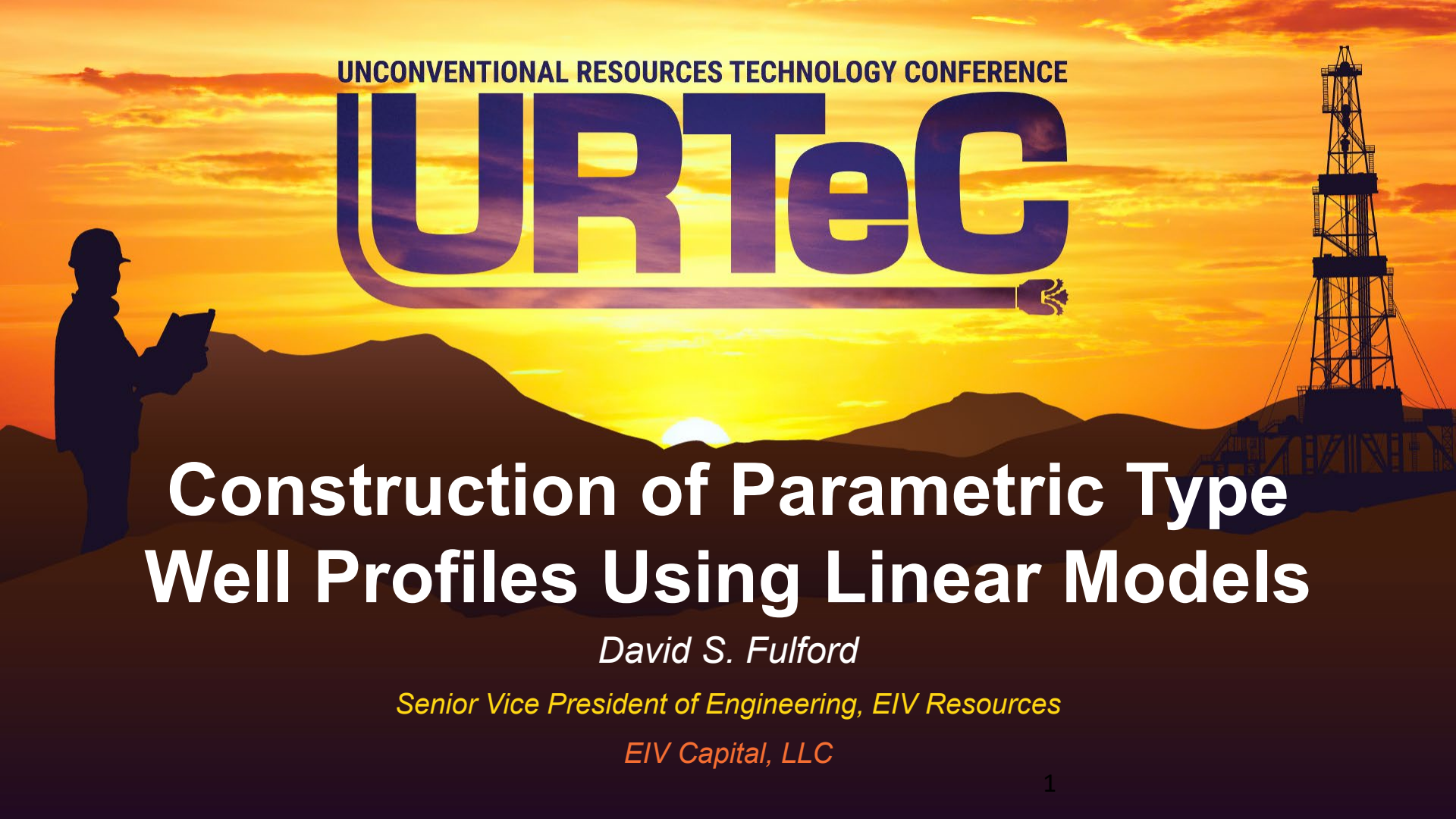

Construction of Parametric Type Well Profiles Using Linear Models

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Introduction

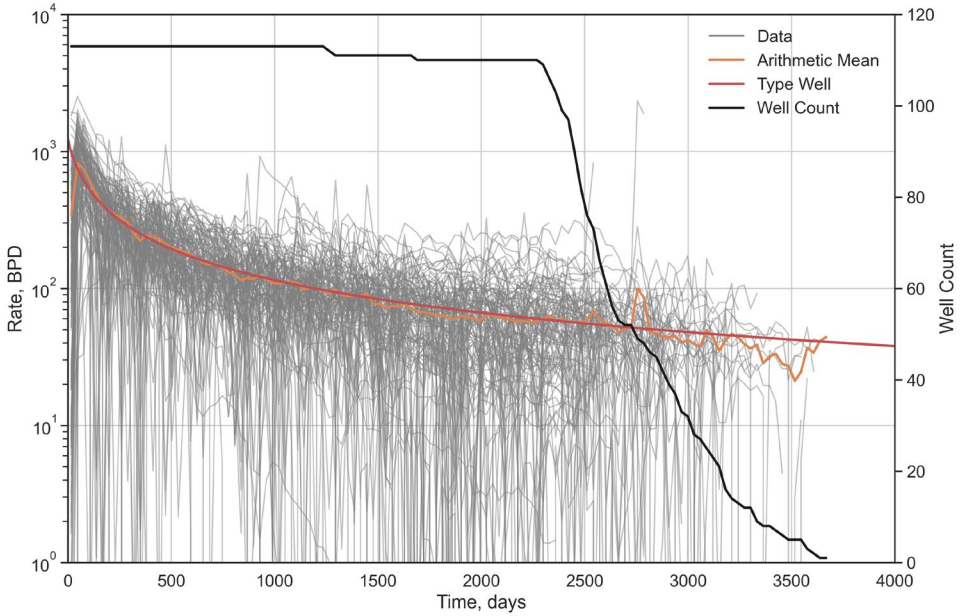
- Type Well Profiles (TWP) are:
  - an empirical construct
  - intended to characterize the “typical” well performance
  - of a population of wells

- *However!!!*
  - No rigorous basis for the industry-standard method of construction

- How did we learn to do this?
  - Knowledge by tradition…
  - an old dude taught a young dude the Weirding Way

My Mind Affects My Reality

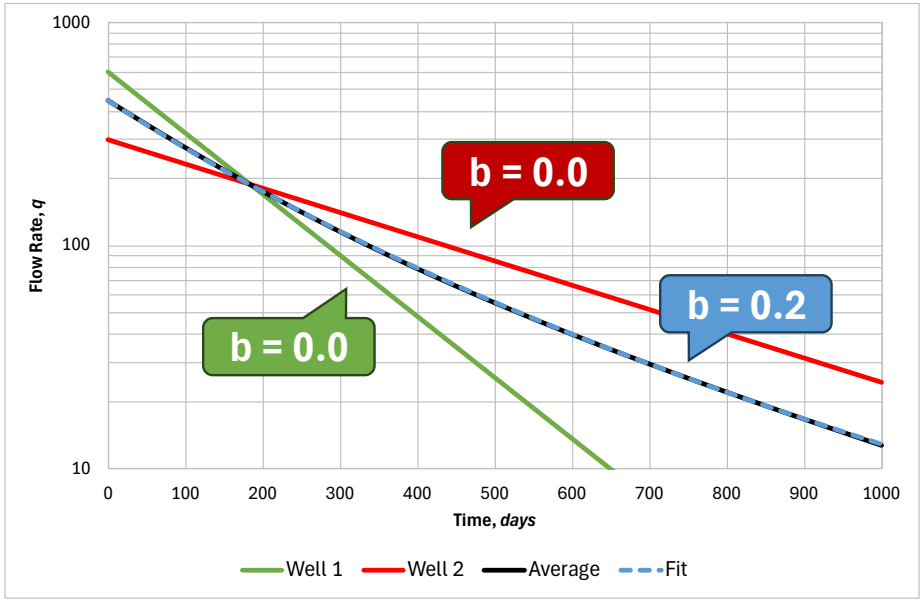
- Is this a good TWP?
- How does one judge?
- Is this a valid diagnostic?
- Has anyone ever validated this plot?
- What could go wrong?
- (everything…)

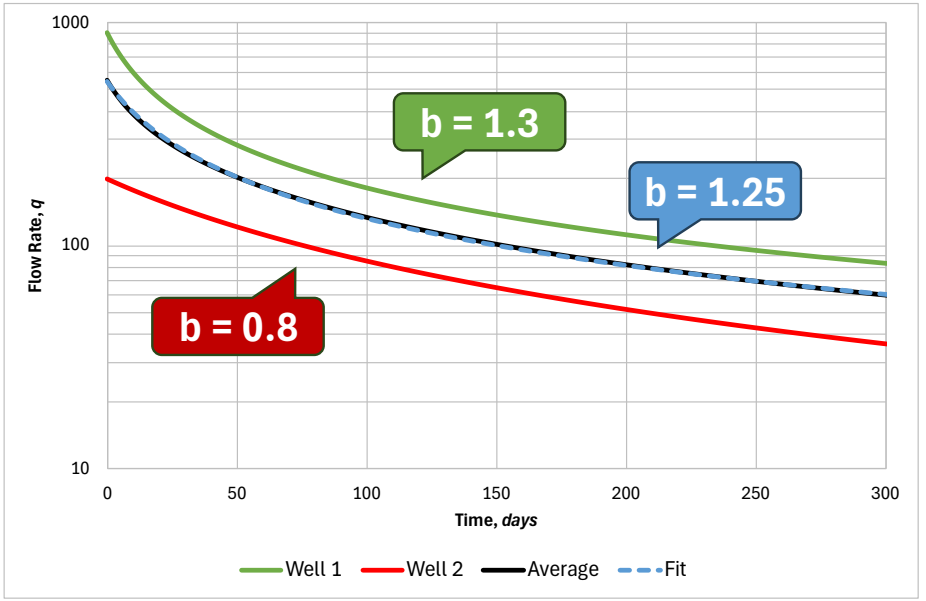


Back to Basics

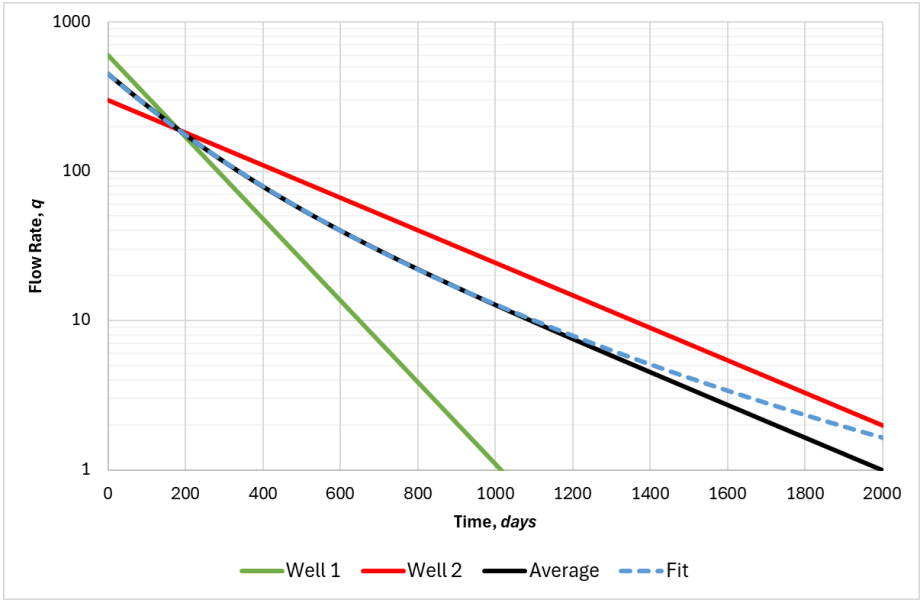
- What is an average? Does it mean the same as typical?
  - The average of ratios is not the same as the ratio of averages
  - The integral of the average of derivatives is not the same as the average of integrals
- The problem is simple:
  - the average of two exponential functions is not an exponential function
  - the average of two power functions is not a power function
  - the average of two hyperbolic functions is not a hyperbolic function

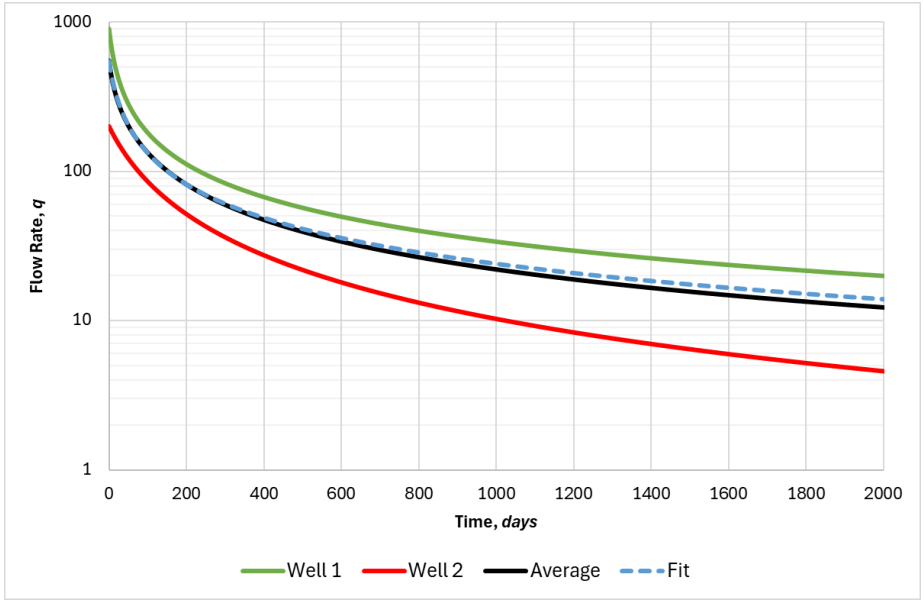
Back to Basics





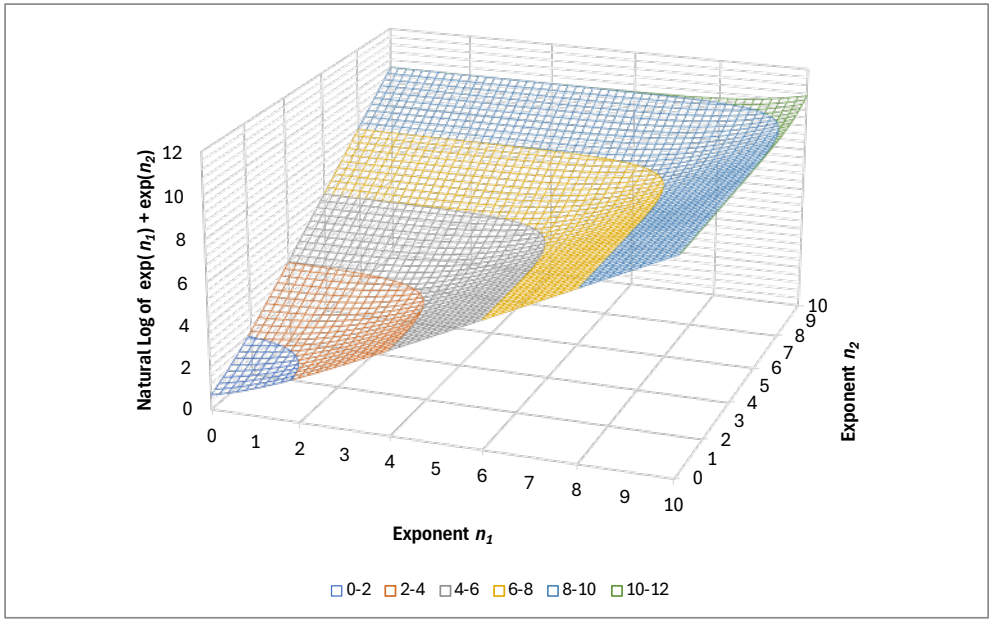
Back to Basics





Back to Basics

- The behavior is clearly dominated by the ***larger value***



We *know* this isn't right

- Interestingly, this feature of averages is used to good effect by reservoir engineers in other contexts:
  - "Layered, No-Crossflow Decline Behavior": Fektovich et al. (1996)
  - Diffusivity Equation Solution for Linear Reservoir: Wattenbarger (1998)
  - Fracture Heterogeneity: Nobakht et al. (2011); Fulford and Blasingame (2013); Acuña (2020)
  - Flow regime behavior in composite reservoirs: Clarkson et al. (2014); Fulford (2017)
- It is clear that sums and averages are useful to model complex reservoir behaviors, but this complex behavior shows up even when we don't want it—*such as when creating TWPs!!!*

We know this isn't right

- The average of production data does not look like any constituent well
- Would be a non-issue if we only wanted a statistical description… but we do not!
- TWPs are used to characterize a "typical" well's behavior and economic value
  - Investment decisions are made on the basis of the present value and capital efficiency of cash flows predicted by the TWP
- Therefore, we should strive to create a TWP that actually represents a typical well

A Better Way

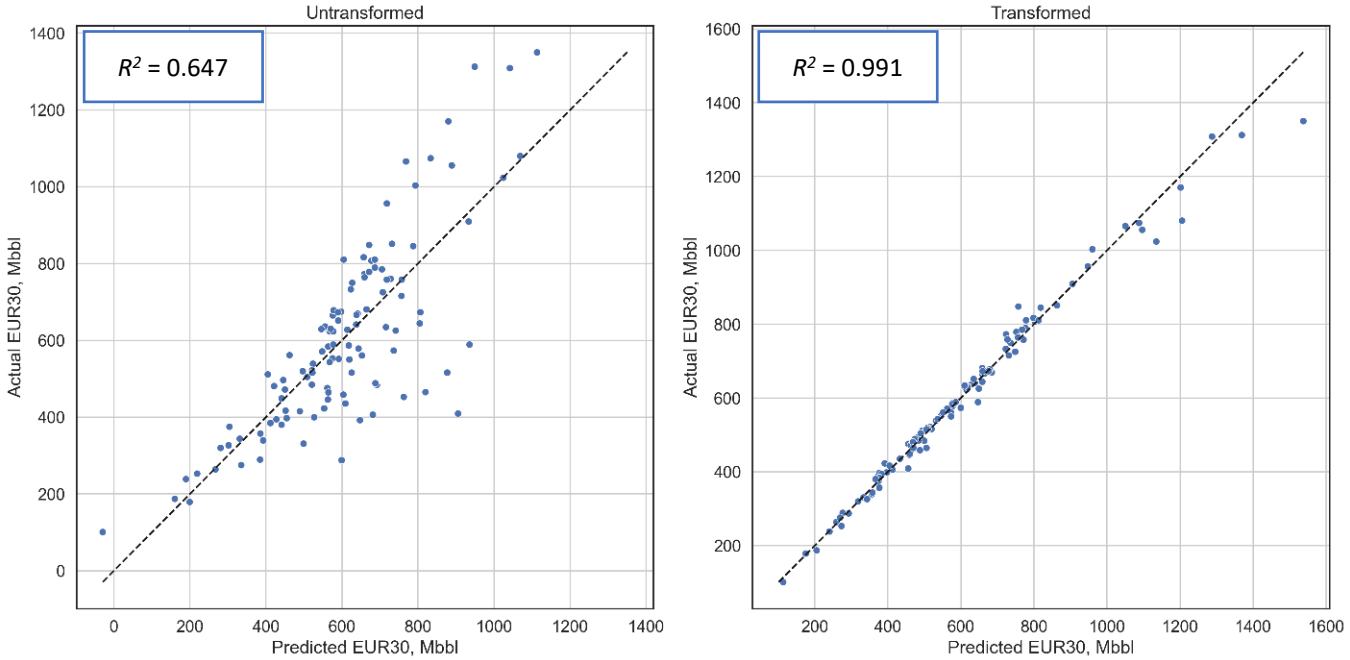
- A production forecast is a parametric characterization of a well's production history… so why not use it?
- Construct a linear model to predict EUR given decline parameters
- $EUR = f(q_i, D_i, b_i, b_f, t_{elf}, t) \rightarrow EUR \sim q_i + D_i + b_i, + b_f + t_{telf}$
- However, this model is not heteroskedastic (variance is not constant) because the distribution of each parameter is not symmetrical
- So, let's make them [symmetrical]…

Power Transforms

- The Box-Cox[1] power transform serves our purpose:
  - $f(y,\lambda) = \begin{cases} y^{\lambda} & \lambda \neq 0 \\ \log y & \lambda = 0 \end{cases}$
- Inspecting the definitions of dimensionless rate and dimensionless time, we find that they are primarily a product of multiple parameters… so we expect a lognormal distribution
- [2]Nominal decline for transient linear flow is $D = \frac{1}{2t}$, so we also expect a lognormal distribution (… usually)

[1] Box and Cox, 1964
[2] Fulford et al., 2013

Residual Value



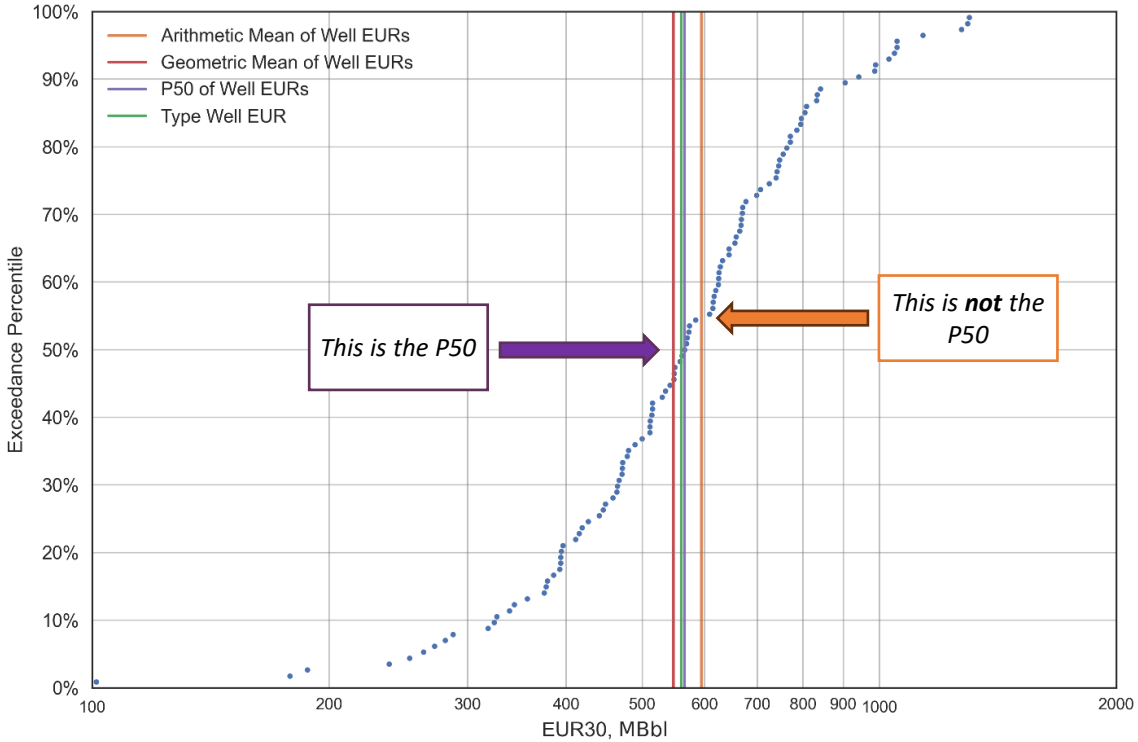
Linearity and Back

- We have a valid model… so what?
- Being linear means the property of a function being compatible with addition and scaling, i.e., the superposition property
  - Definition: for all linear systems, the net response caused by two or more inputs is the sum of the responses caused by each input individually
  - Example: in a linear differential equation, a solution can be constructed from the scaling and addition of any other solution(s)!
  - Practical use: rate and/or pressure normalization, i.e., RTA/PTA, is based upon this

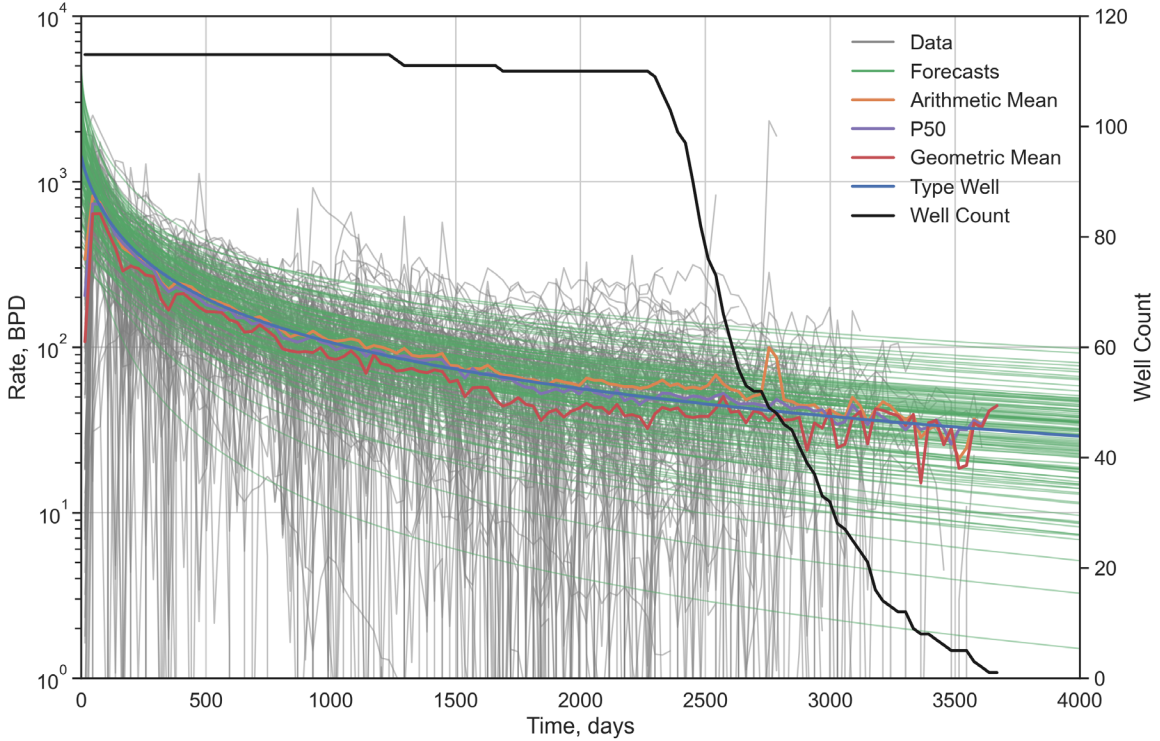
Linearity and Back

- We are doing something much simpler… averaging each parameter to predict the EUR
- After averaging, we back-transform
- In our case, just exponentiate!!!

Results

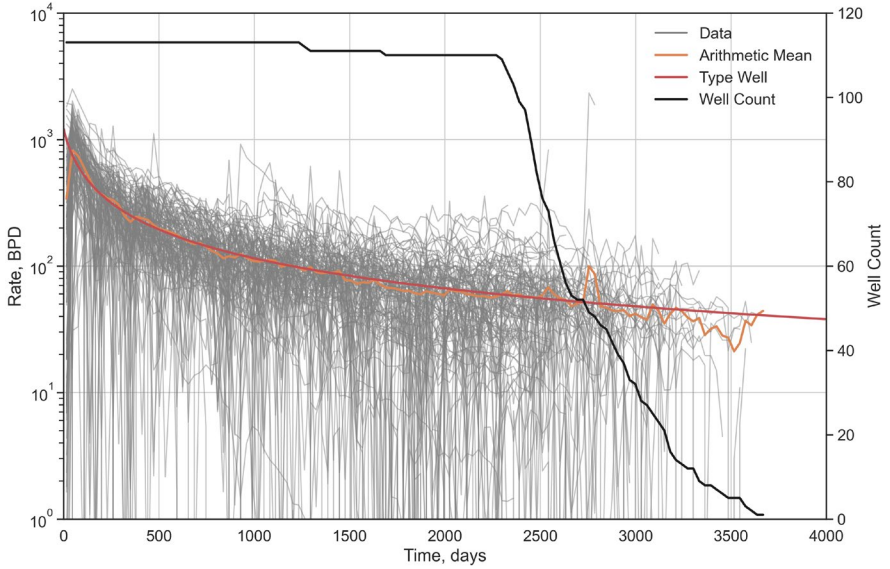

Arithmetic Mean of Well EURs
Geometric Mean of Well EURs
P50 of Well EURs
Type Well EUR
This is the P50
This is **not** the P50
Exceedance Percentile
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
100
200
300
400
500
600
700
800
900
1000
2000
EUR30, MBbl

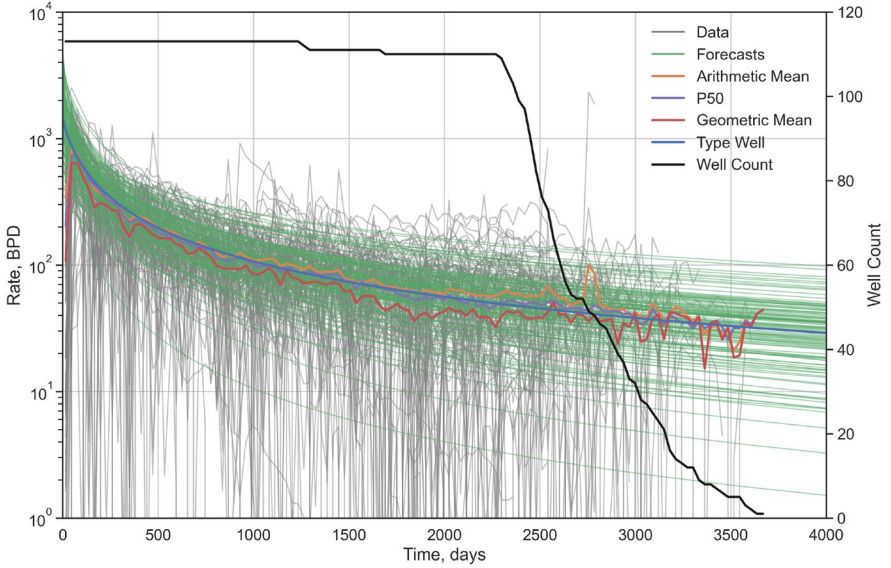
Results


Data
Forecasts
Arithmetic Mean
P50
Geometric Mean
Type Well
Well Count
Rate, BPD
Well Count
Time, days
10^4
10^3
10^2
10^1
10^0
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
4000

Results

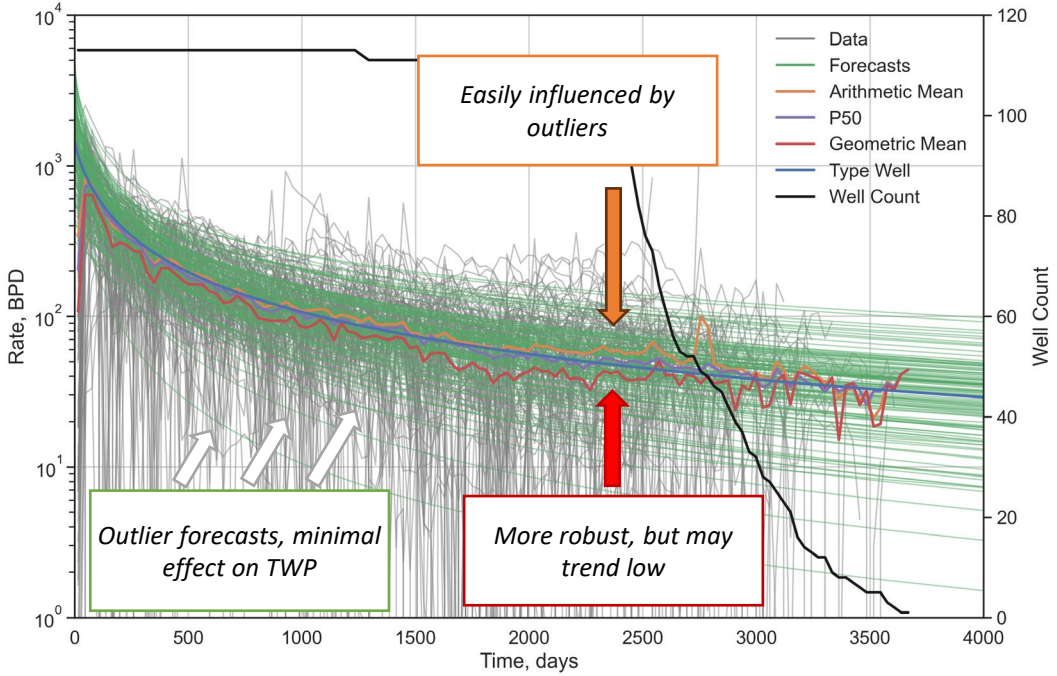
- Did you catch that these were different?
- 9% greater EUR on the left (what could I do if I were a sell-side engineer… ?)





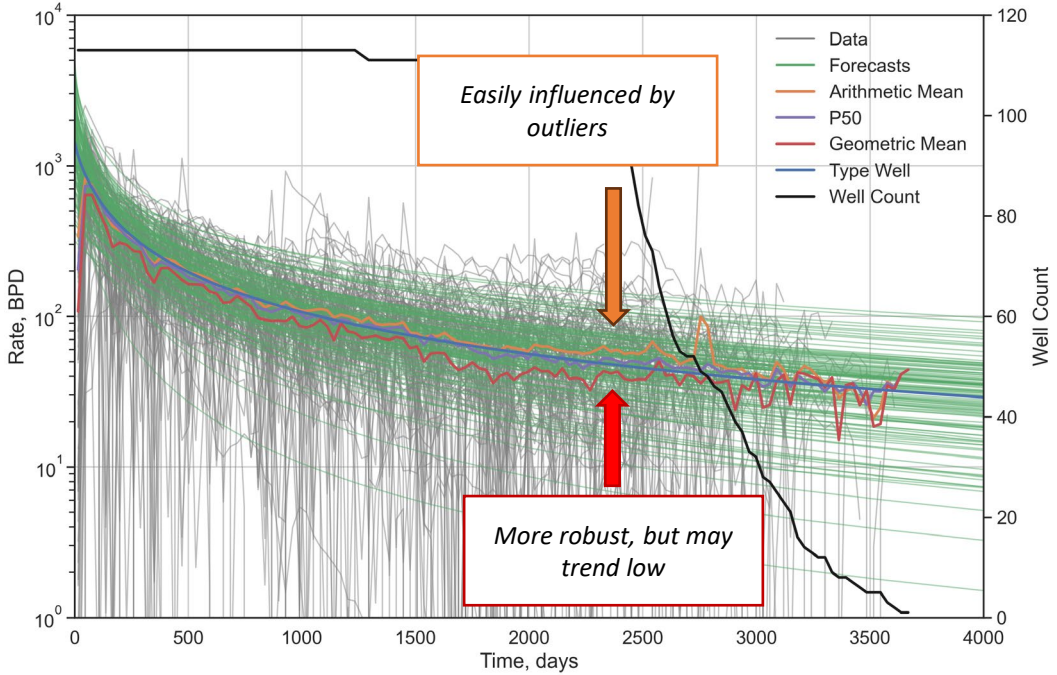
Results

- The arithmetic mean is highly biased by outliers and is not reliable to use as a basis for a TWP nor [by itself] as a diagnostic
- The geometric mean is less biased by outliers, but susceptible to skewness in low values
- The P50 presents the least biased representation as it is wholly unaffected by values, only ordering



Recommendation

- New diagnostic proposed:
- The deviation of the arithmetic and geometric means from the P50 indicates data stability issues
- Stable periods of history should be relied upon more than unstable periods of history



Discussion

- This method is simple and straightforward, using math no more complex than that covered in freshman level college statistics.
- It is fast, direct, and removes nearly all subjectivity from the TWP creation workflows that are standard across industry.
- While it is not common for evaluators to forecast every well, note that in this example we have used autoforecasting. Modern software makes this trivial.
- The forecasts do not need to be created when a TWP is needed. Only an analog well set is needed. So, create them ahead of time!
- We can perform a similar process for associated phase TWPs (GOR/CGR/WOR/WGR). See paper for more details.

Thank You