CIRAIG™

Interuniversity Research Centre for the
Life Cycle of Products, Processes and Services

Effects of distribution choice on the modeling of LCI uncertainty

Stéphanie Muller, Chris Mutel, Pascal Lesage, Réjean Samson

2013/09/13

53rd LCA Discussion Forum

And with...

ESD
ecological systems design

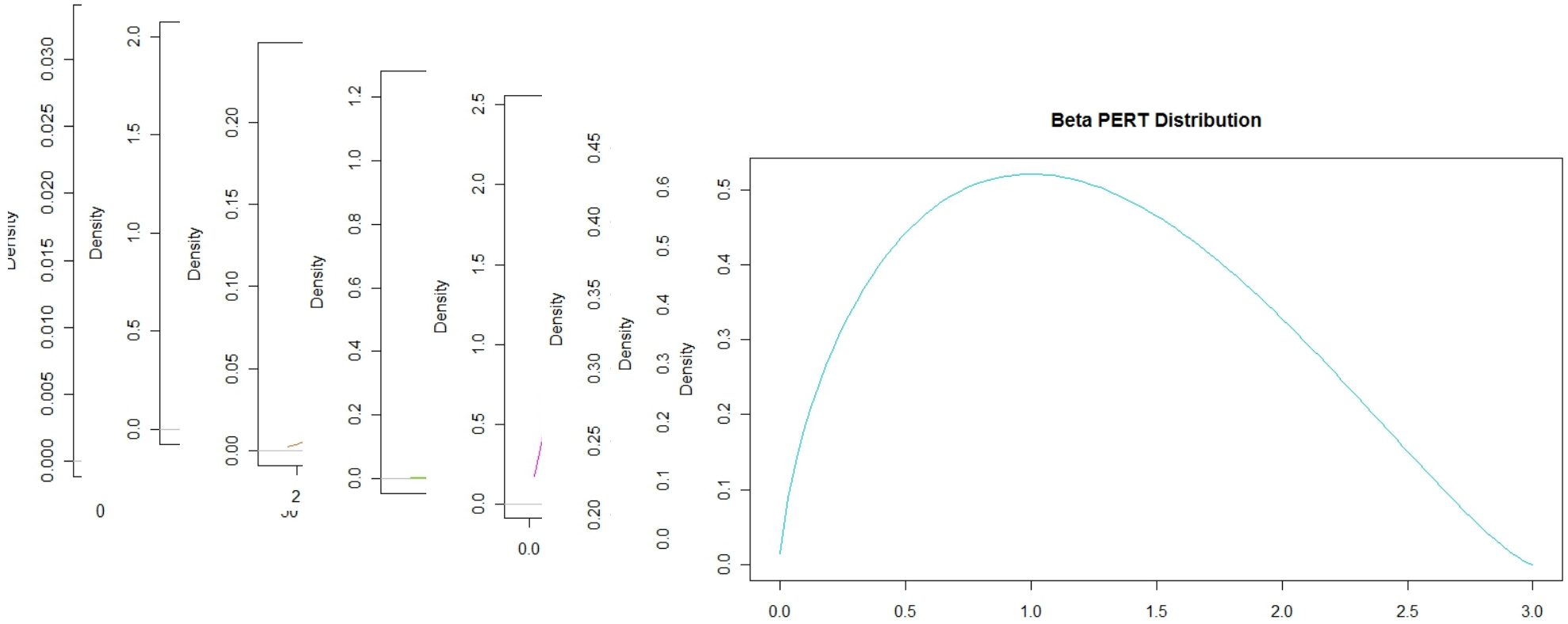
POLYTECHNIQUE MONTRÉAL
WORLD-CLASS ENGINEERING
UT TENSIO SIC VIS

INTRODUCTION

When performing LCA uncertainty assessments:

Major LCA software offer the possibility to run Monte Carlo analysis

→ The practionner needs to define PDF to model a datum with its uncertainty



INTRODUCTION

When performing LCA uncertainty assessments:

Major LCA software offer the possibility to run Monte Carlo analysis

→ The practionner needs to define PDF to model a datum with its uncertainty

Lack of time and lack of data, for modelling both background and foreground:

Experts' judgments to derive PDFs

Use of default distributions

→ **Beta** (Kennedy et al., 1996; Canter et al. 2002; Wang et al. 2012)

→ **Beta PERT** (Koffler and Kalish, 2012)

→ **Ecoinvent database – Lognormal** (Frischknecht et al., 2005)

CIRAIG[MC]

PROBLEMATICS

DOES THE CHOICE OF THE DISTRIBUTION MATTER WHEN PERFORMING A MONTE CARLO LCA UNCERTAINTY ASSESSMENT ?

HOW DOES THE CHOICE OF THE DEFAUT DISTRIBUTION DRIVE RESULTS' CHARACTERISTICS ?

CIRAIG MC

OUTLINE

1. PDFs CHARACTERISTICS
2. THE SPECIFIC CASE OF THE LOGNORMAL DISTRIBUTION
3. DEVELOPED METHODOLOGY TO SWITCH DISTRIBUTIONS
4. MAIN RESULTS
5. SOME THOUGHTS

CIRAIG

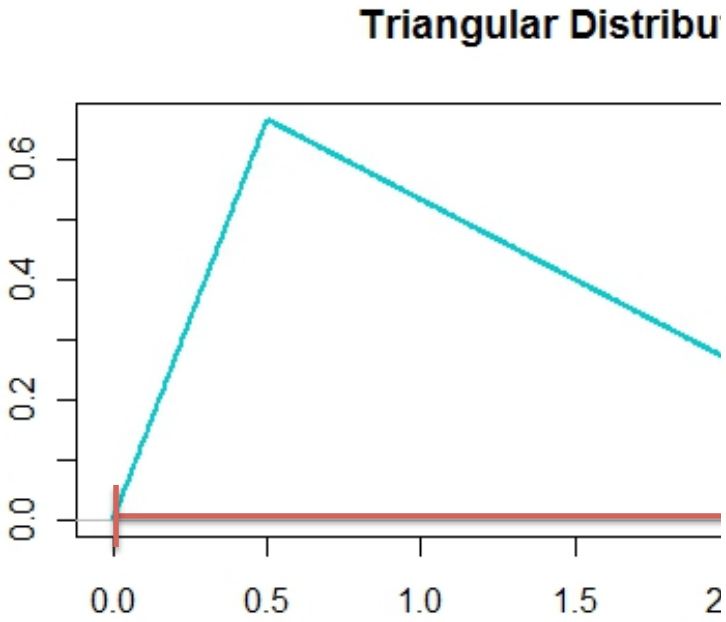
1. PDFs CHARACTERISTICS

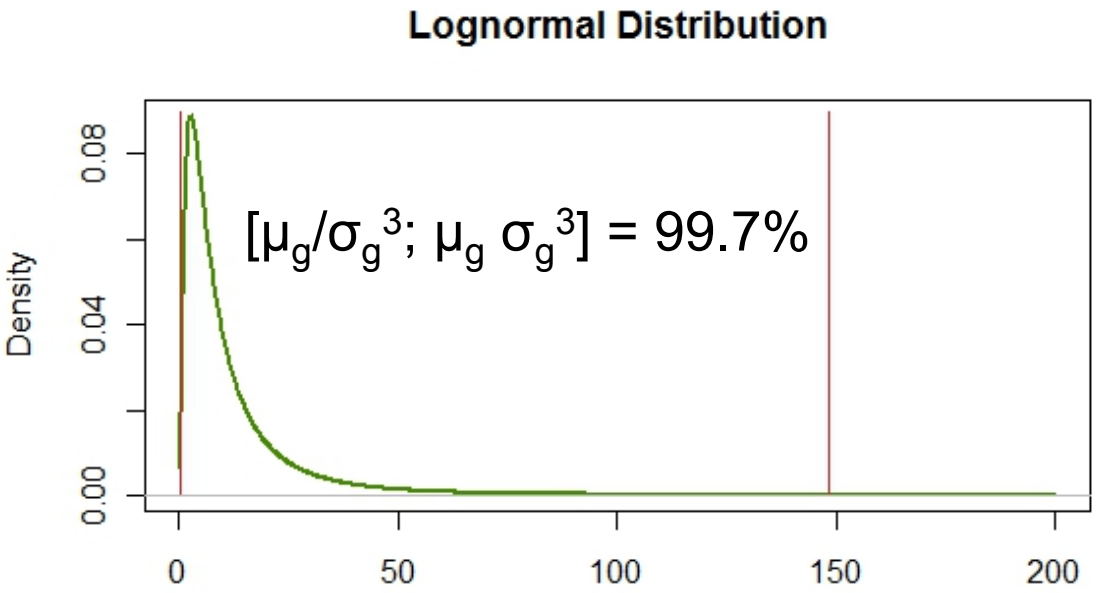
Generally distributions are defined through:

a. Their location parameter(s) (i.e. range)

b. Their shape

a. Bounded vs. unbounded distributions





1. PDFs CHARACTERISTICS

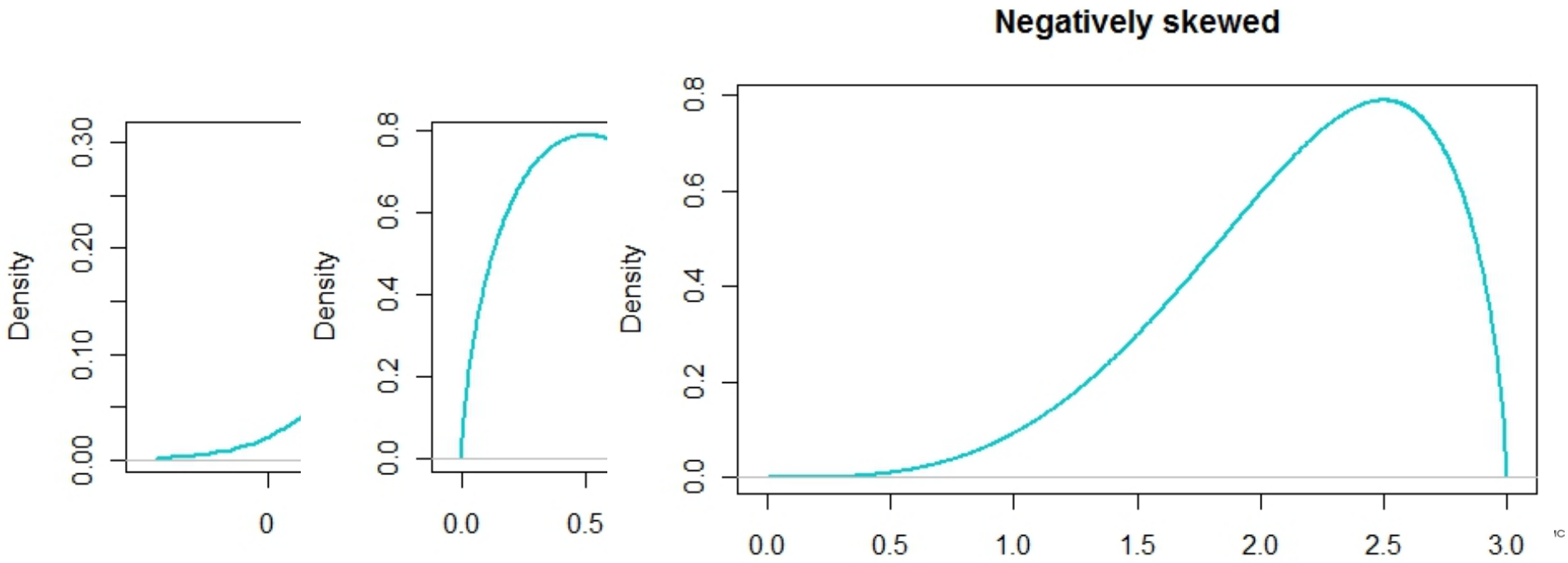
Generally distributions are defined through:

a. Their location parameter(s) (i.e. range)

b. Their shape

a. Bounded vs. unbounded distributions

b. Symmetric vs. skewed distributions



2. THE LOGNORMAL DISTRIBUTION

The distribution by default to model uncertainty on parameters in the Ecoinvent database:

Is the result of the multiplication of independent processes

→ as many variables in natural science

Its resemblance to the normal distribution

→ definition parameters that can more easily be determined

Is a positive and a positively skewed distribution

→ convenient to model physical parameters with large uncertainties or based on experts' judgments

Permits to apply analytical uncertainty propagation methods

CIRAIG[MC]

WHAT IF THE LOGNORMAL DISTRIBUTION IS NOT THE ONE USED BY DEFAULT?

CIRAIG

3. DISTRIBUTIONS SWITCH - TOOLBOX

Distributions switch | Datasets selection | LCA and Monte Carlo calculations | Results comparison

Test the lognormal distribution against positively skewed distributions:

A bounded distribution **: triangular**

Similar distributions but less skewed: **gamma and weibull**

How to switch:

Gamma and weibull:

→ Solve the equations that link the parameters to the **median and variance** of the lognormal distributions

Triangular distribution defined by **location parameters:**

→ The min and max are derived from the lognormal **95th confidence interval**

CIRAIG^{MC}

3. DISTRIBUTIONS SWITCH - TOOLBOX

Among all the processes available in Ecoinvent v2.2.

→ 100 were kept

CIRAIG

3. DISTRIBUTIONS SWITCH - TOOLBOX

Distributions switch | Datasets selection | **LCA and Monte Carlo calculations** | Results comparison

LCA calculations based on the Global Warming category for each process

Uncertainty assessment based on a Monte Carlo simulation

→ **5000 steps** calculations

→ For the **initial distributions** and for **the switch** from the lognormal to the other "by default" distribution

Software used

→ **Brightway2:** open source tool to perform LCA calculations

For more info http://brightwaylca.org/

CIRAIG[MC]

3. DISTRIBUTIONS SWITCH - TOOLBOX

Distributions switch | Datasets selection | LCA and Monte Carlo calculations | Results comparison

Assessment of differences in the resulting distributions:

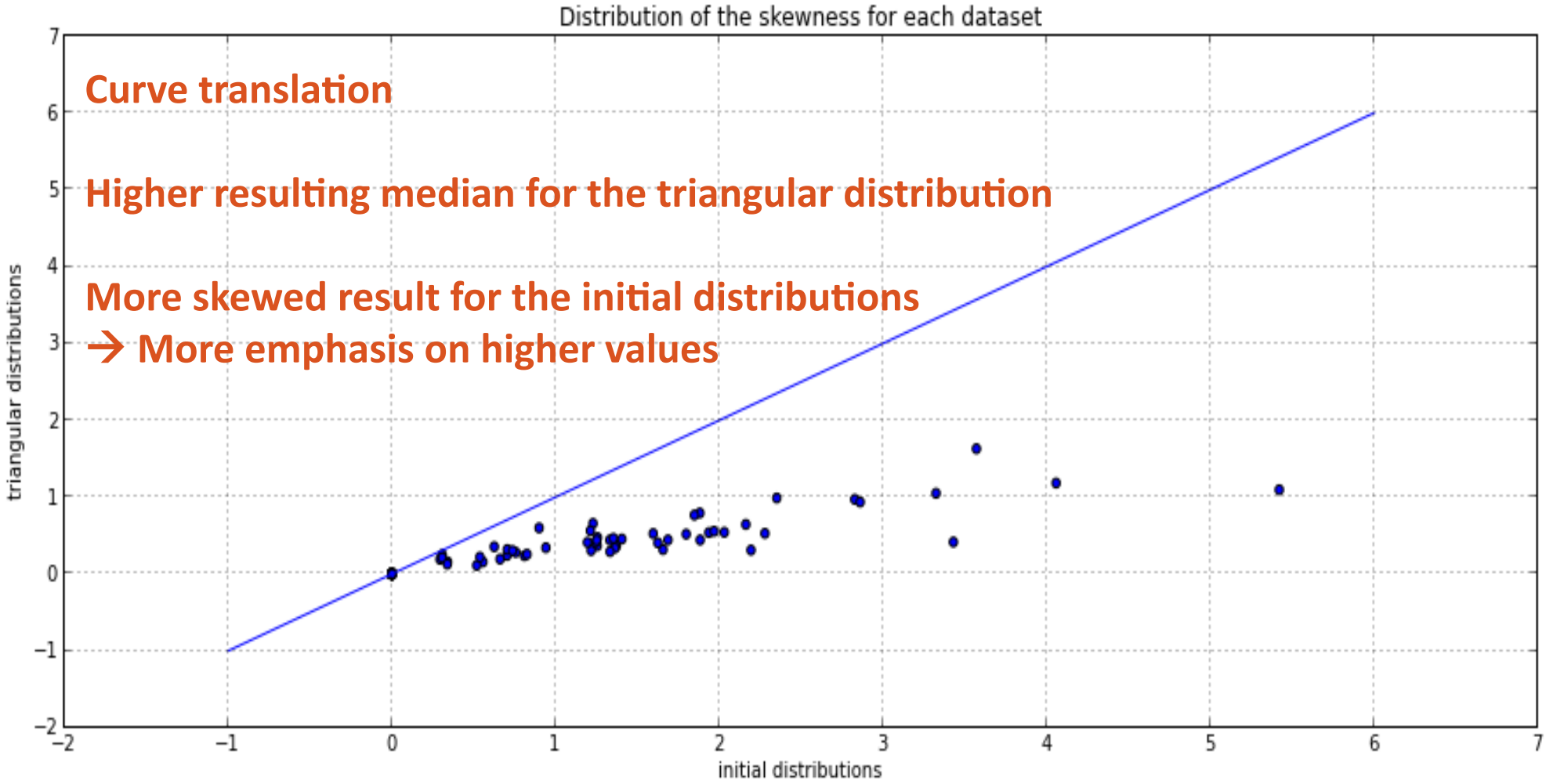
- → the **shape**
- → the **range**
- → the **determistic value**, the median

Use of descriptive statistics

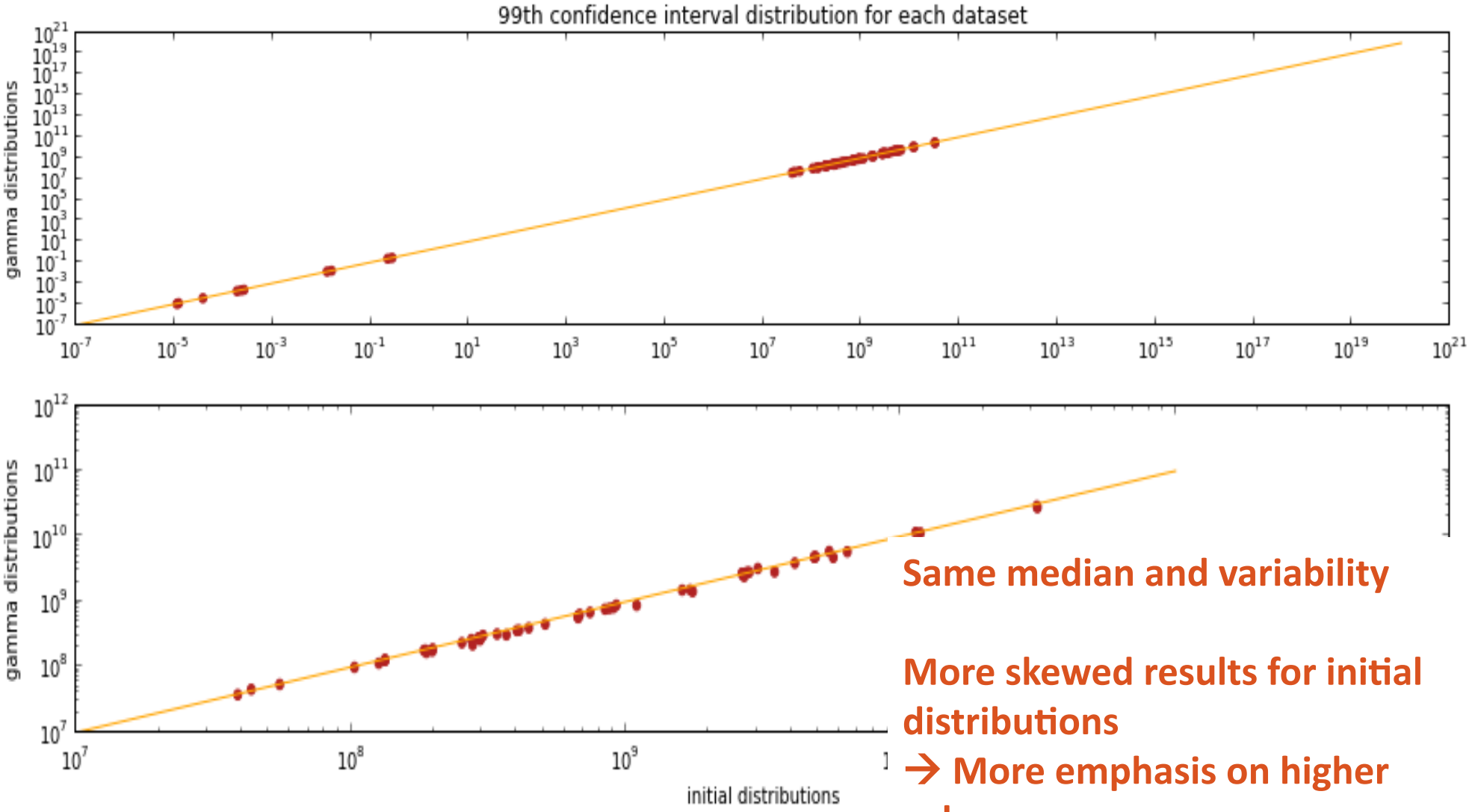
CIRAIG MC

SOME RESULTS

4. RESULTS – LOGNORMAL AGAINST TRIANGULAR



4. RESULTS – LOGNORMAL AGAINST GAMMA

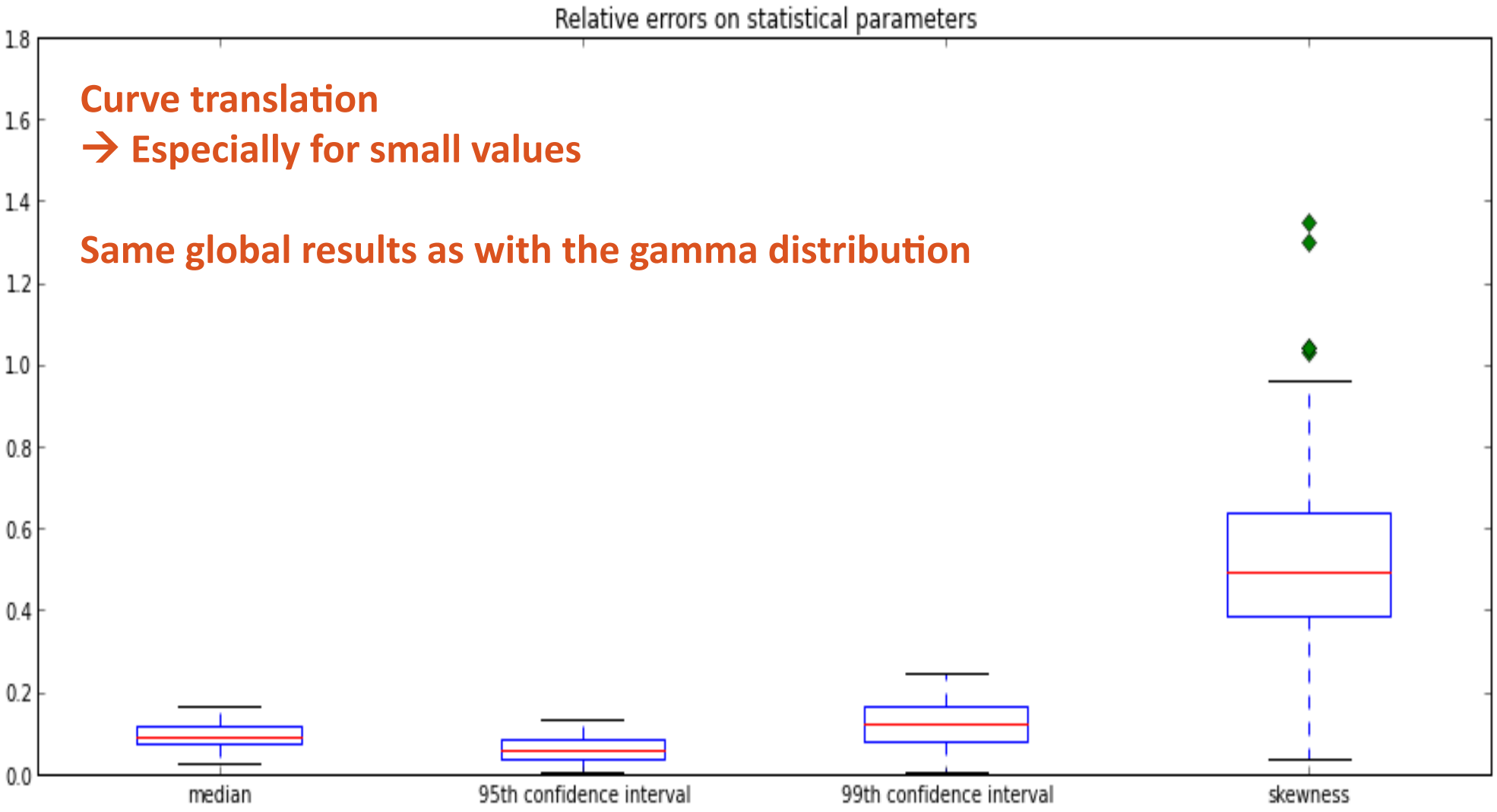


Same median and variability

More skewed results for initial distributions
→ More emphasis on higher values

CIRAIG

4. RESULTS – LOGNORMAL AGAINST WEIBULL



Curve translation
→ Especially for small values

Same global results as with the gamma distribution

CIRAIG

5. SOME THOUGHTS

A sensitivity assessment around the use of “by default distributions”

Showing the global behaviour

→ Globally, same conclusions for all datasets

Resulting distributions are not the same

→ Depend on the characteristics of the initial used distributions

Distributions can easily be switched

More flexibility for the analyst

→ Choosing the distribution based on the data characteristics

→ Parameters derivation based on some assumptions

→ Being consistent in the way to model uncertainties

CIRAIG[MC]

REFERENCES

Canter, K., D. Kennedy, et al. (2002). "Screening stochastic Life Cycle assessment inventory models." The International Journal of Life Cycle Assessment **7**(1): 18-26.

Frischknecht, R., N. Jungbluth, et al. (2005). "The ecoinvent Database: Overview and Methodological Framework (7 pp)." The International Journal of Life Cycle Assessment **10**(1): 3-9.

Kennedy, D., D. Montgomery, et al. (1996). "Data quality: Stochastic environmental life cycle assessment modeling." The International Journal of Life Cycle Assessment **1**(4): 199-207.

Koffler, C. and D. Kalish (2012). Quick-but-Clean? A Screening Tool using BERT Estimates to Incorporate Uncertainty. LCA XII, Tacoma (WA).

Limpert, E., W. A. Stahel, et al. (2001). "Log-normal Distributions across the Science: Keys and Clues." BioScience **51**(5): 341-351.

Wang, E., Z. Shen, et al. (2012). "An AHP-weighted aggregated data quality indicator (AWADQI) approach for estimating embodied energy of building materials." The International Journal of Life Cycle Assessment: 1-10.

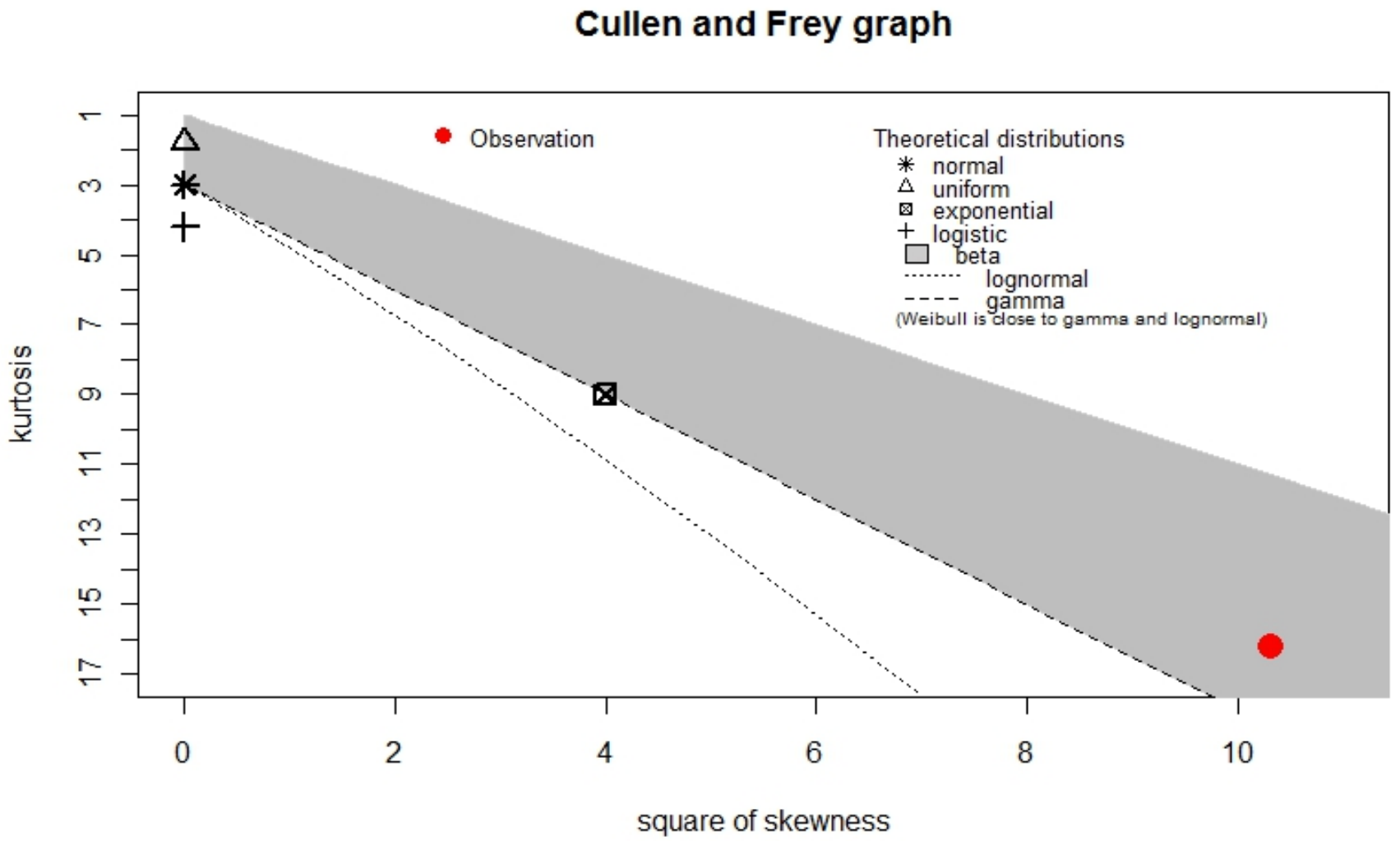
CIRAIG[MC]

COMMITTED PARTNERS

THANKS FOR YOUR ATTENTION

stephanie.muller@polymtl.ca

CIRAIG[MC]


Cullen and Frey graph
Observation
Theoretical distributions
normal
uniform
exponential
logistic
beta
lognormal
gamma
(Weibull is close to gamma and lognormal)
kurtosis
1
3
5
7
9
11
13
15
17
0
2
4
6
8
10
square of skewness

CIRAIG MC

DATASETS SELECTION

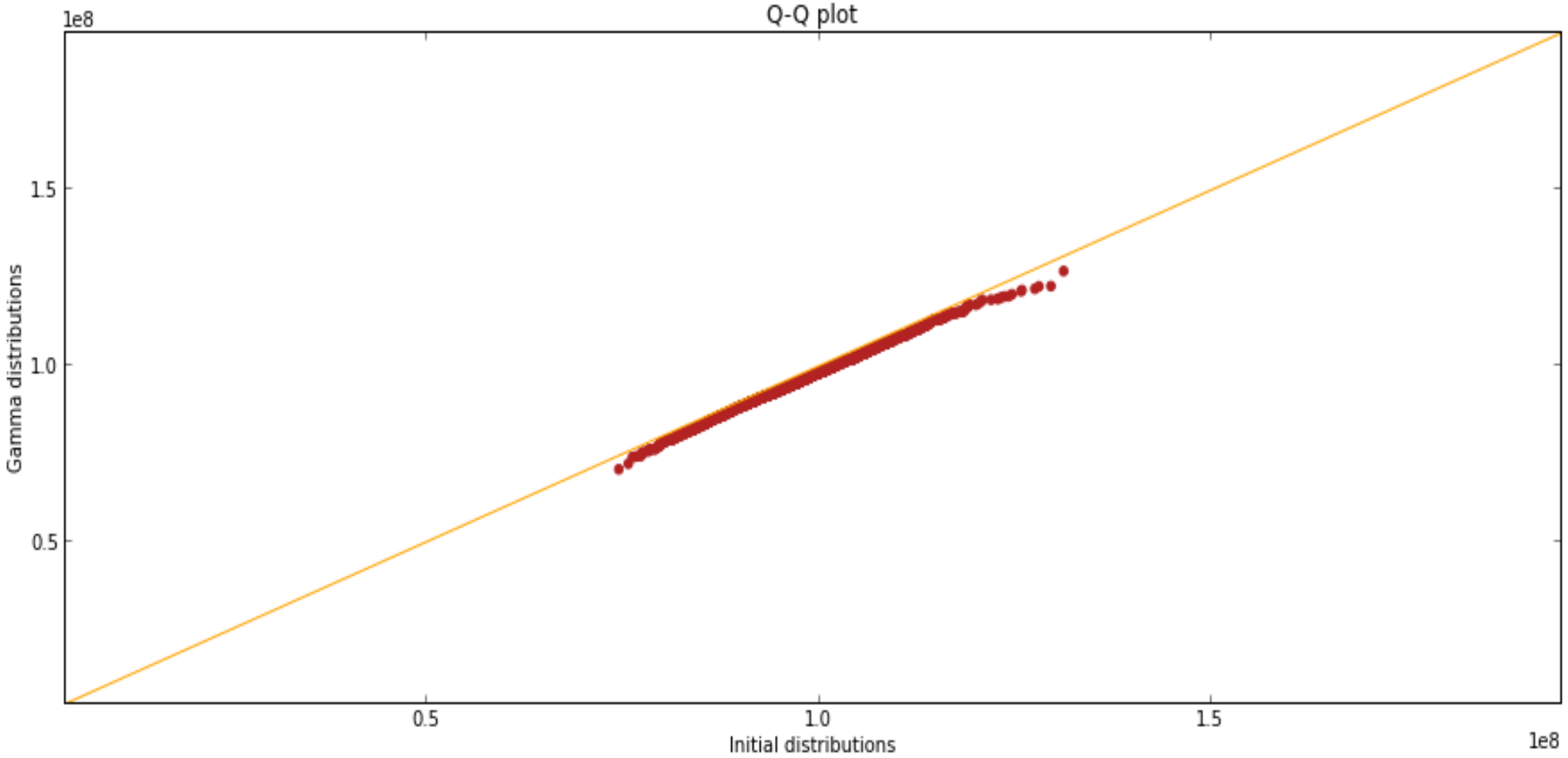
100 were kept

→ their differences was assessed through a correlation analysis for 12 LCIA methods

→ The “most” different were kept

CIRAIG

EXAMPLE


Q-Q plot
1e8
1.5
1.0
0.5
Gamma distributions
0.5
1.0
1.5
1e8
Initial distributions