Design

- Retrospective longitudinal cohort (2000-2004) in 4 VAMCs in NW, N & S Central US
- Non-equivalent, co-located control group

■ Administrative data

- Outcomes: VA utilization & expenditures
- Covariates: Demographics, diagnoses
- Census: Median income in zip code (2000)

Hypertension Cohort Inclusion



Copayment Status Groups

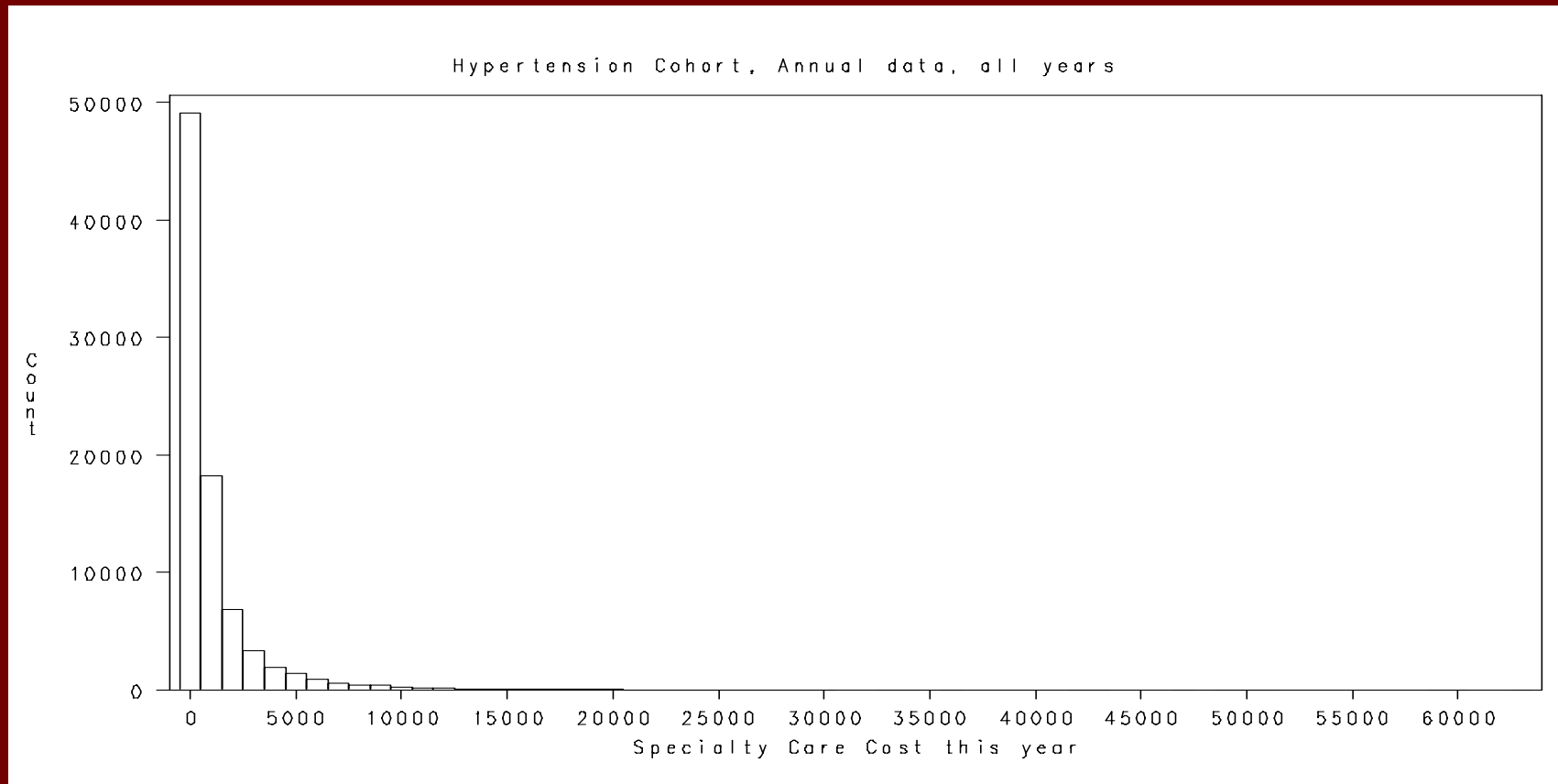
<i>Group</i>	<i>Copay Status</i>
Control	Priority Group 1: Exempt from VA copays for life
?	Priority Groups 2-6: Not clear what meds are free (excluded)
Treat- ment	Priority Group 7 & 8: Must pay all copays

Descriptive Statistics At Baseline

Hypertension Cohort	All	Exempt	Must Pay	
	N=7,731	N=4,307	N=3,424	p
VA Medical Center				
#1	979	534	445	<.0001
#2	2217	512	1705	
#3	2538	1712	826	
#4	1997	1549	448	
Marital Status				
Not married (%)	30.3	33.4	26.4	<.0001
Male (%)	97.1	96.8	97.6	
Race				
White (%)	61.0	68.4	51.7	<.0001
Non-White (%)	15.4	21.2	8.2	
Unknown (%)	23.5	10.3	40.1	
	mean (s.d.)	mean (s.d.)	mean (s.d.)	p
Age (2000)	64.5 (11.4)	61.5 (12.0)	68.3 (9.4)	<.0001
DCG (2000)	0.85 (1.22)	1.09 (1.30)	0.55 (1.03)	<.0001
Total num. Rx	8.3 (6.1)	9.8 (6.5)	6.6 (4.9)	<.0001
Total Num. HTN Rx	1.6 (.97)	1.6 (.95)	1.5 (.99)	<.0001

Characteristics of Specialty Expenditures, 2000-03

- Semicontinuous, longitudinal response variable that is a mixture of zeros and positive values at each year



Proportion of Veterans with Specialty Expenditures, 2000-03

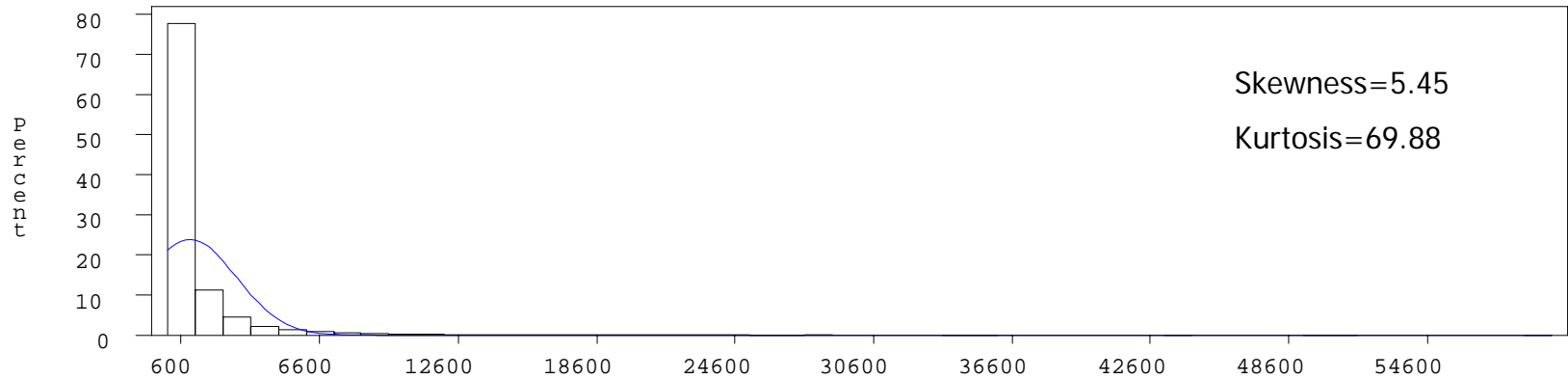


Mean Specialty Expenditures of Users by Copay Status, 2000-03

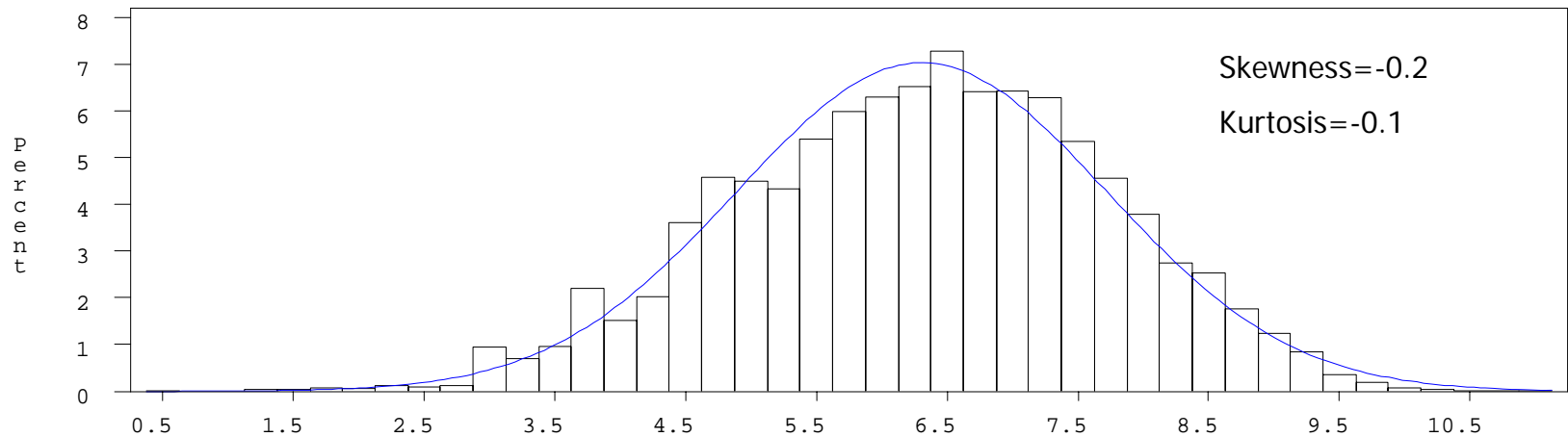


Distribution of Specialty Expenditures for Users

Unlogged Annual Specialty Expenditures, All Years



Logged Annual Specialty Expenditures, All Years



Analytic Methods

semicontinuous response

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graph TD; A[semicontinuous response] --> B[binary part]; A --> C[continuous part];
```

binary part

$\Pr(\text{Specialty } \$) > 0$

continuous part

$E(\text{Specialty } \$ | \text{Spec } \$ > 0)$

- Possible solution: fit separate longitudinal models (GEE or mixed effects models) to model each process separately
 - “Naïve” or uncorrelated model
- Issue: This does not allow presence/absence of expenditure and amount of expenditure to influence one another

Possible Reasons for Correlation between Probability and Level

- Cost-related visit avoidance can exacerbate a condition that will require even more care next year, leading to higher mean costs among users and negative correlation
- Specialists may find additional issues that need addressing leading to higher mean costs among users and positive correlation

Two-part random effects model

- Let Y_{ij} = specialty expenditure for patient i , year j
- Recode as
 - $U_{ij} = 1$ if $Y_{ij} > 0$ or $U_{ij} = 0$ if $Y_{ij} = 0$
 - $V_{ij} = \log Y_{ij}$ if $Y_{ij} > 0$
- Fit correlated random effects models for
 - Logit probability of $U_{ij} = 1$
 - Mean response $E(V_{ij})$ for years where $U_{ij} = 1$
 - Olsen & Schafer (2001), Tooze (2002)

Estimation Methods

- Computational approaches similar to those available for generalized linear mixed models
 - First part involved intractable likelihood
- Bayesian estimation via MCMC
 - Computationally intensive (Cooper et al, 2007)
- Penalized quasi-likelihood
 - Biased results in GLMM with binary outcome
- Likelihood approximation
 - Laplace (Olsen & Schafer, 2001)
 - Adaptive quadrature (Tooze et al 2002)

Two-part random effects model: software implementation

- Olsen & Schafer (2001)
 - Uses Laplace approximation to the likelihood
 - Fast & flexible (specify >1 random effect per part)
 - Stand alone Fortran executable
- Tooze (2002)
 - Adaptive quadrature within PROC NLMIXED
 - Only allows 1 random effect for each part
- Cooper et al (2007) – provides WinBUGS code

Two-part random effects model of VA specialty expenditures

- 1st part: Binary outcome of $\Pr(U_{ij} = 1)$
 - Logistic mixed effects model (PROC NLMIXED)
- 2nd part: Continuous outcome of $E(V_{ij} | U_{ij} = 1)$
 - Mixed effect model (PROC MIXED)
 - Log-transformed expenditures
- Correlated random intercepts
 - Bivariate normality assumed

Model Specification

- Copay status
 - Main effect (MUSTPAY)
 - Interaction between year * MUSTPAY
- Year fixed effect dummies (2000=reference)
- Demographics
 - Age, Race (white=reference), Marital status
- Median income in county (2000 Census)
- Health status at baseline
 - DCG, Number of medications, Baseline Dx of depression
- Site fixed effects

Impact of Specialty Visit Copay on Odds of Specialty Use

	<i>Uncorrelated Model</i>	<i>Correlated Model</i>
Must pay copay	-1.15 (0.09) ^{***}	-1.16 (0.09) ^{***}
Must pay * 2001	0.05 (0.10)	0.06 (0.10)
Must pay * 2002	-0.01 (0.10)	-0.02 (0.10)
Must pay * 2003	0.03 (0.10)	0.04 (0.10)
Year dummy (2001)	0.30 (0.07) ^{***}	0.31 (0.07) ^{***}
Year dummy (2002)	0.50 (0.07) ^{***}	0.49 (0.07) ^{***}
Year dummy (2003)	0.27 (0.07) ^{***}	0.27 (0.07) ^{***}
DCG score in 2000	0.39 (0.04) ^{***}	0.37 (0.03) ^{***}
# medications in 2000	0.18 (0.01) ^{***}	0.17 (0.01) ^{***}
Var(Random intercept)	3.11 (0.12) ^{***}	3.08 (0.13) ^{***}
Log-Likelihood	28182.2	30976.6
AIC	28222.2	30976.6

Impact of Specialty Visit Copay on Level of Log(Cost) by Users

	<i>Uncorrelated Model</i>	<i>Correlated Model</i>
Must pay copay	-0.17 (0.04) ^{***}	-0.23 (0.04) ^{***}
Must pay * 2001	-0.016 (0.04)	-0.030 (0.04)
Must pay * 2002	-0.256 (0.04)^{***}	-0.272 (0.04)^{***}
Must pay * 2003	-0.191 (0.04)^{***}	-0.200 (0.04)^{***}
Year dummy (2001)	0.05 (0.03) ^{***}	0.05 (0.03)
Year dummy (2002)	0.10 (0.03) ^{***}	0.11 (0.03) ^{***}
Year dummy (2003)	0.15 (0.03) ^{***}	0.15 (0.03) ^{***}
DCG score in 2000	0.12 (0.01) ^{***}	0.14 (0.01) ^{***}
# medications in 2000	0.06 (0.001) ^{***}	0.07 (0.001) ^{***}
Var(Random intercept)	0.57 (0.02) ^{***}	0.63 (0.02) ^{***}
Covariance		0.96 (0.03) ^{***}
Log-Likelihood	368236.5	78708.4
AIC	368194.5	78708.4

Limitations

- Random intercepts only
 - Other correlation structures may be more appropriate
- Log transformation: distribution fit here
- Non-equivalent control group
 - Observed variables imbalanced
- Copay effect embeds cross-price effects
 - Same time: Primary care visit copay up from \$0 to \$15
 - 3 months later: Rx copay up from \$2 to \$7
- Limited adjustment of covariates
 - Likely to be unobserved confounding
- For last two reasons, policy implication must be interpreted cautiously

Policy Conclusion

- Specialty visit copay increase had
 - No impact on whether to seek specialty care
 - Significant impact on specialty expenditures *for those who used specialty care and had to pay the copay* in two years following copay increase
- Appears to be driven by fewer visits, not lower cost per visit

Methods Conclusion

- With random intercepts, the probability is related to the level of expenditures over time
 - Covariance of 0.96 = correlation of 0.68
- Correlated two-part model results were fairly similar to point estimates of uncorrelated model
 - Not necessarily a general result given limited number of covariates

Questions?