TMF Workshop: Anonymization tools and their practical relevance (for biomedical research)

ARX

A Comprehensive Tool for Anonymizing Biomedical Data

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ARX: Towards useful data anonymization

- **Usability has many dimensions**
  - Ability to balance data utility with privacy requirements
- **Need to support a broad spectrum of methods**
  - Privacy models
  - Transformation models
  - Methods for analyzing data utility
  - Methods for analyzing risks
- **Further “non-functional” requirements**
  - Integrated and harmonized: ARX is not a “tool box”
  - Compatibility (syntactic and semantic)
  - Performance and scalability
  - Intuitive visualization and parameterization
  - Provide methods to end-users as well as programmers

ARX: Highlights

- **Compatibility**
  - **Built-in data import facilities**
    - Relational databases (MS SQL, DB2, SQLite, MySQL)
    - MS Excel
    - CSV (all common formats, auto-detection)
  - **Support for different data types and scales of measure**
    - Strings (with nominal and ordinal scale)
    - Dates (interval scale)
    - Numbers (ratio scale)
    - Automatic detection of data types and formats
  - **Methods for handling and cleaning low-quality data**
    - Handles missing and invalid values correctly
    - In privacy models, transformation methods, visualizations
    - Manual removal of tuples, query interface, find & replace

ARX: Highlights

- **Flexible transformation methods**
  - **Global recoding**
    - Full-domain generalization
    - Top- & bottom coding
  - **Local recoding**
    - Tuple suppression
  - **Fully integrated and parameterizable**
    - Importance of attributes, suitability of methods
- **Functional representations of transformation rules**
  - Especially functional representations of hierarchies
  - Support for categorical and continuous variables (categorization)
- **Multiple methods for measuring data utility**
  - Parametrizable, e.g., with different aggregate functions
  - Use functional representations of transformation rules

ARX: Highlights

- **Multiple apriori privacy models**
  - k-Anonymity
  - ℓ-Diversity (distinct, entropy, recursive-(c, ℓ))
  - t-Closeness (equal and hierarchical ground distance)
  - δ-Presence
- **Multiple methods for risk-based anonymization**
  - Sample characteristics
    - Average cell size
    - Sample uniqueness
  - Super-population models
    - Decision rule by Dankar et al.
    - Based on models by Pitman, Zayatz and the SNB model
- **Support for arbitrary combinations of these models**
  - Optimal solution within our coding model

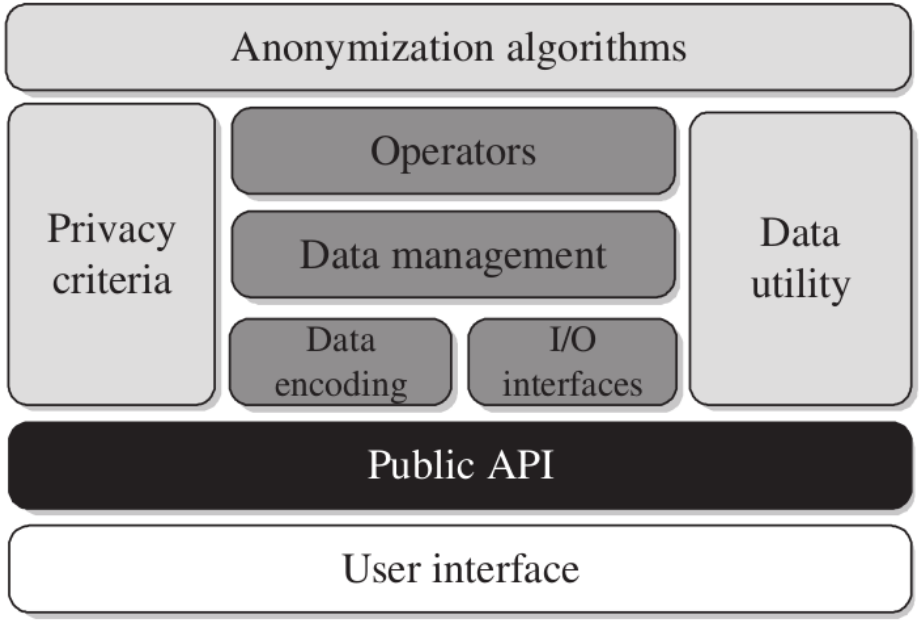
ARX: Highlights

- **Scalability:** ARX can handle large datasets (several million data entries) on commodity hardware
- **Efficient in-memory data management engine**
  - Works with compressed data representations
  - Tight coupling between transformation operators and the „database kernel”
  - Provides a space-time trade-off
- **Optimized search strategy:** Based on multiple pruning strategies
- **Efficient implementations of further complex tasks**
  - Evaluations of privacy criteria (e.g. t-closeness, δ-presence)
  - Methods for solving non-linear equation systems
  - Background jobs in the user interface

ARX: Highlights

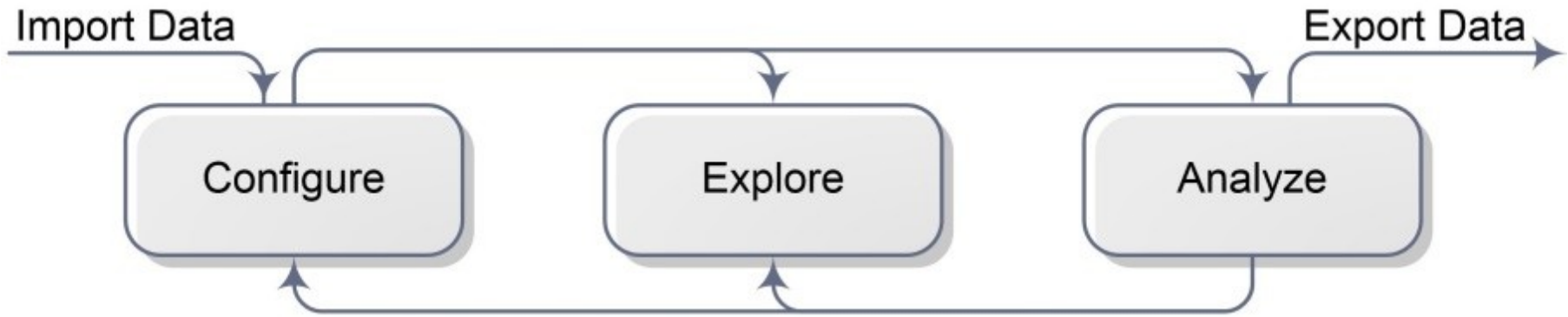
- **Comprehensive graphical interface**
  - Scalablity comparable to the ARX API
  - Supports all methods provided by the ARX API
  - Cross-platform (Windows, Linux/GTK, OSX) with native interfaces
  - Available as binary distributions with installers

- **Independent API**
  - User interface sits on top of the API
  - Java library
  - All methods provided by ARX are first-class citizens in both worlds



ARX: Anonymization workflow

- Iterative process to successively refine transformations
- Supported by the scalability of our framework
- Three (repeating) steps, mapped to four perspectives

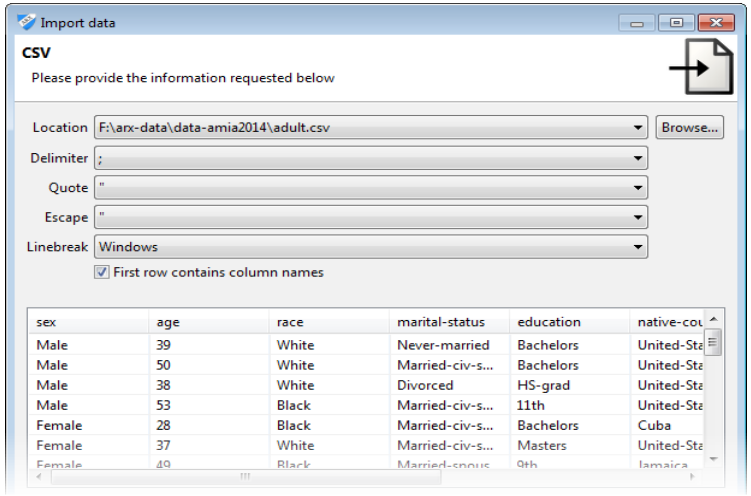


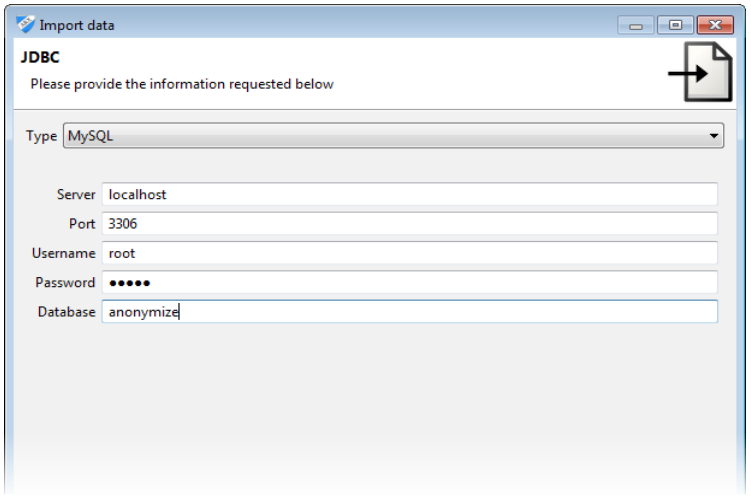
- Define transformation model
- Define privacy model
- Define coding model

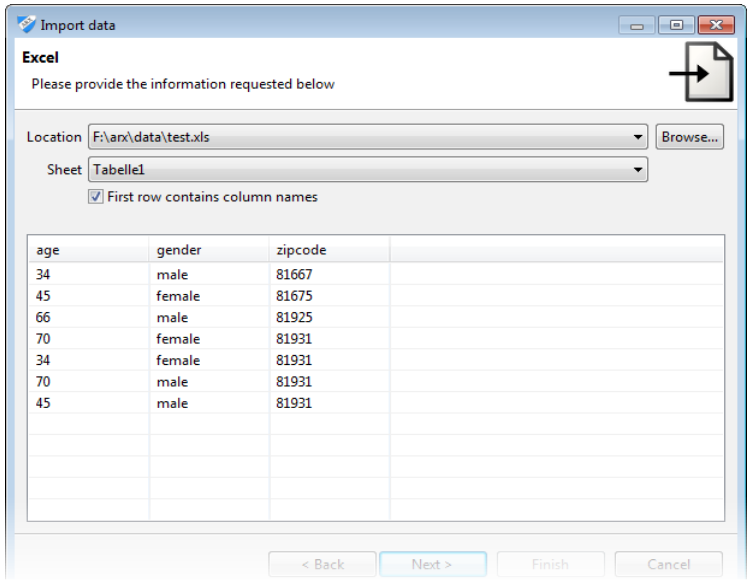
- Filter and analyze the solution space
- Organize transformations

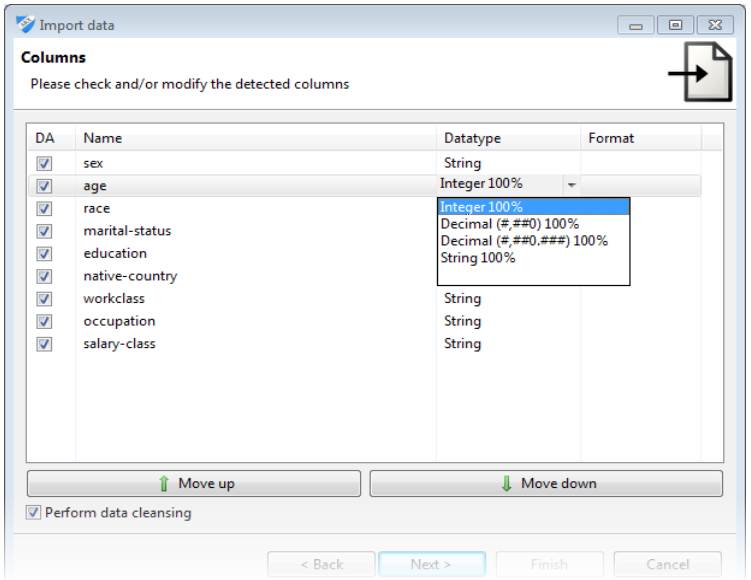
- Compare and analyze input and output
- Regarding risks and utility

ARX: Wizard for data import

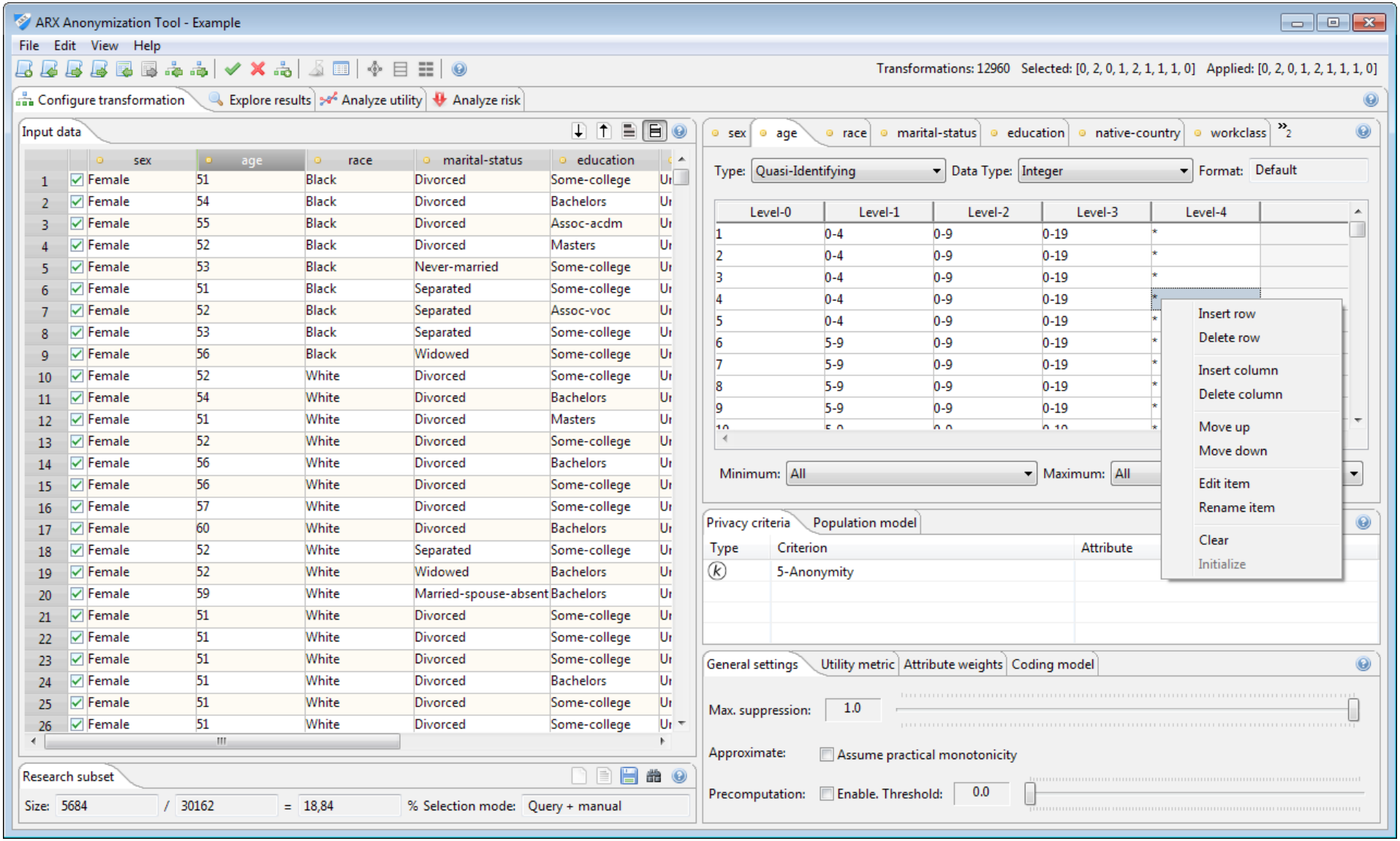




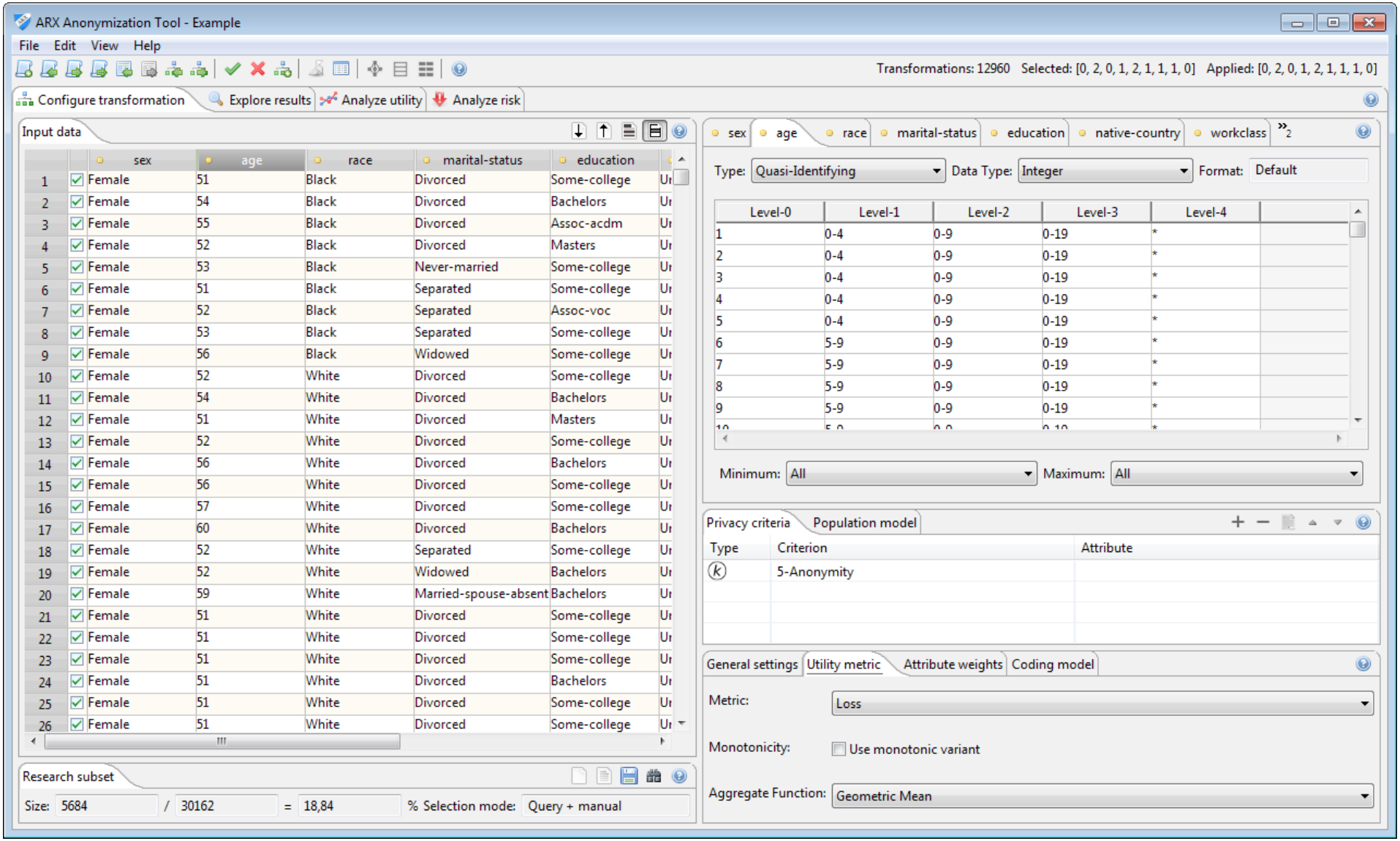




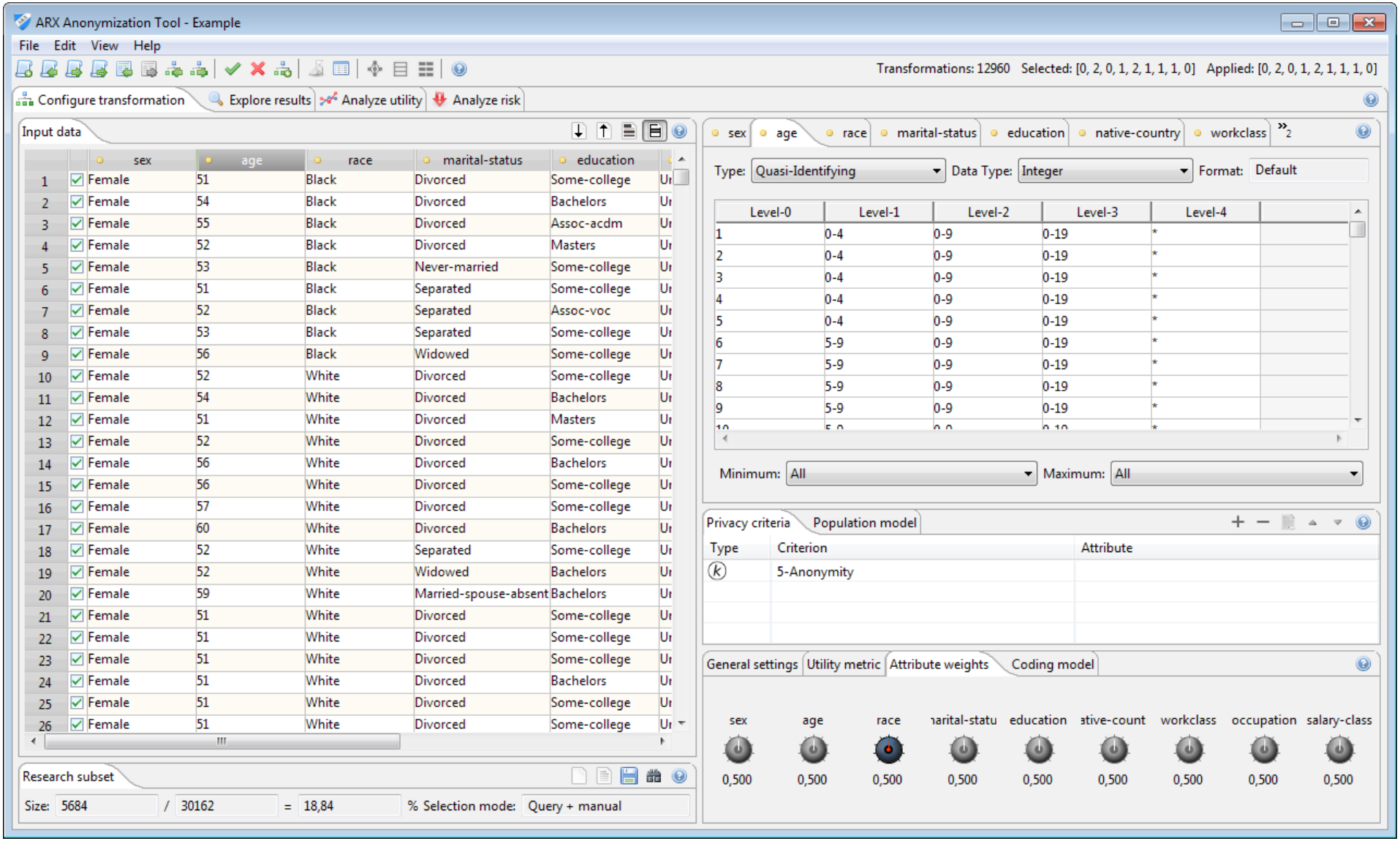
ARX: Configuration (1)



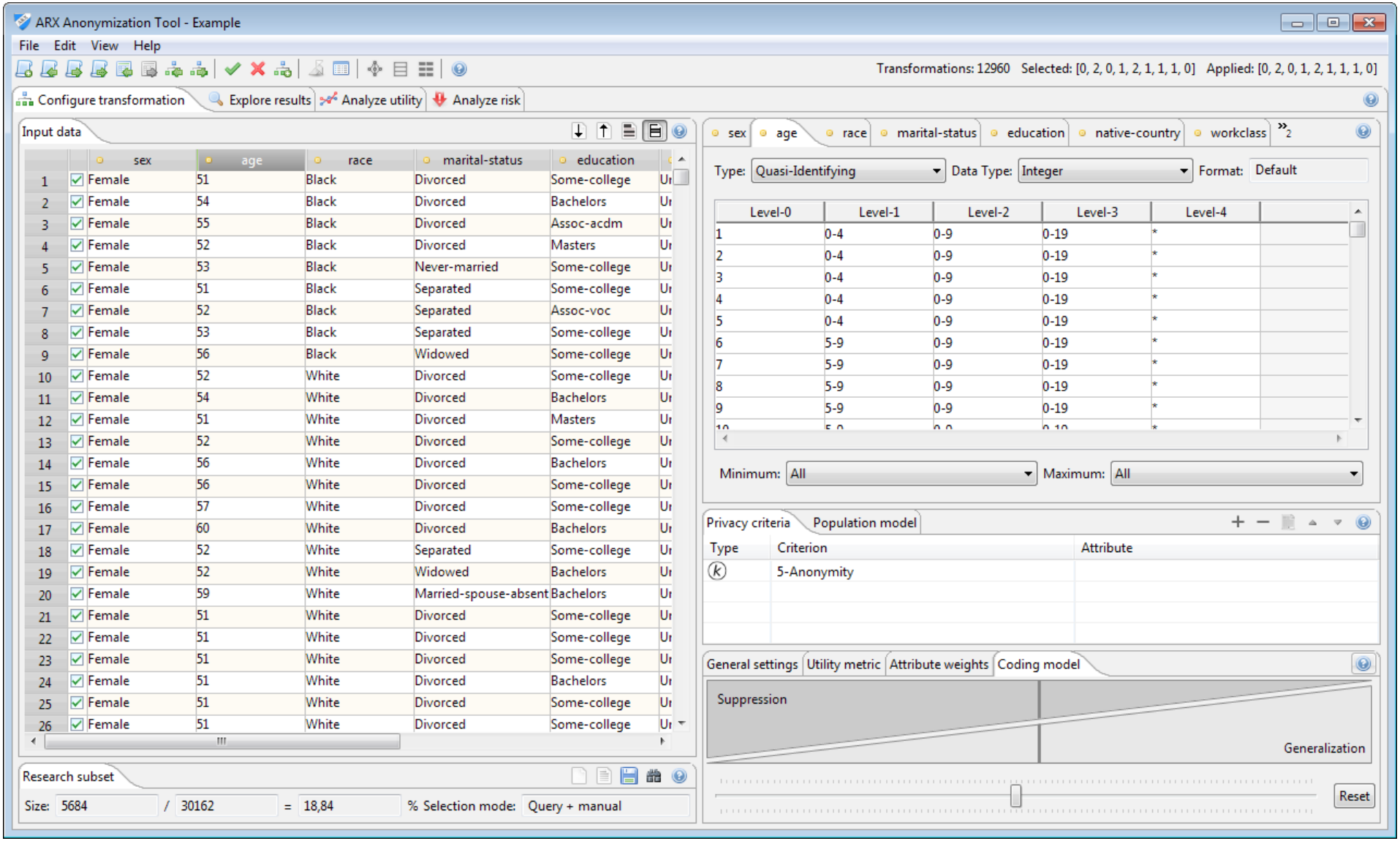
ARX: Configuration (2)



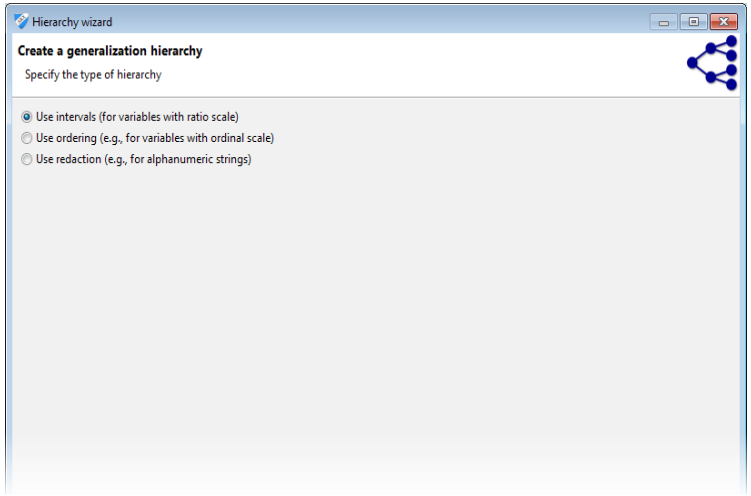
ARX: Configuration (3)

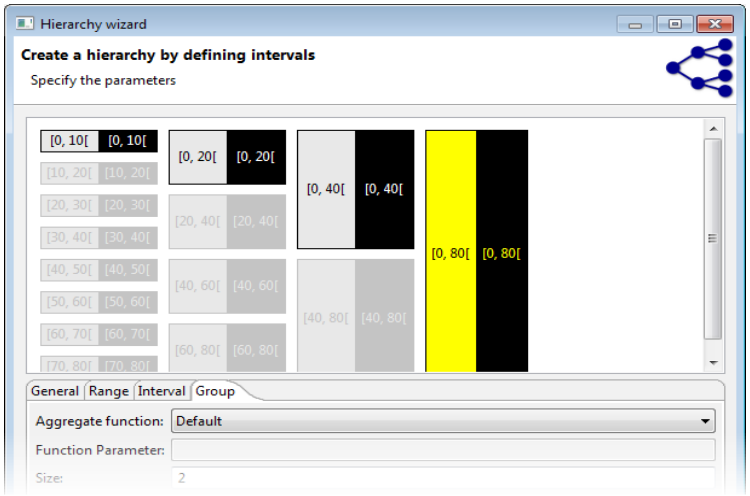


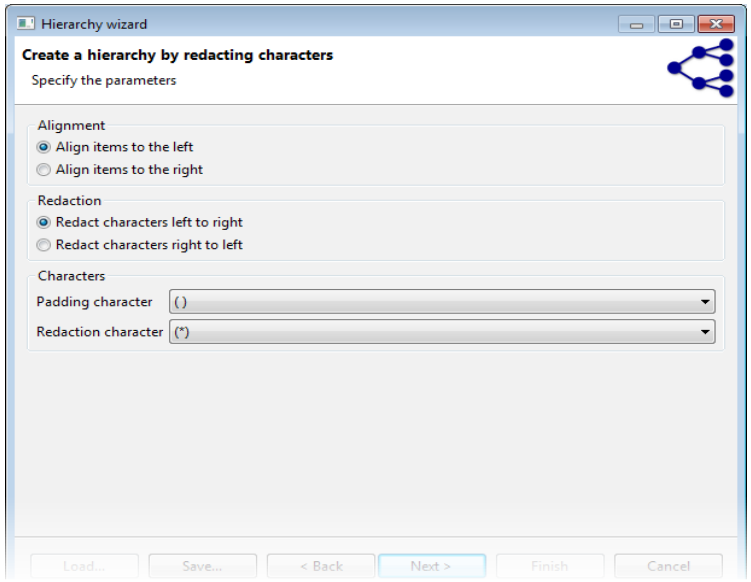
ARX: Configuration (4)

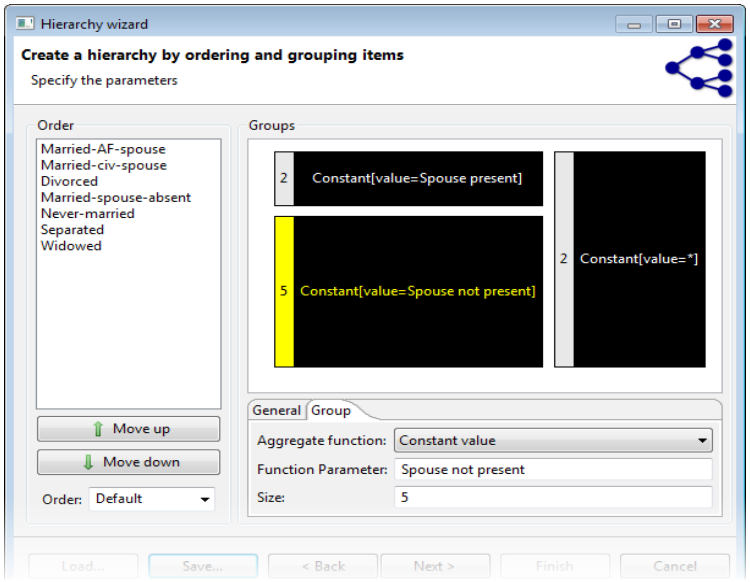


ARX: Wizard for transformation rules

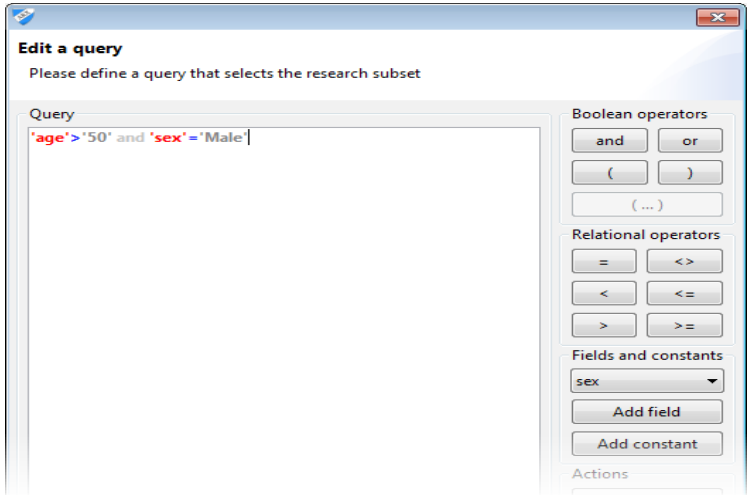


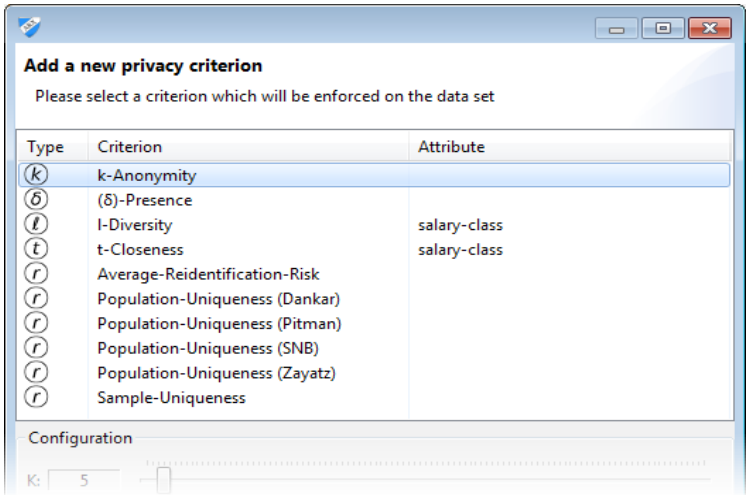




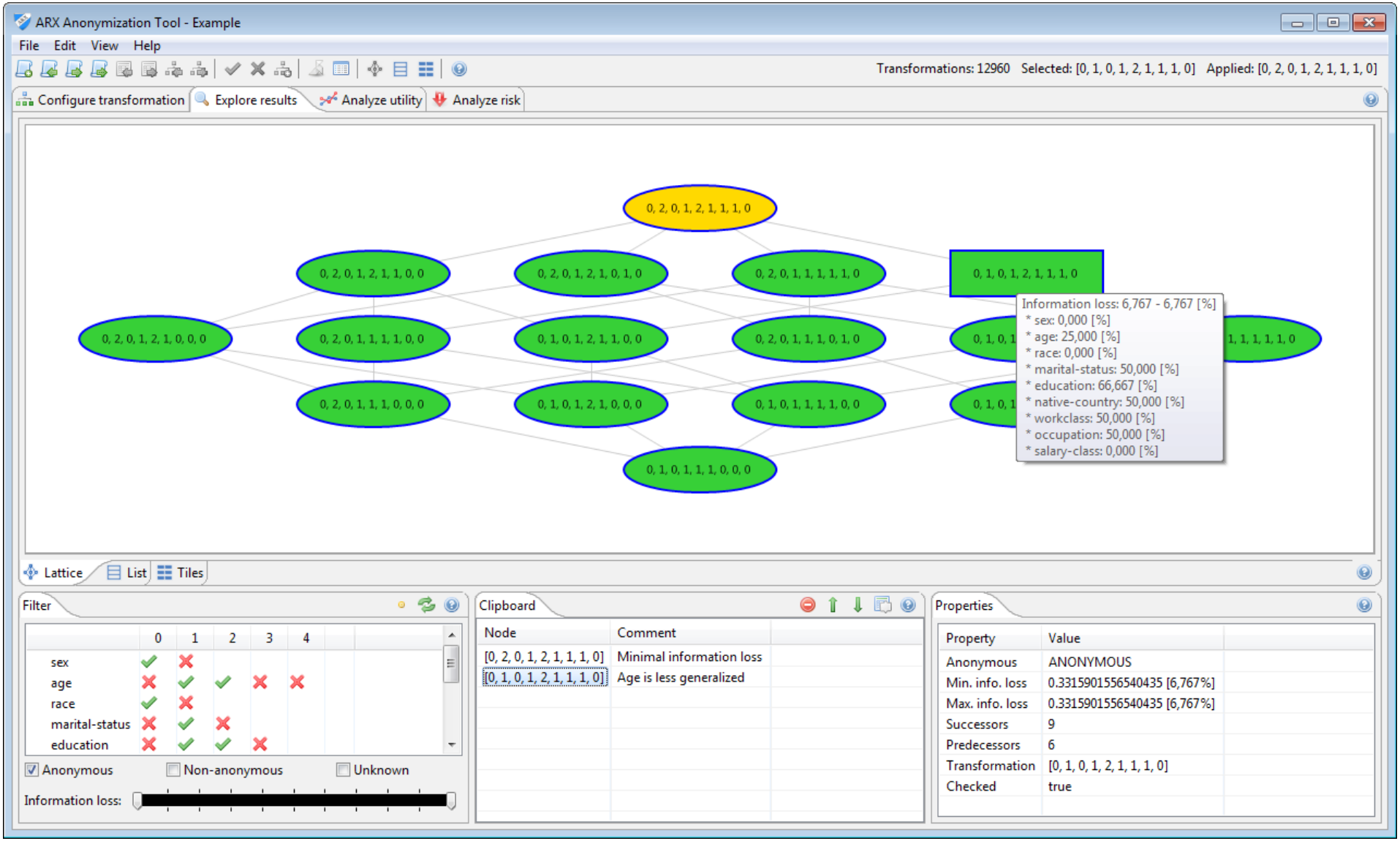


ARX: Further dialogs

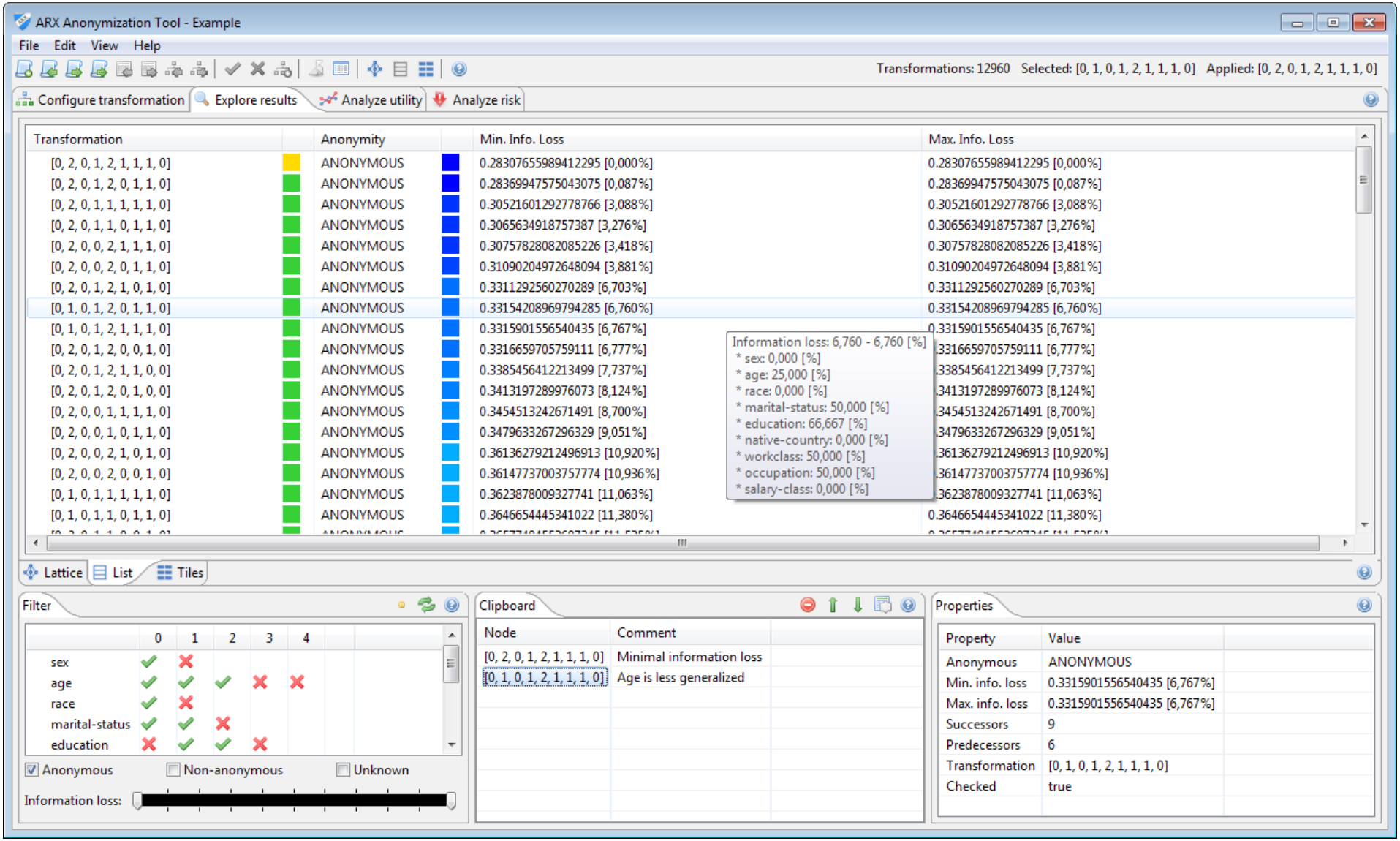




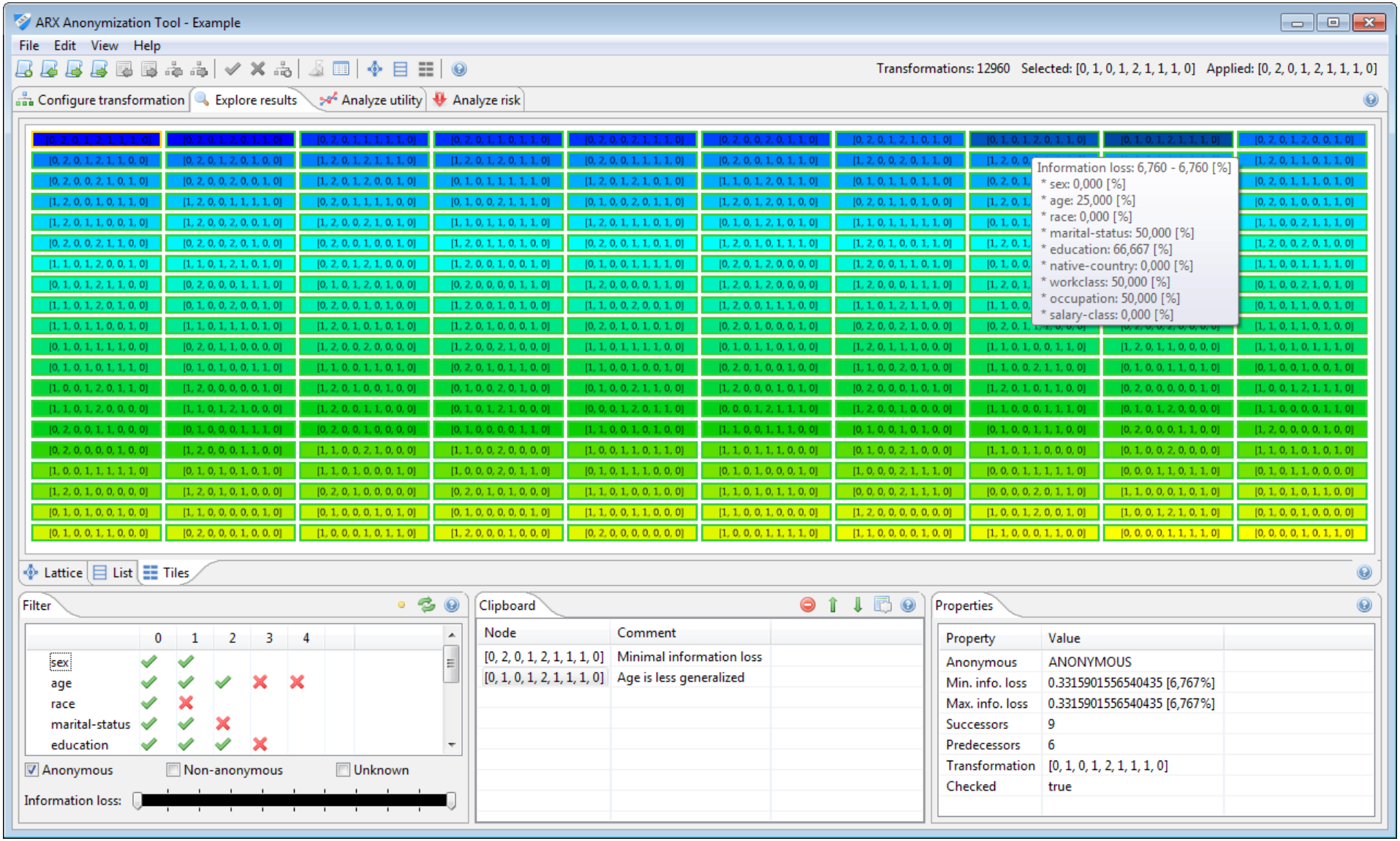
ARX: Exploration (1)



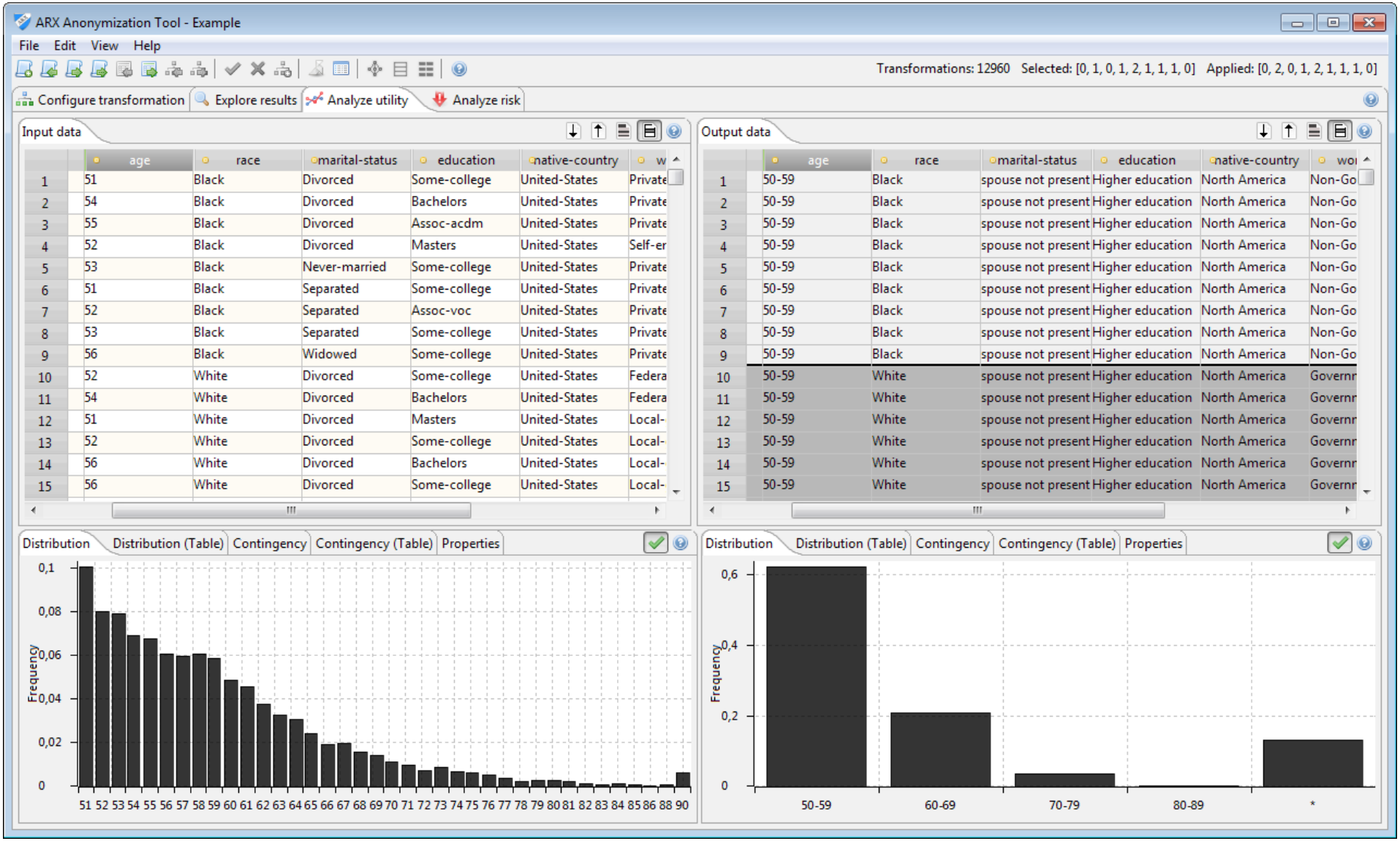
ARX: Exploration (2)



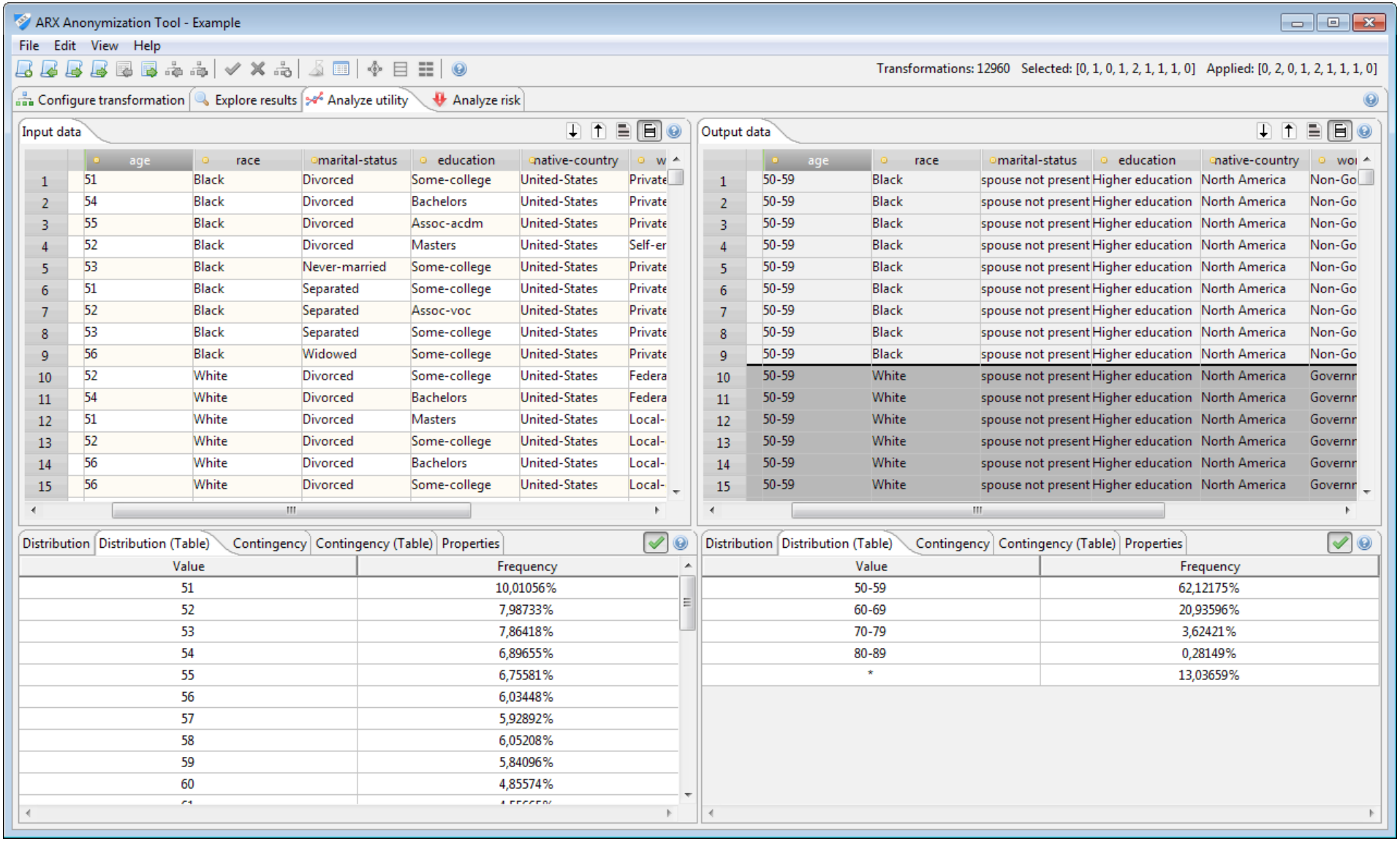
ARX: Exploration (3)



ARX: Utility analysis (1)



ARX: Utility analysis (2)



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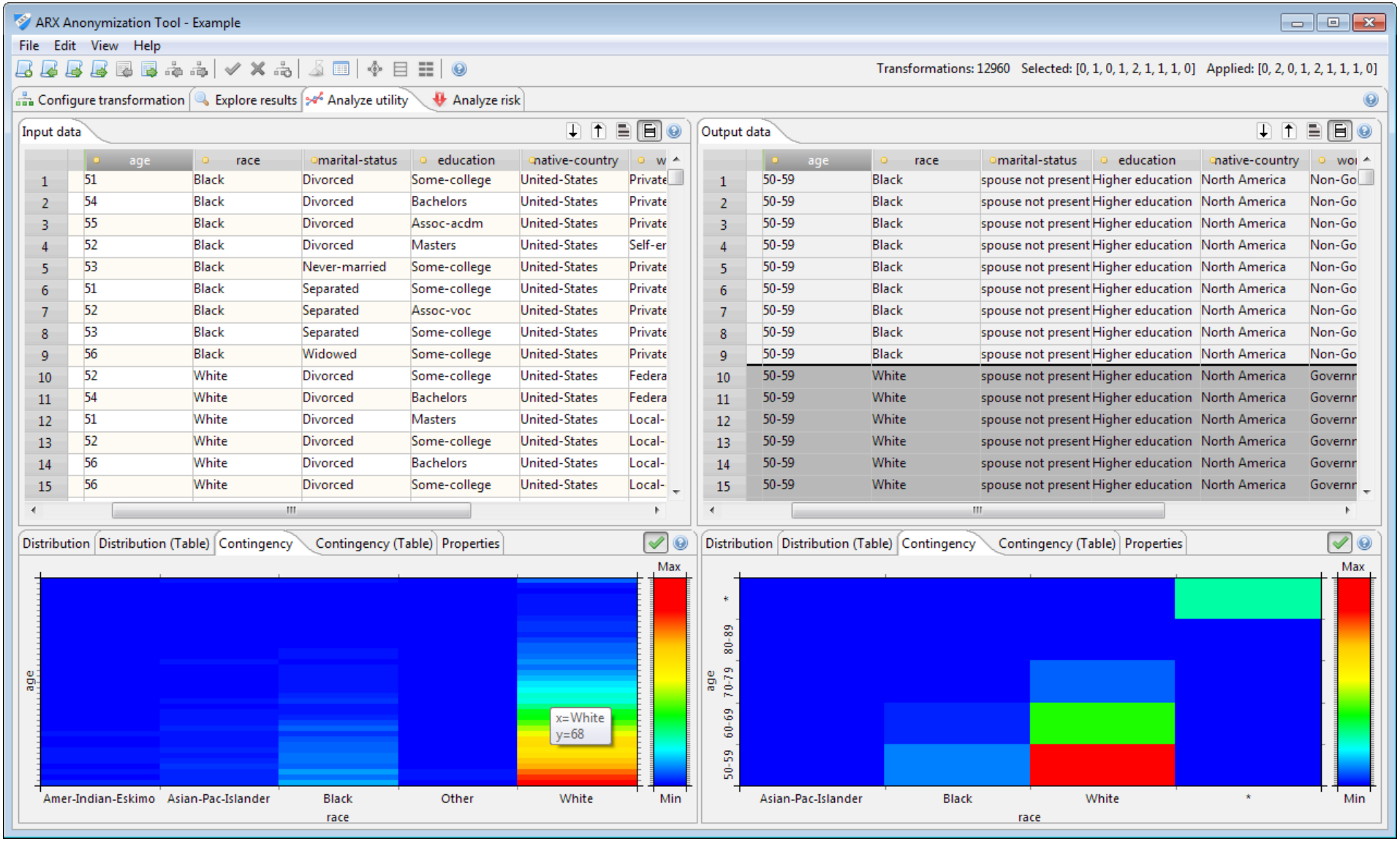
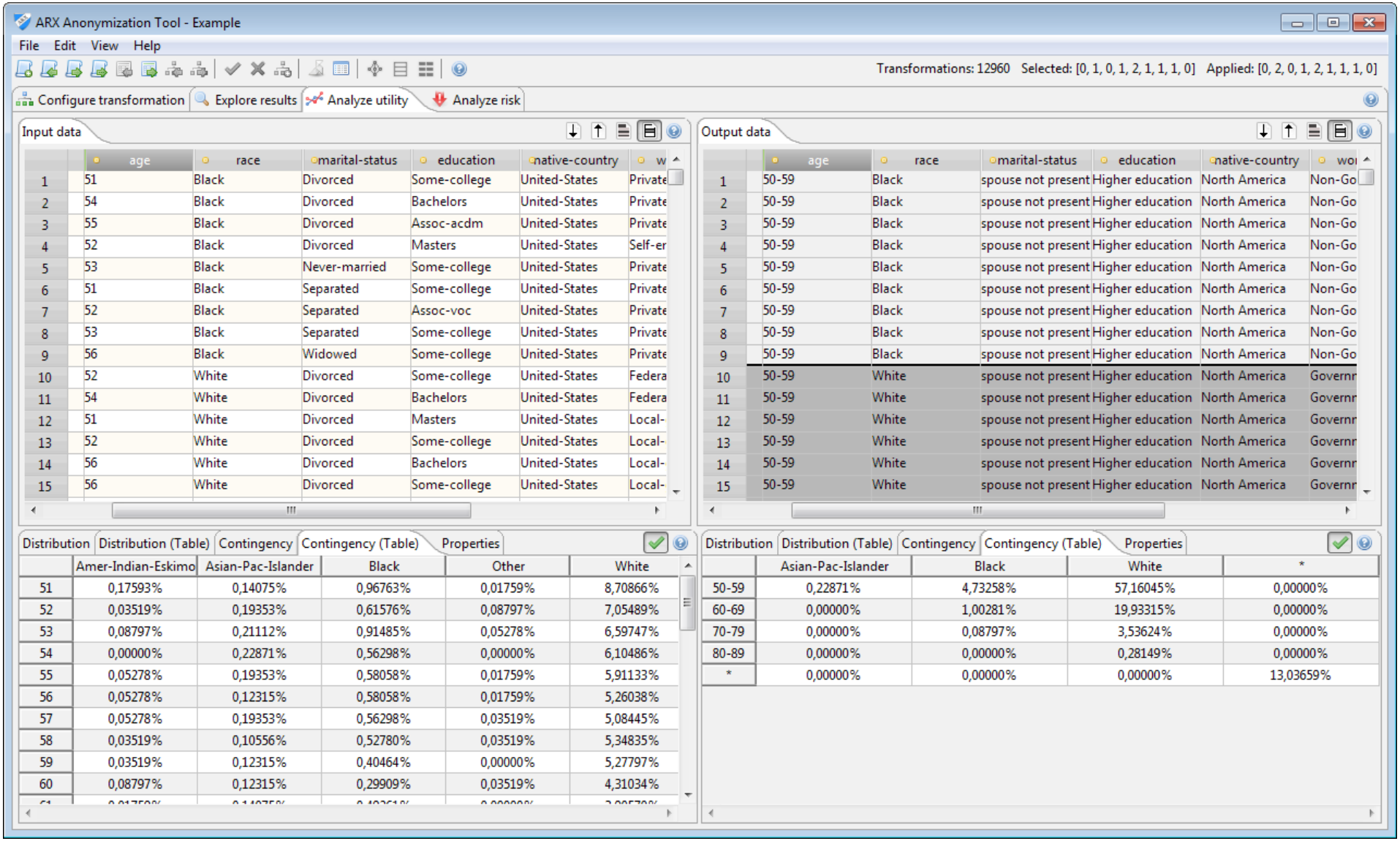


ARX: Utility analysis (4)



Input data

	age	race	marital-status	education	native-country	w
1	51	Black	Divorced	Some-college	United-States	Private
2	54	Black	Divorced	Bachelors	United-States	Private
3	55	Black	Divorced	Assoc-acdm	United-States	Private
4	52	Black	Divorced	Masters	United-States	Self-er
5	53	Black	Never-married	Some-college	United-States	Private
6	51	Black	Separated	Some-college	United-States	Private
7	52	Black	Separated	Assoc-voc	United-States	Private
8	53	Black	Separated	Some-college	United-States	Private
9	56	Black	Widowed	Some-college	United-States	Private
10	52	White	Divorced	Some-college	United-States	Federa
11	54	White	Divorced	Bachelors	United-States	Federa
12	51	White	Divorced	Masters	United-States	Local-
13	52	White	Divorced	Some-college	United-States	Local-
14	56	White	Divorced	Bachelors	United-States	Local-
15	56	White	Divorced	Some-college	United-States	Local-

Output data

	age	race	marital-status	education	native-country	wo
1	50-59	Black	spouse not present	Higher education	North America	Non-Go
2	50-59	Black	spouse not present	Higher education	North America	Non-Go
3	50-59	Black	spouse not present	Higher education	North America	Non-Go
4	50-59	Black	spouse not present	Higher education	North America	Non-Go
5	50-59	Black	spouse not present	Higher education	North America	Non-Go
6	50-59	Black	spouse not present	Higher education	North America	Non-Go
7	50-59	Black	spouse not present	Higher education	North America	Non-Go
8	50-59	Black	spouse not present	Higher education	North America	Non-Go
9	50-59	Black	spouse not present	Higher education	North America	Non-Go
10	50-59	White	spouse not present	Higher education	North America	Governr
11	50-59	White	spouse not present	Higher education	North America	Governr
12	50-59	White	spouse not present	Higher education	North America	Governr
13	50-59	White	spouse not present	Higher education	North America	Governr
14	50-59	White	spouse not present	Higher education	North America	Governr
15	50-59	White	spouse not present	Higher education	North America	Governr

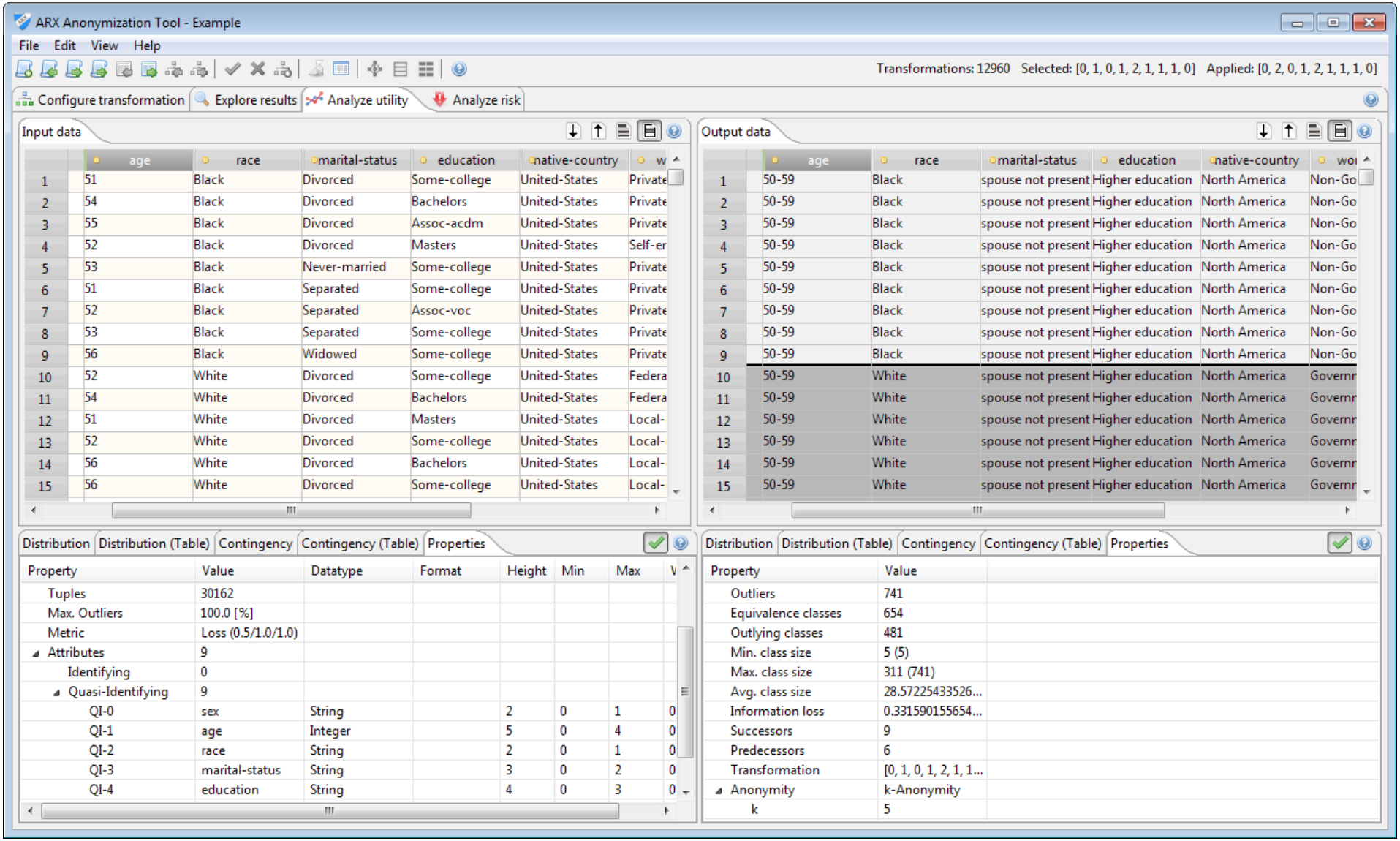
Distribution | Distribution (Table) | Contingency | Contingency (Table) | Properties

	Amer-Indian-Eskimo	Asian-Pac-Islander	Black	Other	White
51	0,17593%	0,14075%	0,96763%	0,01759%	8,70866%
52	0,03519%	0,19353%	0,61576%	0,08797%	7,05489%
53	0,08797%	0,21112%	0,91485%	0,05278%	6,59747%
54	0,00000%	0,22871%	0,56298%	0,00000%	6,10486%
55	0,05278%	0,19353%	0,58058%	0,01759%	5,91133%
56	0,05278%	0,12315%	0,58058%	0,01759%	5,26038%
57	0,05278%	0,19353%	0,56298%	0,03519%	5,08445%
58	0,03519%	0,10556%	0,52780%	0,03519%	5,34835%
59	0,03519%	0,12315%	0,40464%	0,00000%	5,27797%
60	0,08797%	0,12315%	0,29909%	0,03519%	4,31034%

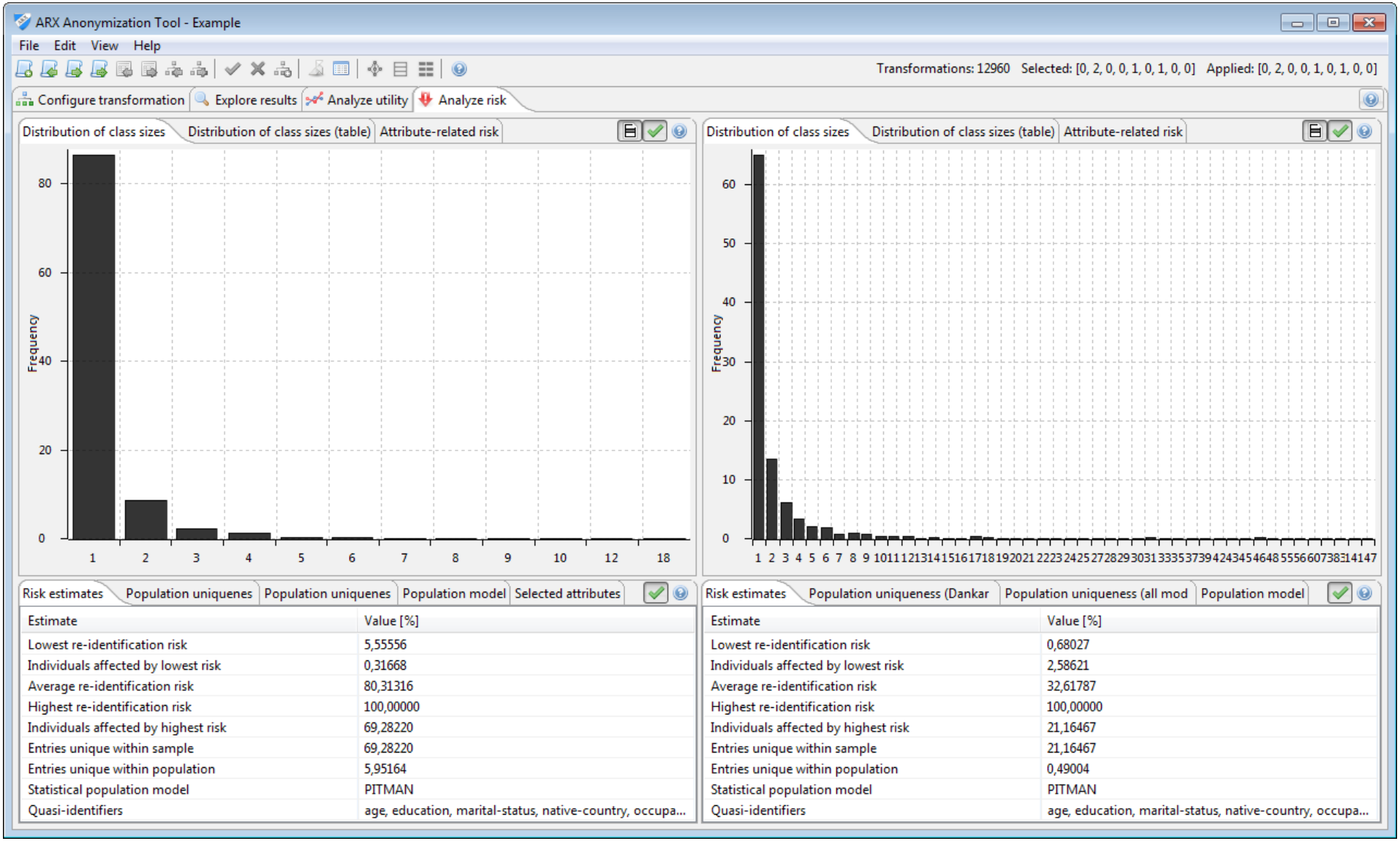
Distribution | Distribution (Table) | Contingency | Contingency (Table) | Properties

	Asian-Pac-Islander	Black	White	*
50-59	0,22871%	4,73258%	57,16045%	0,00000%
60-69	0,00000%	1,00281%	19,93315%	0,00000%
70-79	0,00000%	0,08797%	3,53624%	0,00000%
80-89	0,00000%	0,00000%	0,28149%	0,00000%
*	0,00000%	0,00000%	0,00000%	13,03659%

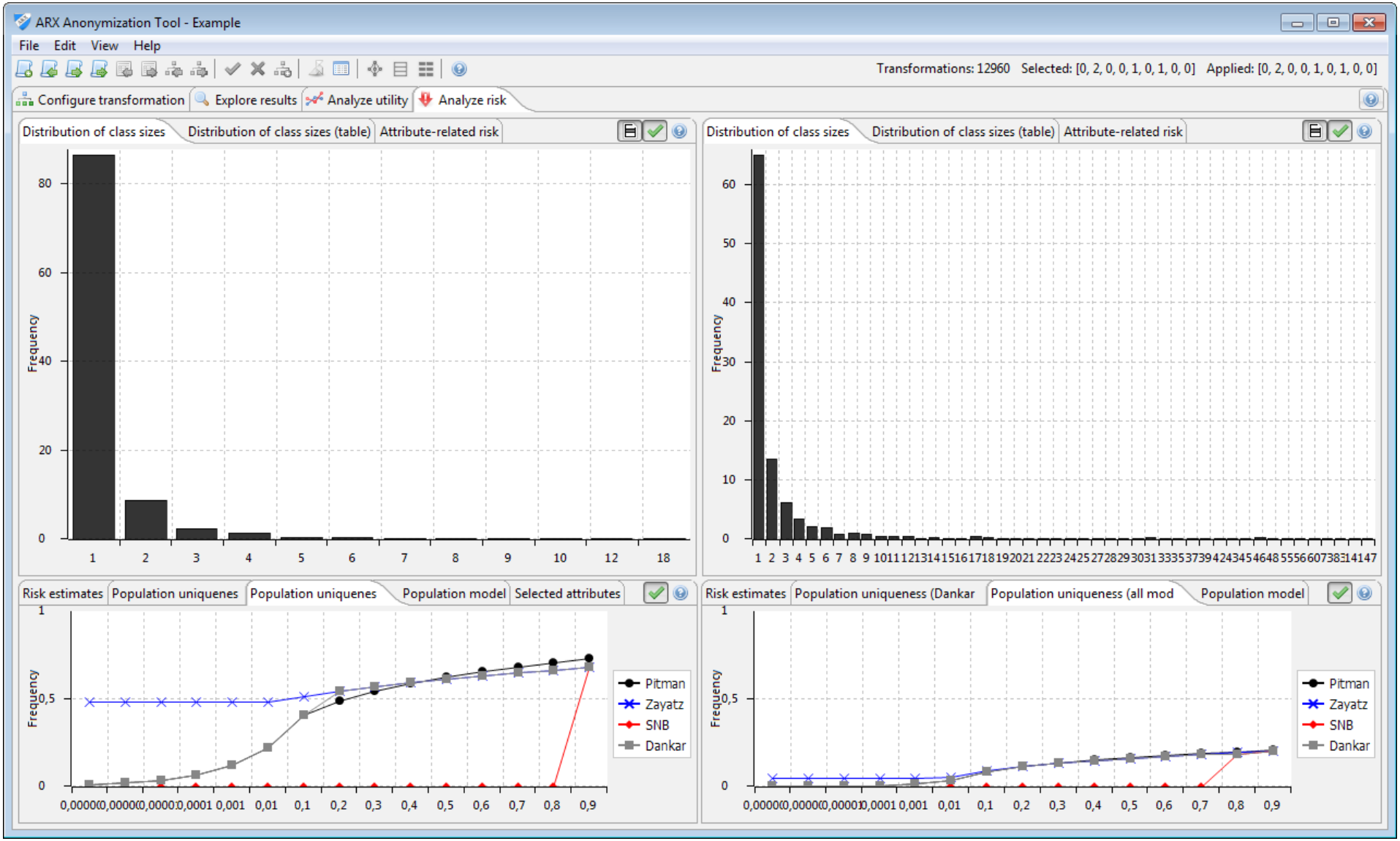
ARX: Utility analysis (5)



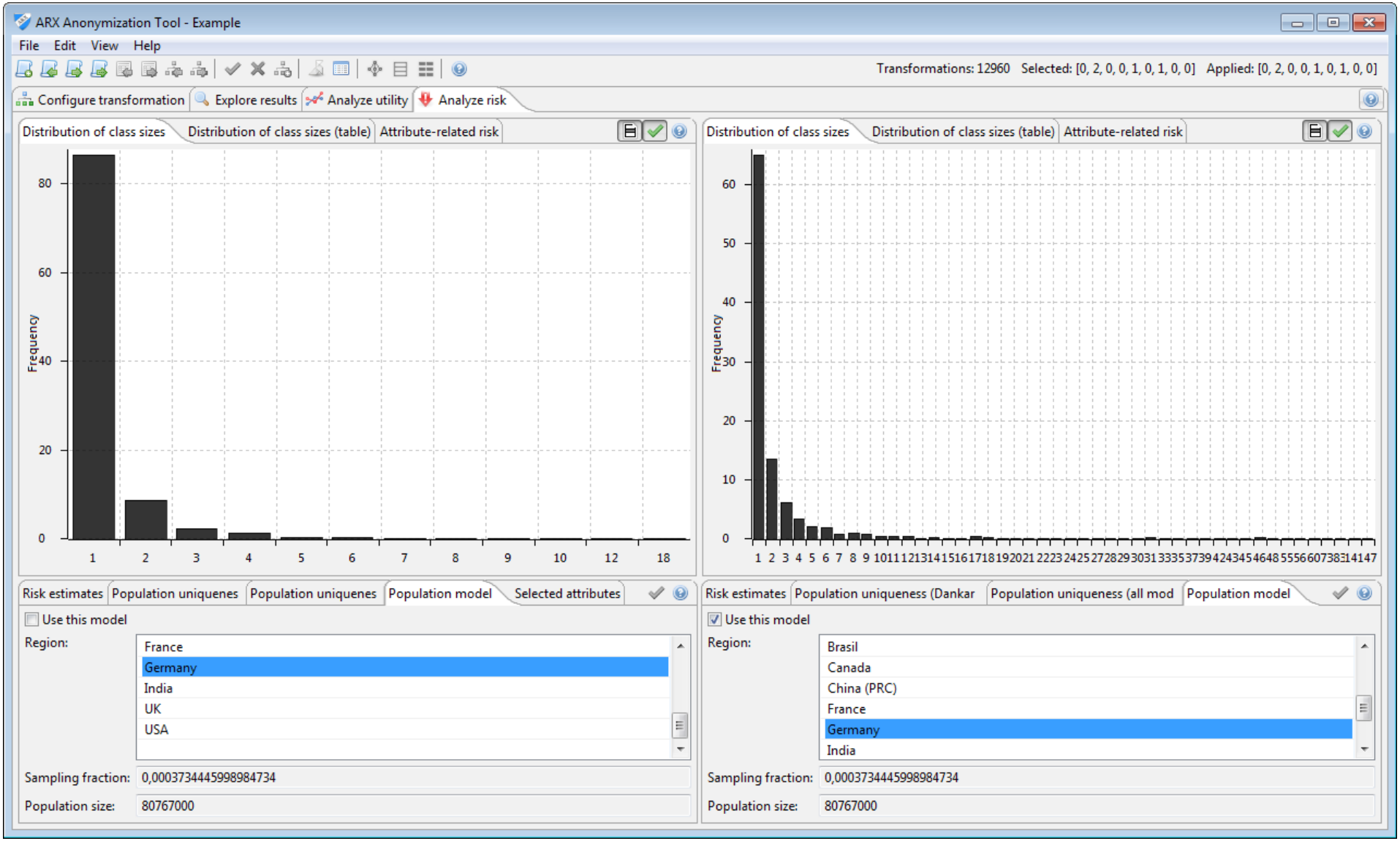
ARX: Risk analysis (1)



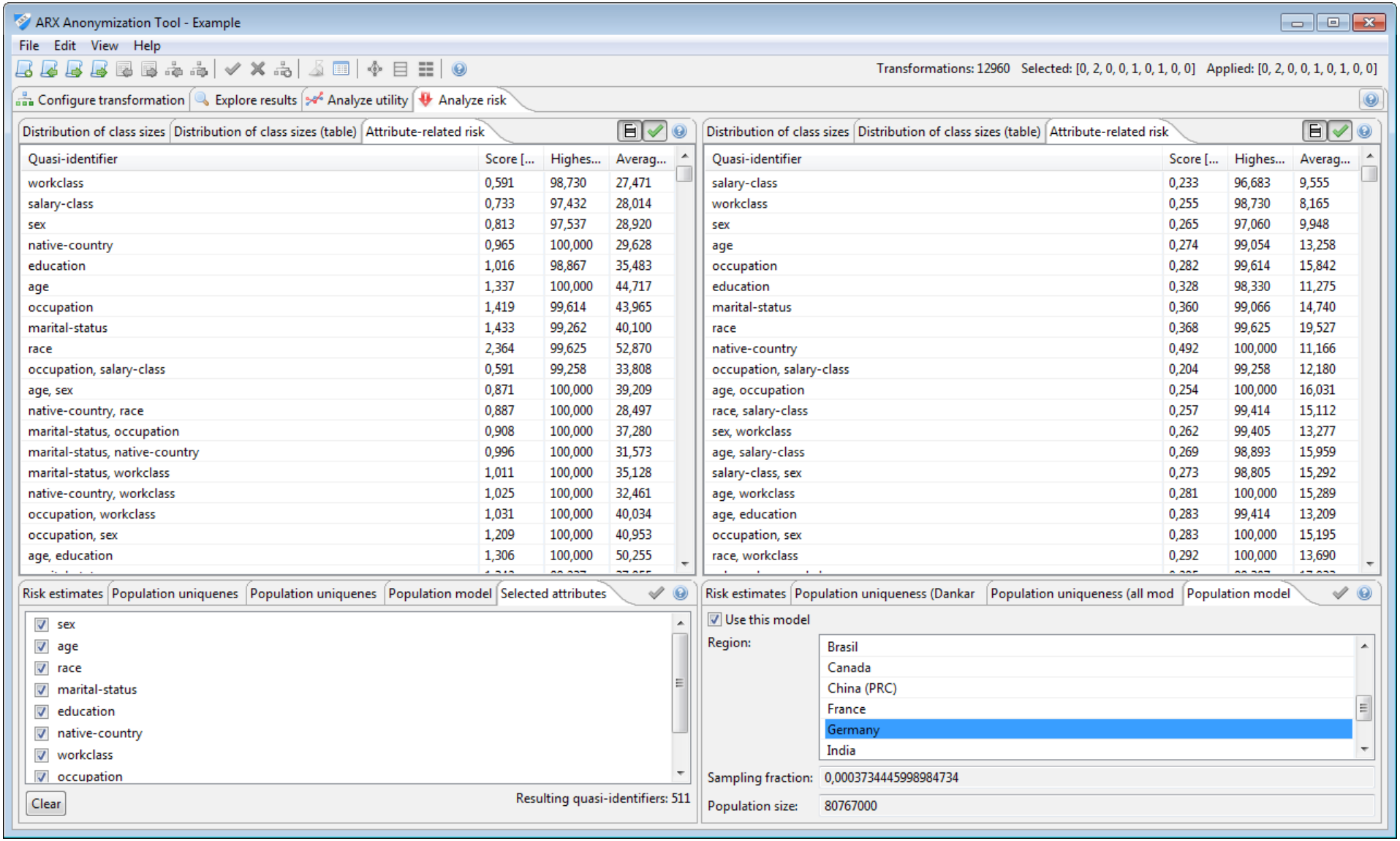
ARX: Risk analysis (2)



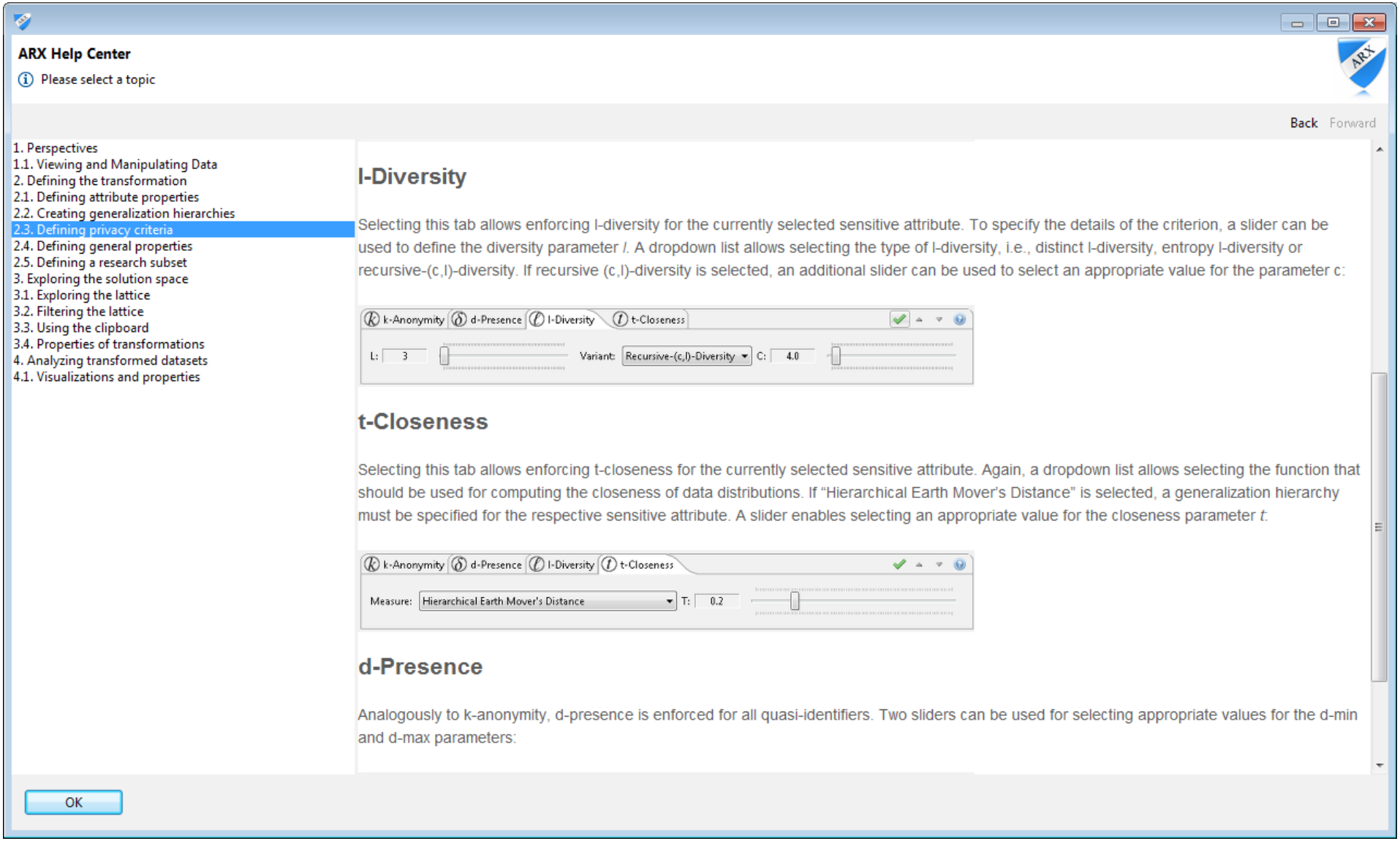
ARX: Risk analysis (3)



ARX: Risk analysis (4)



ARX: Context-sensitive help



ARX: Further developments

- **Current projects**
  - Non-interactive Differential Privacy
  - Support for high-dimensional data: heuristic algorithms
  - Further analyses and visualizations: utility and risks
  - Support for transactional attributes: (k, k^m)-anonymity
  - Integrated data masking methods
  - More flexible definition of quasi-identifiers
  - More risk models
- **Planned projects**
  - Auto-detection of HIPAA identifiers
  - Implement more flexible privacy criteria

Thank you for your attention

- **ARX is open source software**
- **Contribute:** feature requests, code reviews, criticism, enhancements, questions
- **Repository:** https://github.com/arx-deidentifier/arx

- **Further information & download:** http://arx.deidentifier.org

- **Get in touch**
  - Fabian Prasser (prasser@in.tum.de)
  - Florian Kohlmayer (florian.kohlmayer@tum.de)

- **Any questions?**