Using Markov Models in R to Understand the Lifecycle of Exchange-traded Derivatives

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NOTE

THIS PRESENTATION DOES NOT REFLECT THE OPINIONS OF THE CFTC
THE ANALYSIS PRESENTED HERE IS BASED ON PUBLICLY AVAILABLE DATA

My dissertation

What is the chance that exchange-traded El Niño derivatives will take off?

Let's not neglect base rates

What is the chance that *any* exchange-traded derivatives will take off?

The basic methodology

1. Get aggregate stats on annual trading volumes from an institutional database (futures, options, cleared swaps)
2. Add in Mike Penick's work on futures going back to 1954 (volumes for some of the contracts in the database cut out abruptly)
3. Put volume in terms of levels (basically, log 10 rounded down with separate level for 0 values)

The basic methodology cont.

```
> myVolumes[2000:2003,]
     Date  Vol VolLevel nextVolAbs nextVolLevel       CONTRACT_MARKET_NAME COMMODITY_SUBGROUP_NAME EXCHANGE_INITIALS
2000 2011    0        0         50            2 ATLANTA HDD SEAS STRIP JAN                 WEATHER               CME
2001 2012   50        2         NA           NA ATLANTA HDD SEAS STRIP JAN                 WEATHER               CME
2002 2006 1750        4       2400            4 ATLANTA HDD SEAS STRIP NOV                 WEATHER               CME
2003 2007 2400        4       2300            4 ATLANTA HDD SEAS STRIP NOV                 WEATHER               CME
```

The basic methodology cont.

Now ask: given the state that a contract is in this year (year t), what is the probability that it will go to each of the other possible states (i.e. those state we see in the sample) next year (year t+1)?

The basic methodology cont.

```
> str(from3_y)
 num [1:3592] 4 3 5 3 3 1 4 5 6 1 ...
```

The basic methodology cont.

In more mathematical terms:

$$\begin{aligned} \text{Volume level}_{\text{year t+1}} | \text{Volume level}_{\text{year t}} &\sim \text{Categorical}(\theta) \\ \theta &\sim \text{Dirichlet}(x_{\text{vol level 0}}, x_{\text{vol level 1}}, \ldots, x_{\text{vol level } 10^8}) \end{aligned} \tag{1}$$

I estimated this using the Bayesian Gibbs sampling program Martyn Plummer's `JAGS` (using `R` package `rjags`)

The basic methodology cont.

```
117  require(rjags)          # Kruschke, J. K. (2011). Doing Bayesian Data Analysis: (kinda)
118  require(coda)           # A Tutorial with R and BUGS. Academic Press / Elsevier.
119  #---------------------------------------------------------------------------
```

The basic methodology cont.

```
203  # For state 3
204  # Specify the model in JAGS language, but save it as a string in R:
205  modelString = "
206  # JAGS model specification begins ...
207  model {
208  # Likelihood:
209  for ( i in 1:nObs ) {
210  vol[i] ~ dcat(theta[1:cat])
211  }
212  # Prior distribution:
213  priorToState[1]<- 0.01
214  priorToState[2]<- 0.16
215  priorToState[3]<- 0.63
216  priorToState[4]<- 0.14
217  priorToState[5]<- 0.01
218  priorToState[6]<- 0.01
219  priorToState[7]<- 0.01
220  priorToState[8]<- 0.01
221  priorToState[9]<- 0.01
222  priorToState[10]<- 0.01
223
224  theta[1:cat] ~ ddirch(priorToState[1:cat])
225  }
```

The basic methodology cont.

If you run this routine on different grouping of contracts you can see how the rise and fall of trading volumes varies:

- across time
- across exchanges*
- on individual exchanges across time*
- across product subgroup*

**In full paper, not this presentation.*

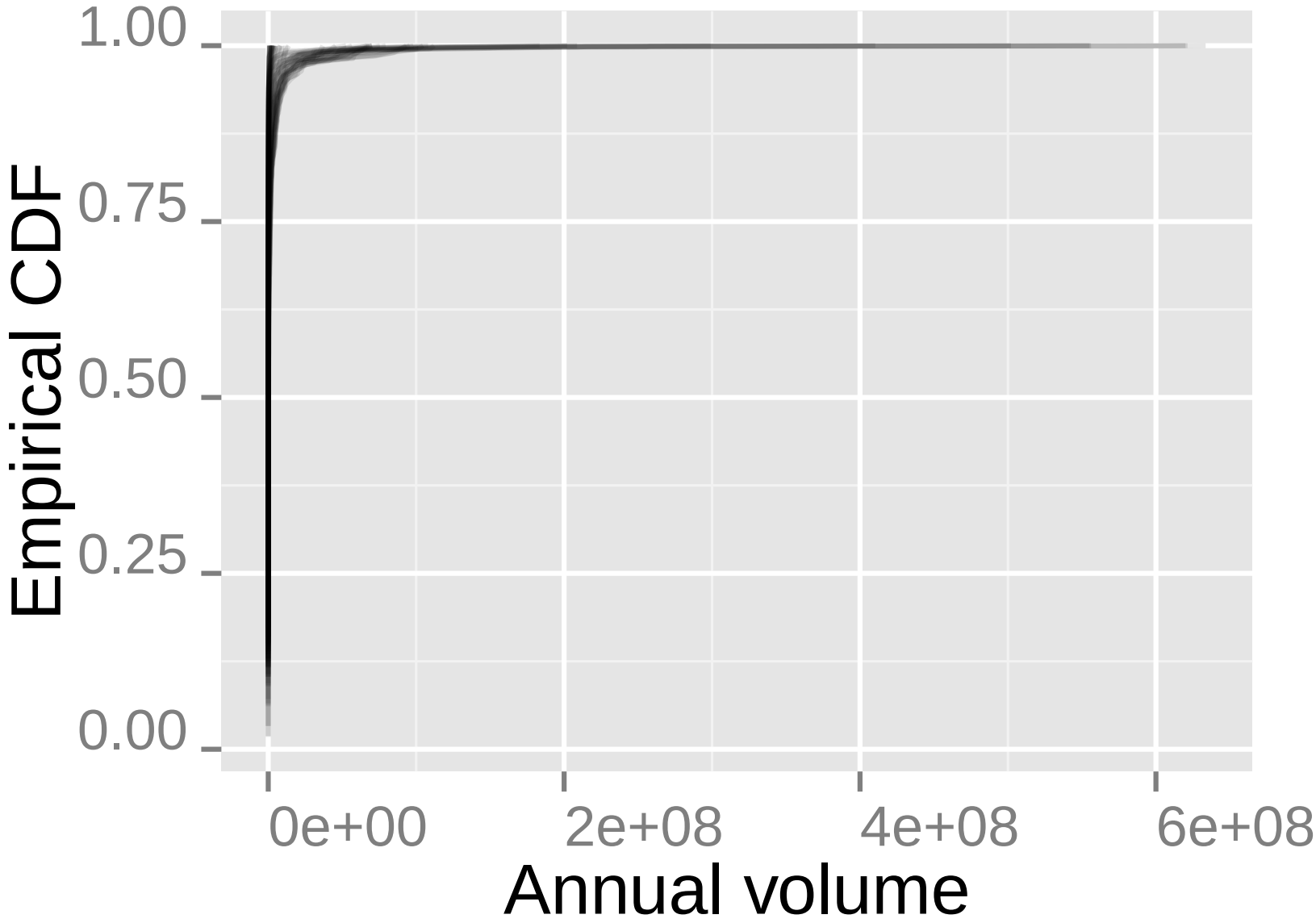
Patterns in trading volume across time

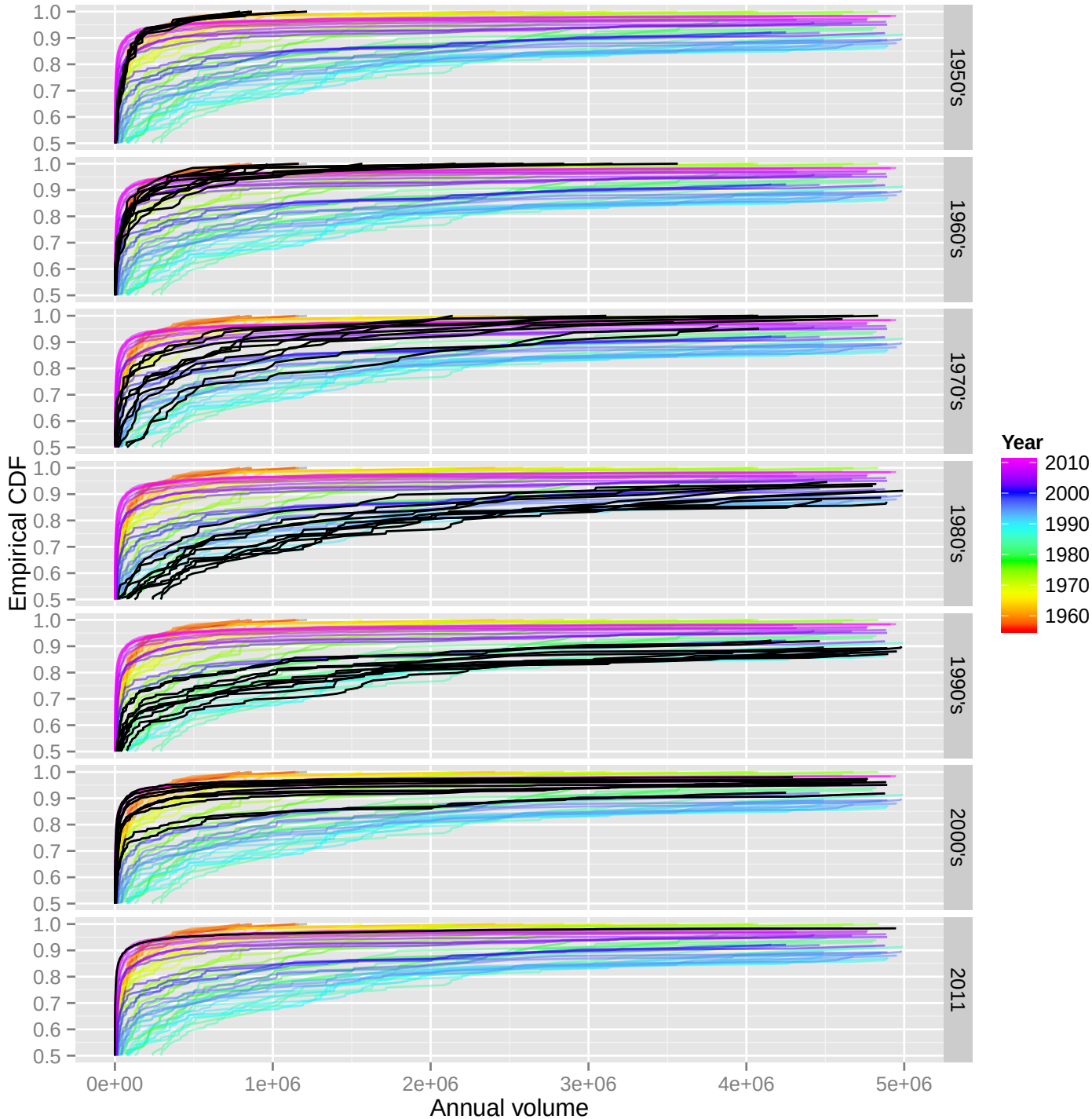
- Has trading on exchanges become more or less concentrated over time?
- Has the number of contracts at little or no annual volume changed over time?

To analyze these questions, look at the empirical cumulative distribution function of trading volumes.

The traditional story

Few contracts have/will ever take off.


1.00
0.75
0.50
0.25
0.00
Empirical CDF
0e+00
2e+08
4e+08
6e+08
Annual volume

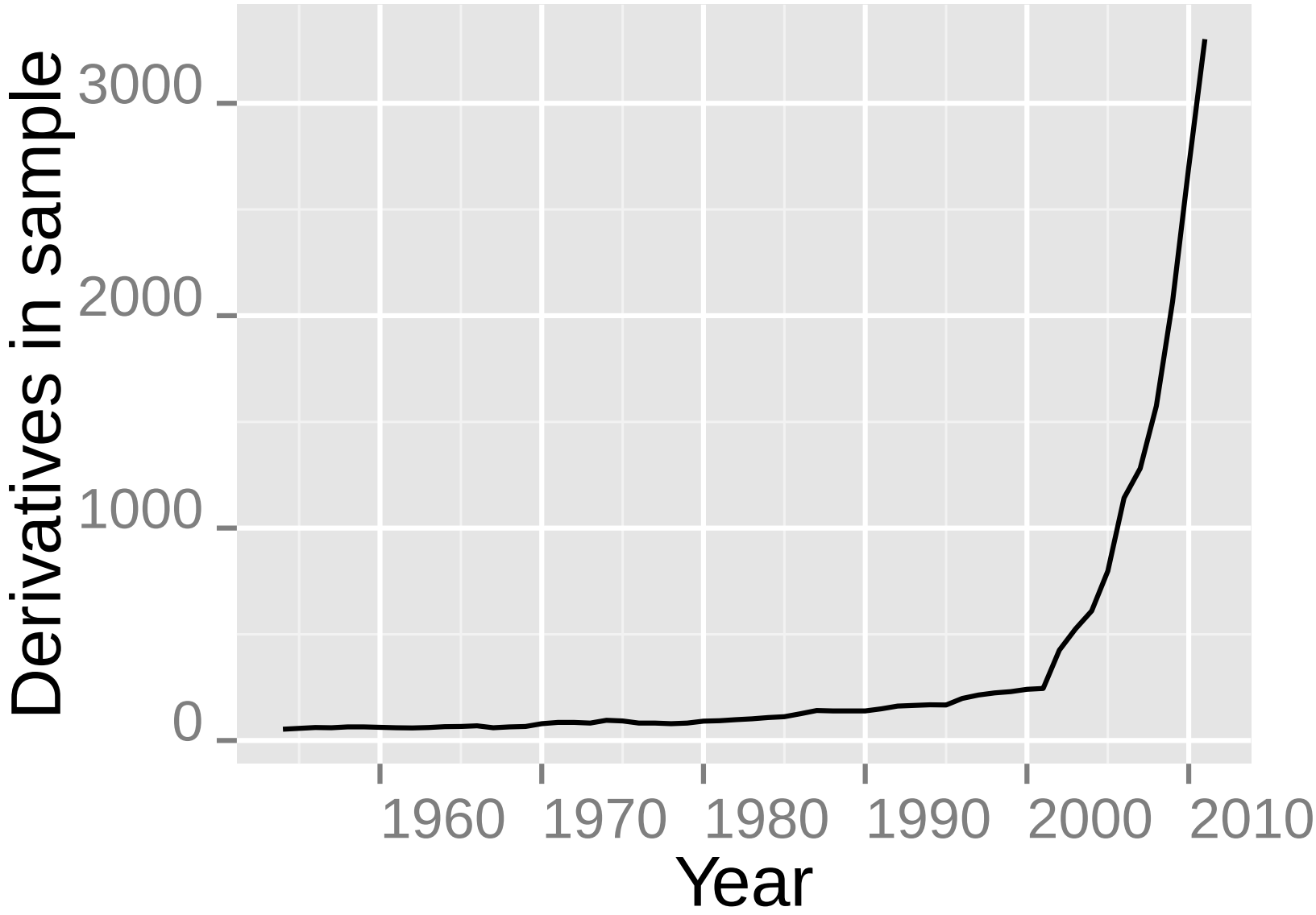

Empirical CDF
1.0
0.9
0.8
0.7
0.6
0.5
1950's
1960's
1970's
1980's
1990's
2000's
2011
0e+00
1e+06
2e+06
3e+06
4e+06
5e+06
Annual volume
Year
2010
2000
1990
1980
1970
1960

ECDFs tell us. . .

Trading volume grew steadily less concentrated between the 1950's and 1990's (perhaps with some retrenchment between the 1980's and 1990's.)
That trend reversed sharply in the 2000's, with the annual ECDFs approaching a right angle.

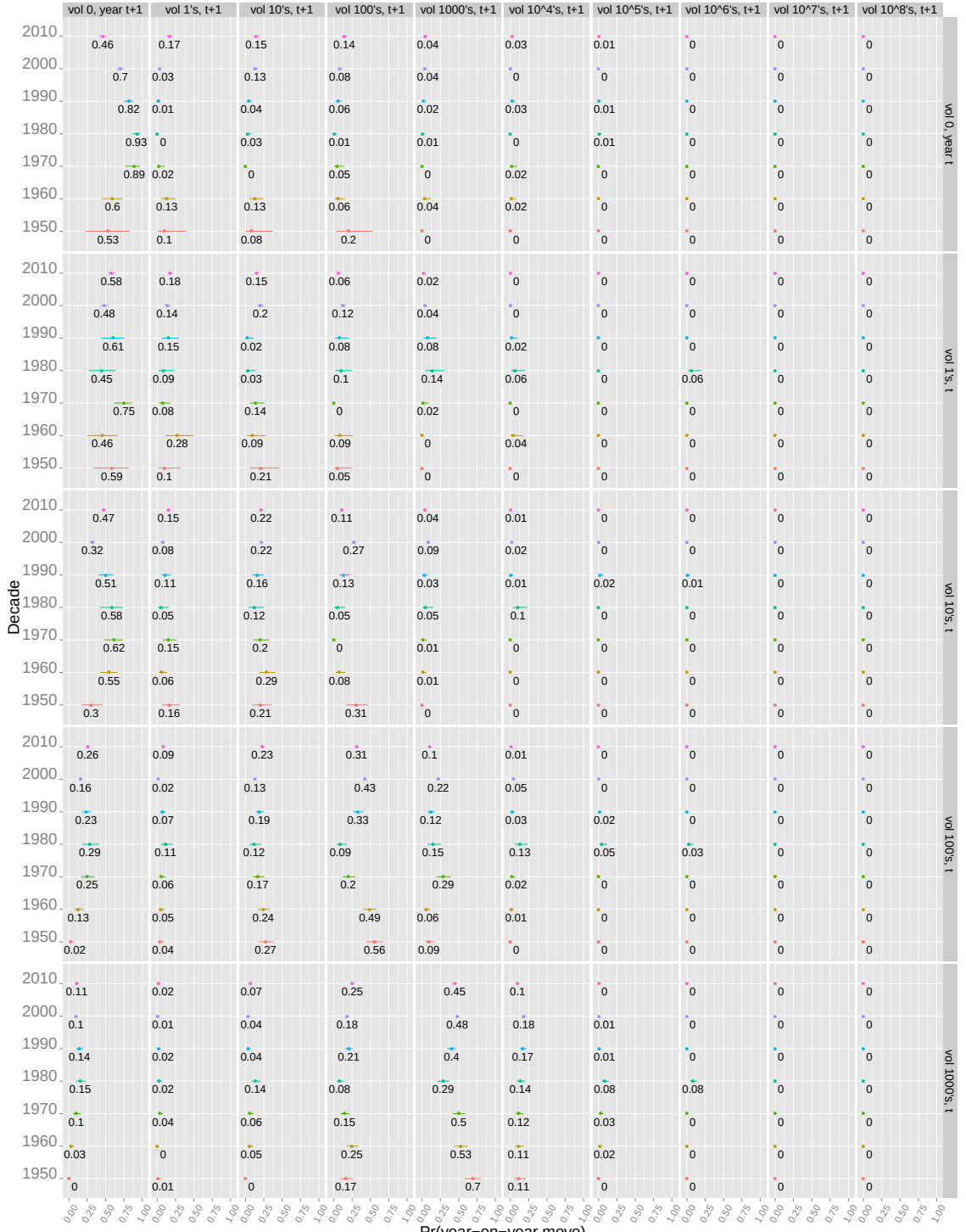
One likely cause...

Innovation exploded during the 2000's.

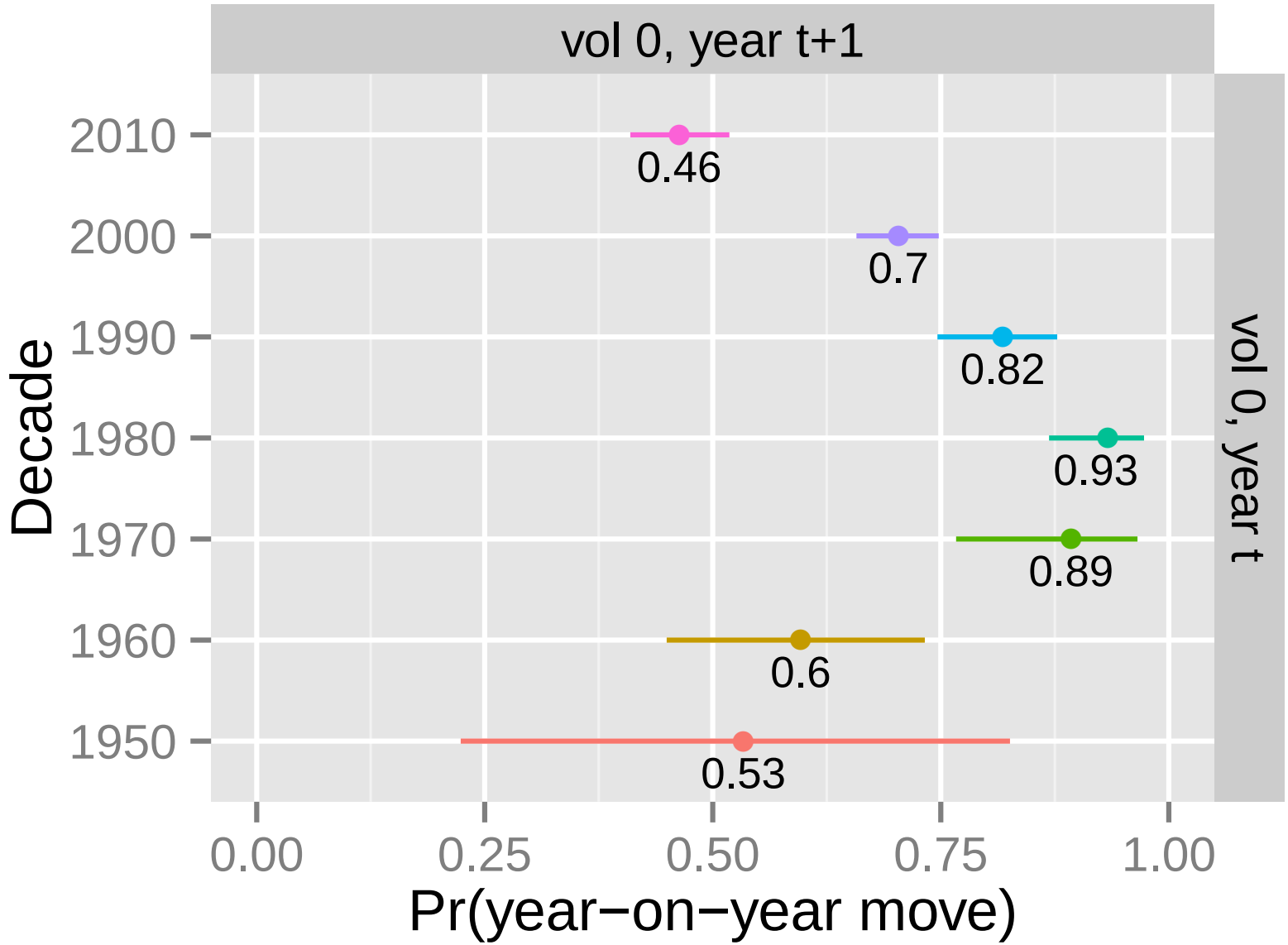

Derivatives in sample
3000
2000
1000
0
1960
1970
1980
1990
2000
2010
Year

Back to our model

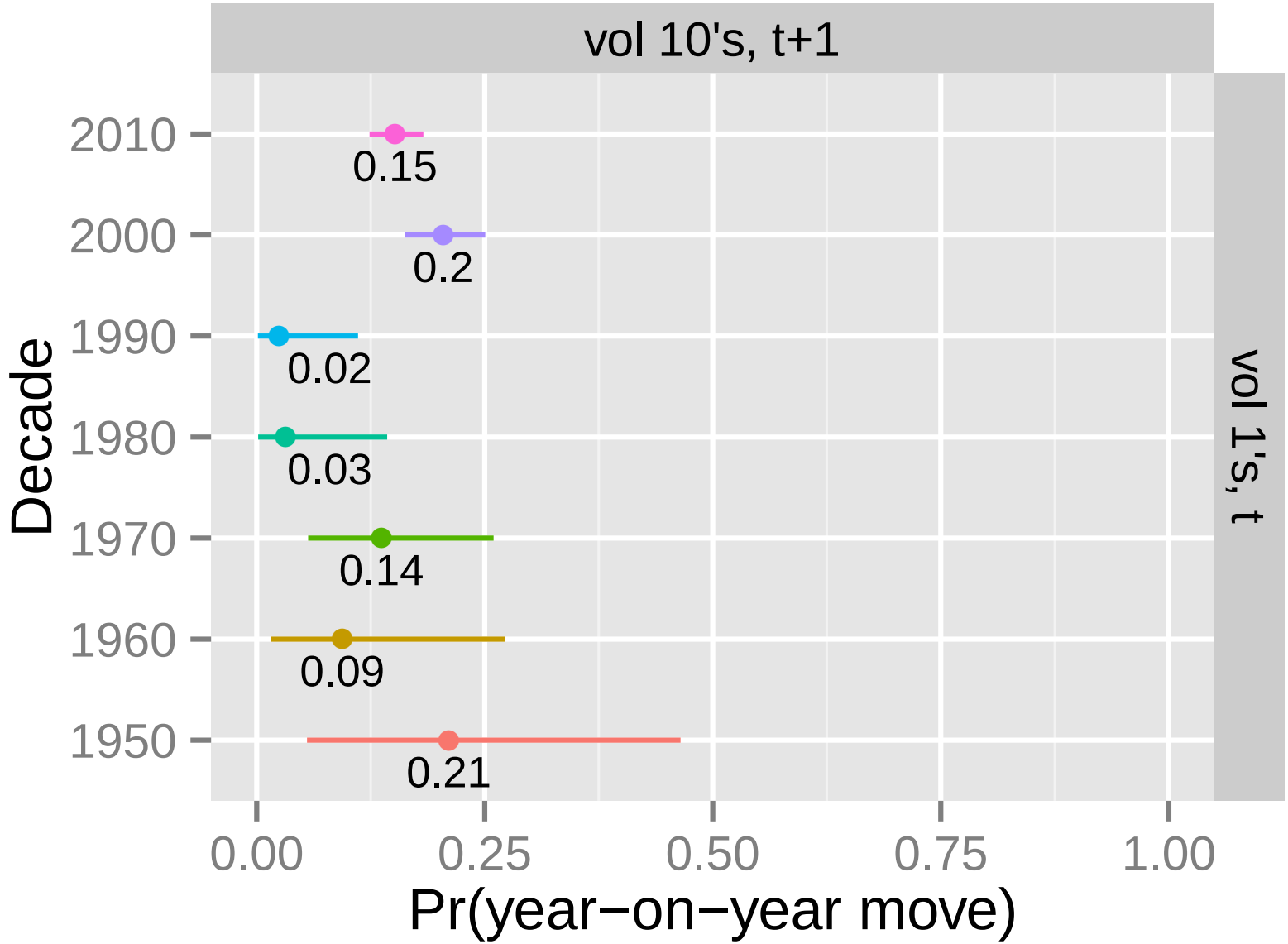
How has the probability of moving between states of annual volume changed over time?


vol 0, year t+1
vol 1's, t+1
vol 10's, t+1
vol 100's, t+1
vol 1000's, t+1
vol 10^4's, t+1
vol 10^5's, t+1
vol 10^6's, t+1
vol 10^7's, t+1
vol 10^8's, t+1
vol 0, year t
vol 1's, t
vol 10's, t
vol 100's, t
vol 1000's, t
Decade
2010
2000
1990
1980
1970
1960
1950
Pr(year-on-year move)
0.00
0.25
0.50
0.75
1.00

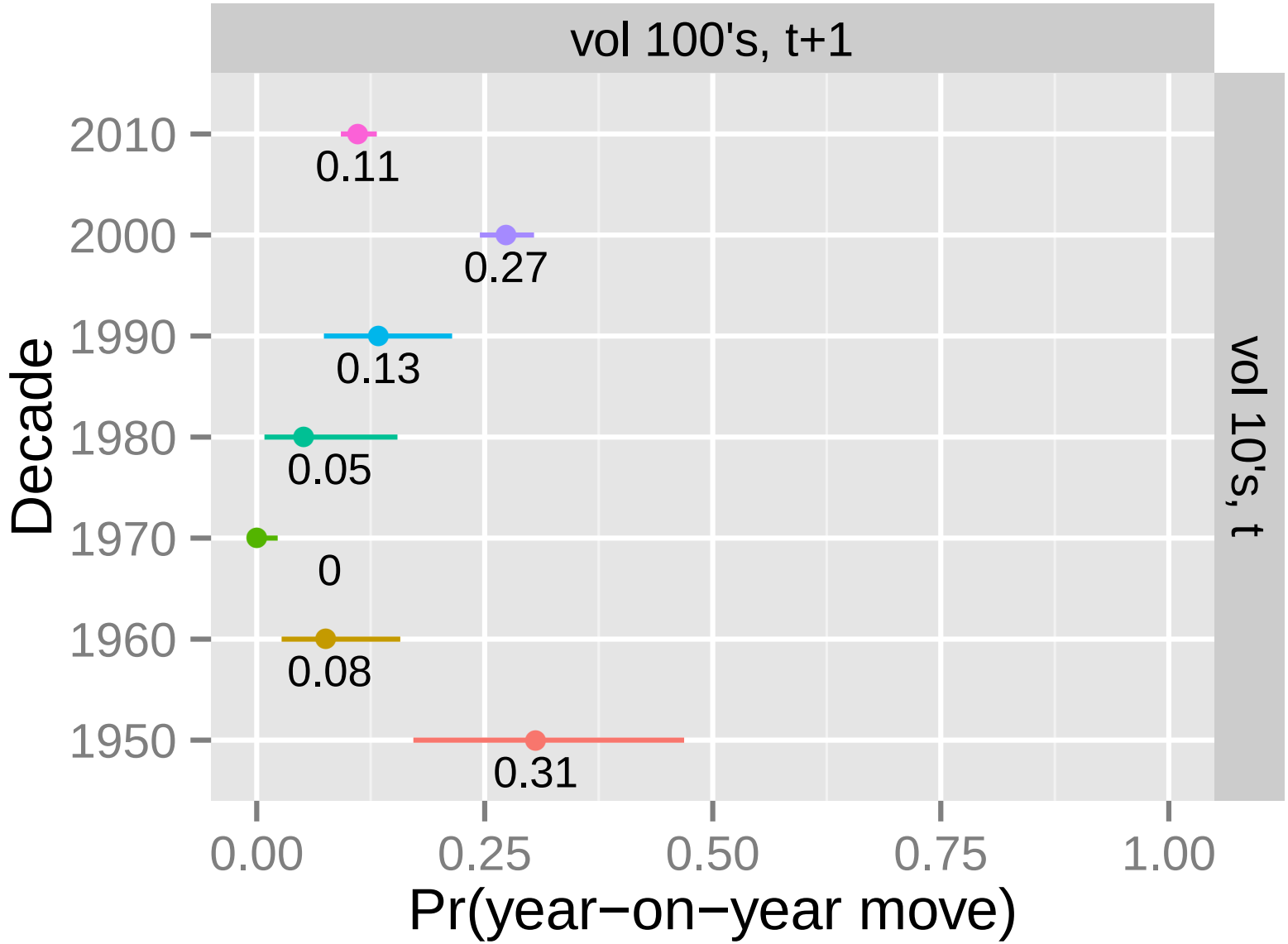
From 0 to 0


vol 0, year t+1
vol 0, year t
Decade
2010
2000
1990
1980
1970
1960
1950
0.46
0.7
0.82
0.93
0.89
0.6
0.53
0.00
0.25
0.50
0.75
1.00
Pr(year−on−year move)

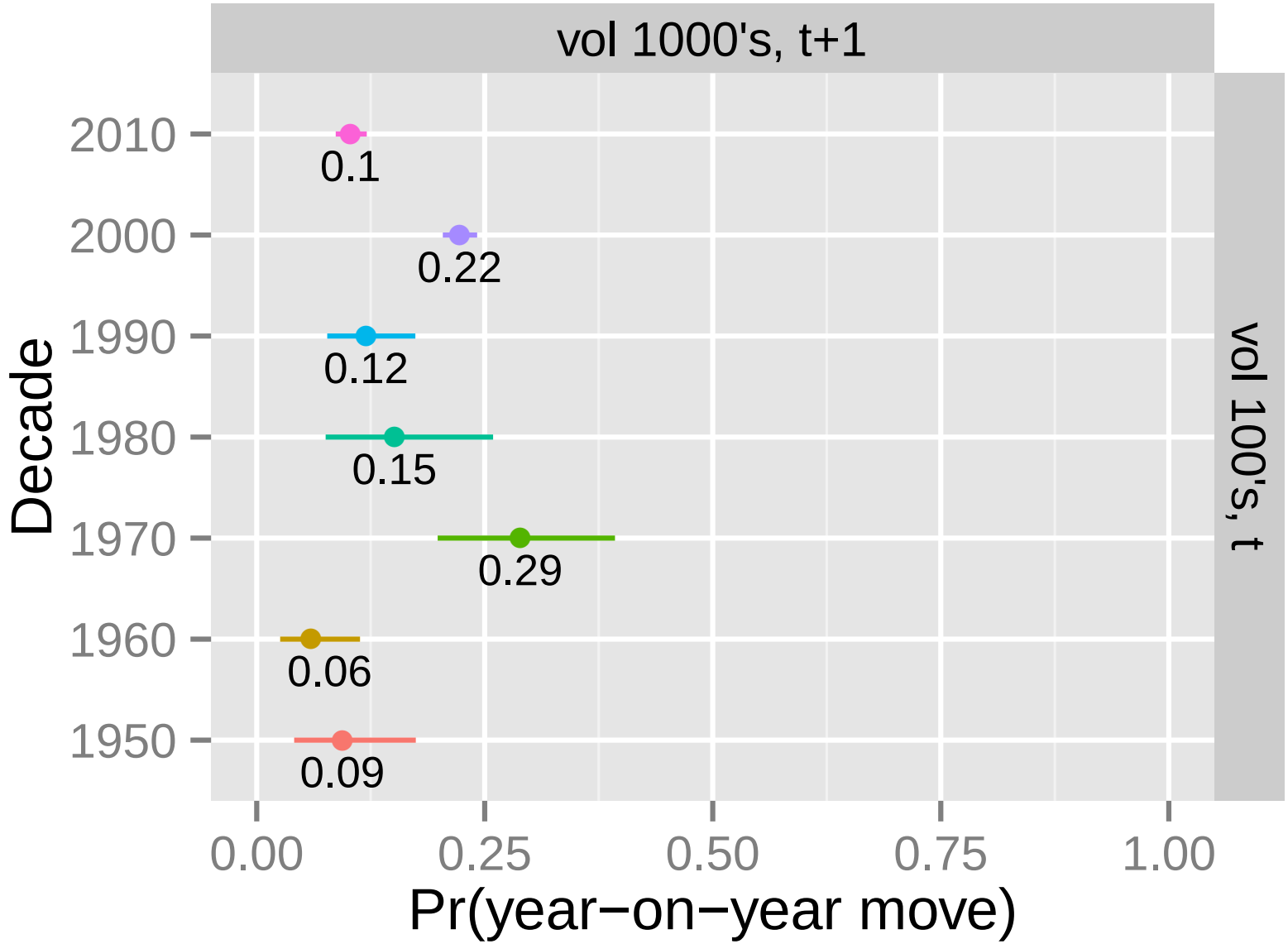
From single digits to double digits



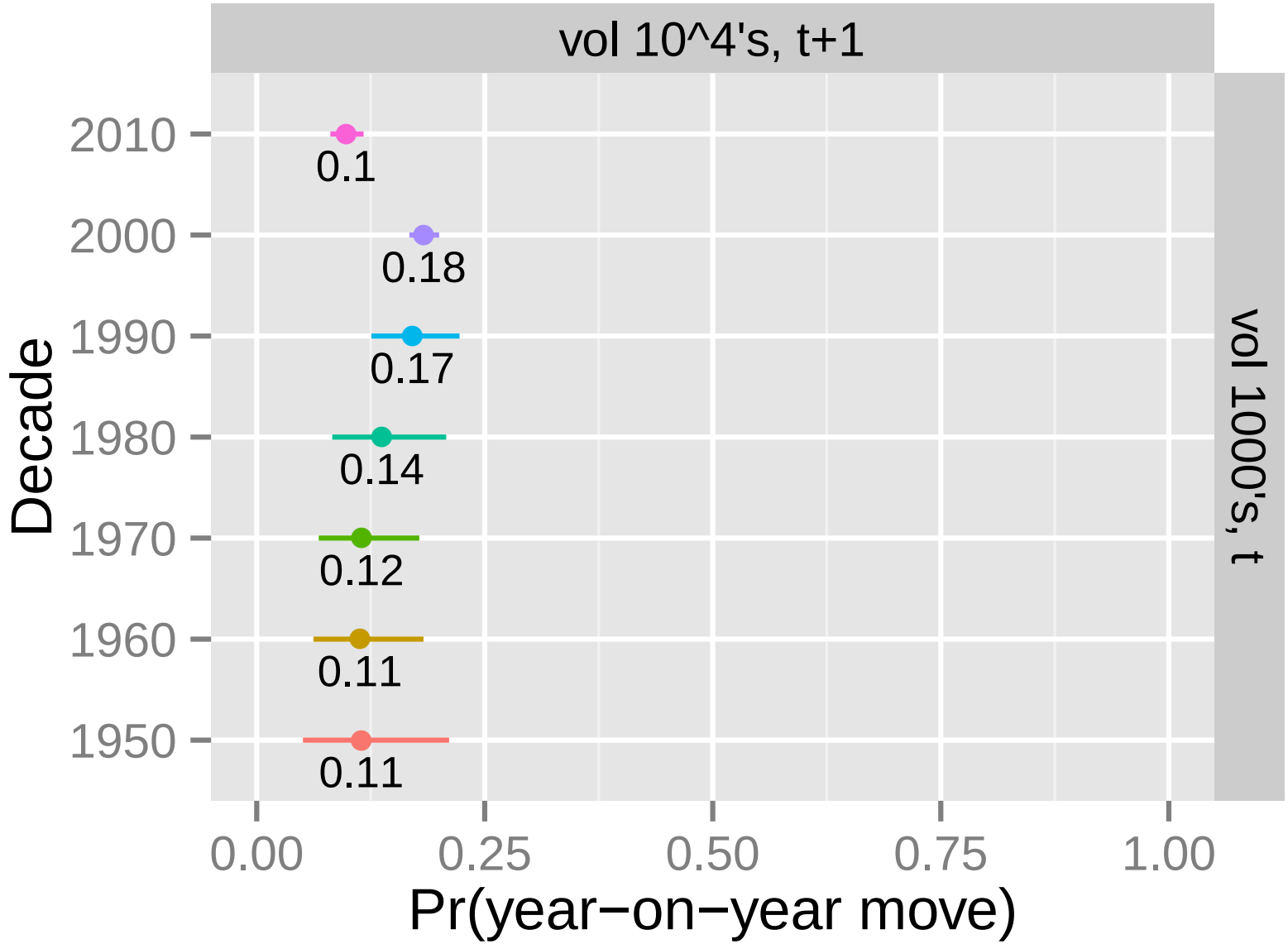
From double digits to 100's



From 100's to 1,000's

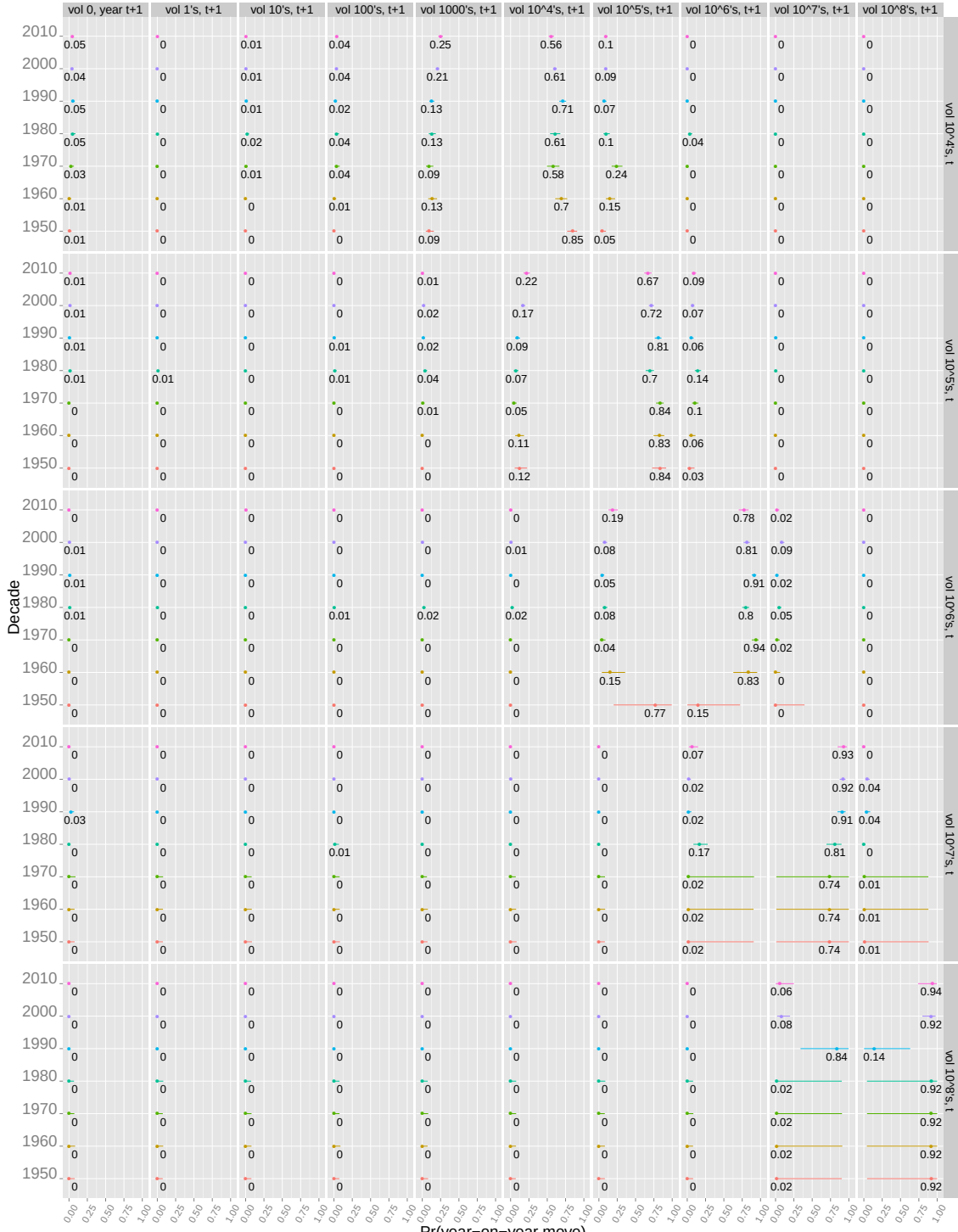


From 1,000's to 10,000's



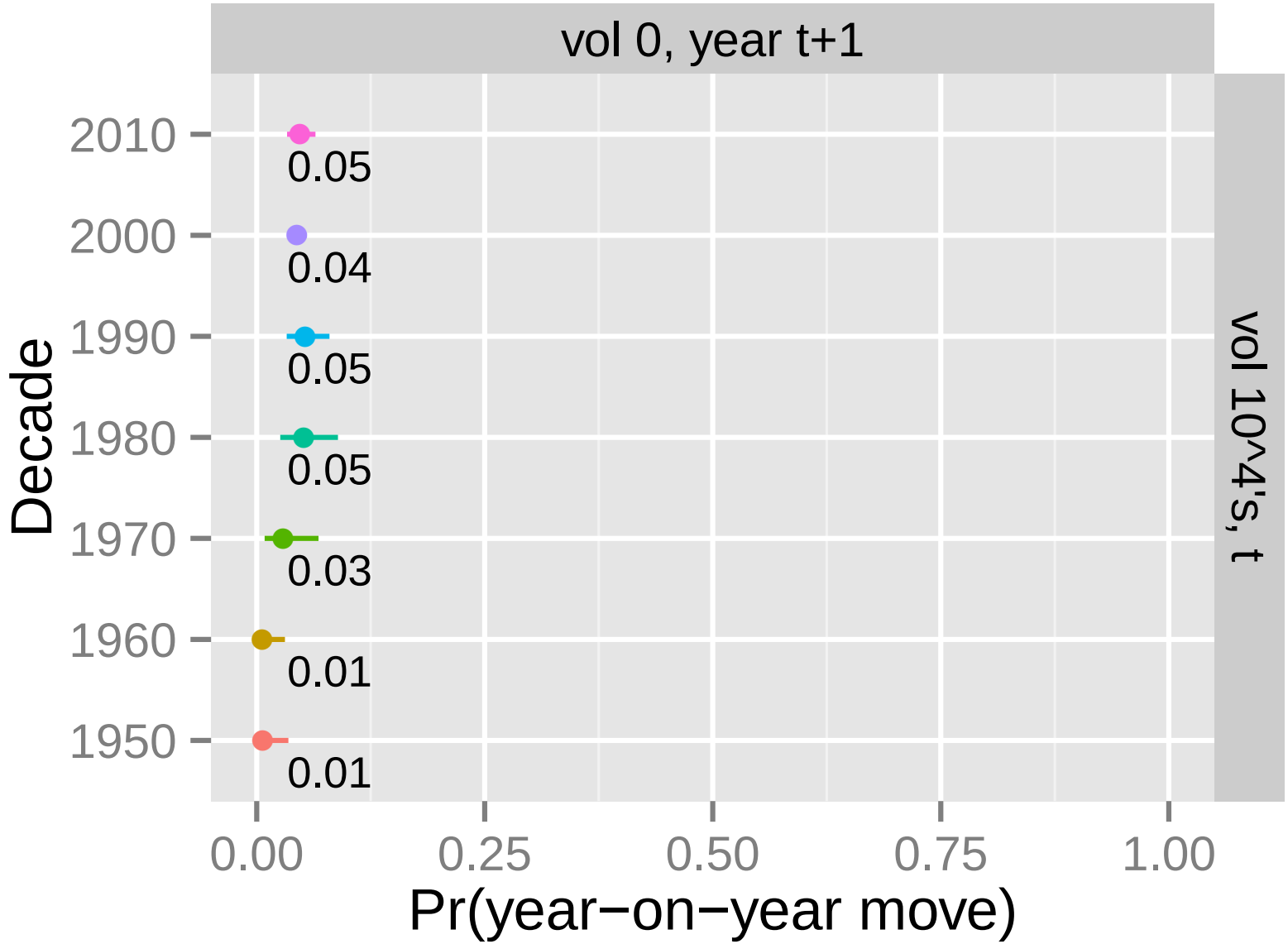
What should we take from this?

Contracts at low levels of trading are more flexible than in the past.
More readily move up to trading in the thousands.
Low trading is no longer the death sentence it once was.


vol 0, year t+1
vol 1's, t+1
vol 10's, t+1
vol 100's, t+1
vol 1000's, t+1
vol 10^4's, t+1
vol 10^5's, t+1
vol 10^6's, t+1
vol 10^7's, t+1
vol 10^8's, t+1
Decade
Pr(year−on−year move)

What should we take from this?

The additional flexibility for low volume contracts coincided with some erosion of the probability of progressing to higher volume levels.


vol 0, year t+1
vol 10^4's, t
Decade
2010
2000
1990
1980
1970
1960
1950
0.05
0.04
0.05
0.05
0.03
0.01
0.01
0.00
0.25
0.50
0.75
1.00
Pr(year−on−year move)

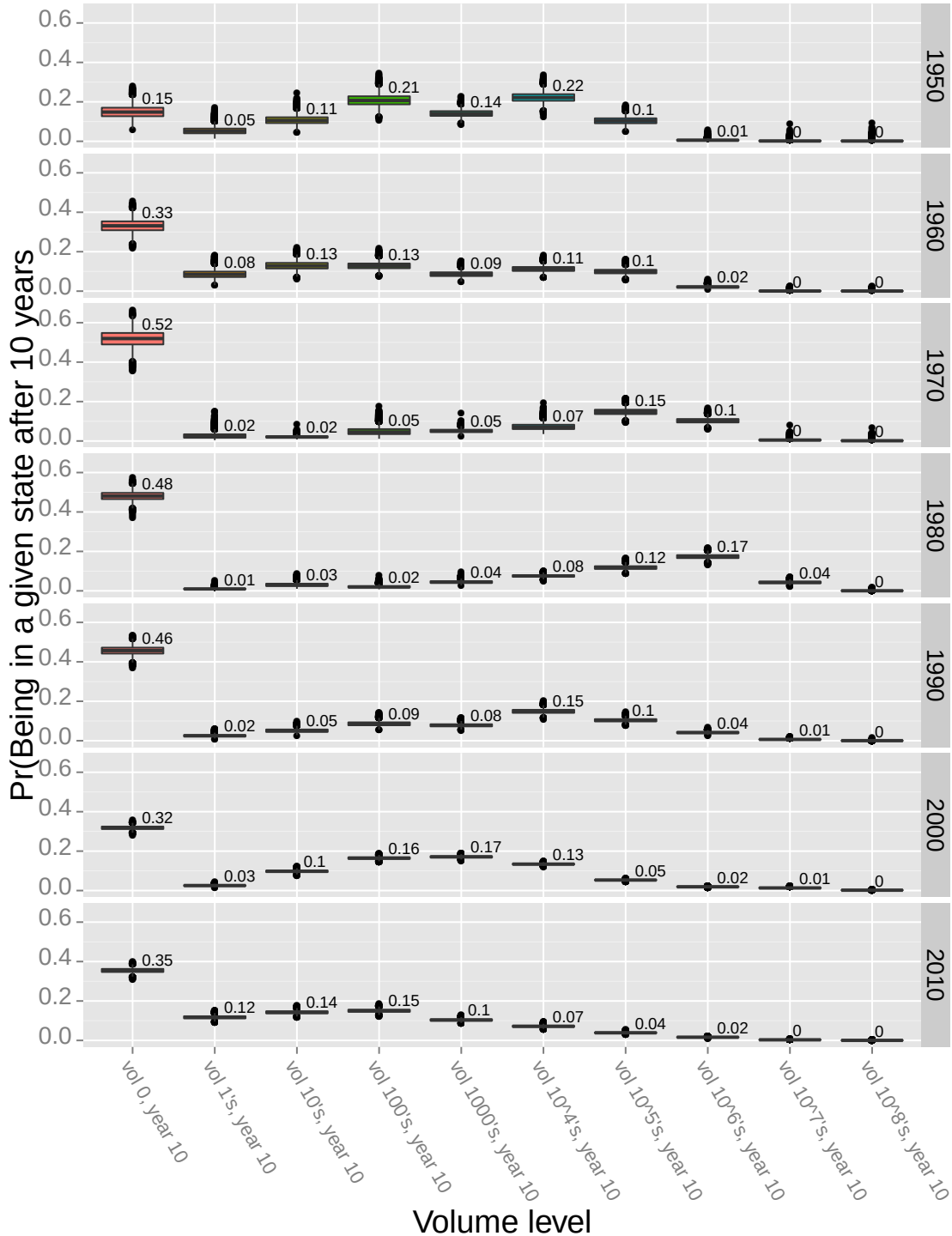
What should we take from this? - looking across all decades in the sample

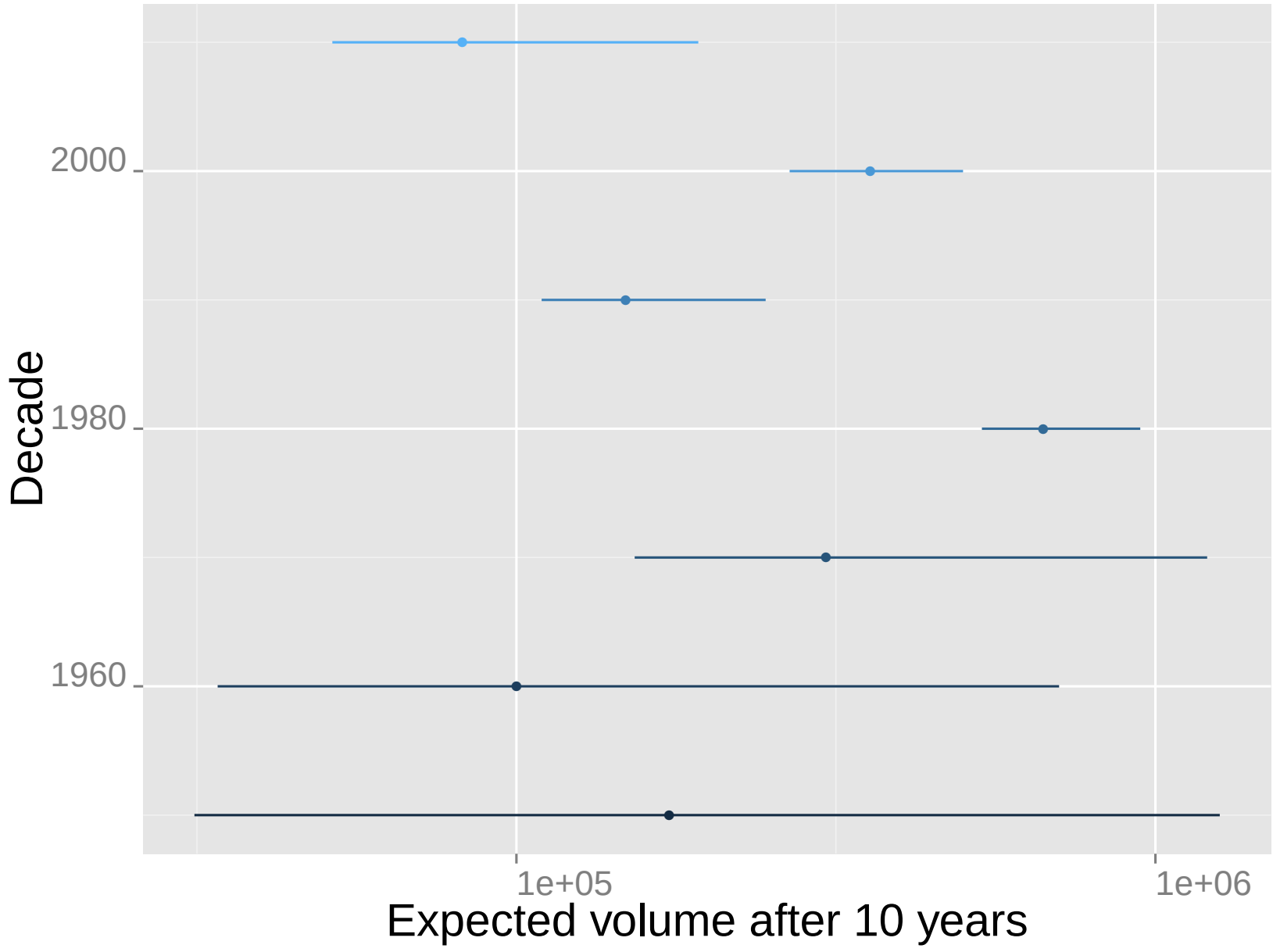
- $10,000$ in annual volume is a key milestone - a full collapse becomes relatively unlikely (4% averaged across all decades, only 10% of falling more than one volume level

Netting out the changes

What is more important from the standpoint of a new contract?

- The substantially increased flexibility from low levels of volume?
- The smaller fall in the probability of progressing to higher levels of volume?


Pr(Being in a given state after 10 years
Volume level
1950
1960
1970
1980
1990
2000
2010
vol 0, year 10
vol 1's, year 10
vol 10's, year 10
vol 100's, year 10
vol 1000's, year 10
vol 10^4's, year 10
vol 10^5's, year 10
vol 10^6's, year 10
vol 10^7's, year 10
vol 10^8's, year 10


Decade
2000
1980
1960
1e+05
1e+06
Expected volume after 10 years

Conclusions

- Markets have become more concentrated in any given year.
- But, contracts are more likely to rise up from low levels of trading.
- On balance, expected trading level after ten years remained in the middle of the historical range.
- So, despite remarkable rates of innovation, the prospects for the marginal innovation have not eroded.

Conclusions - from the full article

Based on our reading of the NYMEX:

- this decadal changes in derivative lifecycles were driven by the switch to electronic trading rather than exchange consolidation

In general:

- variations in expected year ten trading volumes were larger decade to decade than from exchange to exchange or product type to product type

Final thought - the iTune-ization of derivatives markets?

- Paradigm shift in marginal cost structure of a good with elastic demand. (Supply effect)
- New technologies allow for ubiquitous access to that good. (Demand effect)
- The market rewards specialty products more than in the past; and, blockbusters are as large/larger than they've ever been before. . . but some of this change came at the expense of baby blockbusters.