Beamm : online, open-access tax-benefit microsimulation modeling

Tom Truyts Hugues Annoye

CAPE - UCLouvain Saint-Louis - Bruxelles

October 23rd - Statistiek Vlaanderen

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CAPE ?

- Center for Applied Public Economics
  - At UCLouvain Saint-Louis Bruxelles
  - Youngest research center at USLB $\rightarrow$ founded 2019
  - 20-25 researchers $\rightarrow$ economics, statistics, mathematics...

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- Objectives CAPE
  - Principal objective : Beamm project
  - Secondary objective : scientific research + policy support $\rightarrow$ public finance + public policy evaluation

Team beamm

- Professors :
  - **Gilles Grandjean** : Professor of Public Economics
  - **Tom Truyts** : Professor of Public Economics
  - **Cedric Heuchenne** : Professor of Statistics and Quantitative Methods
  - **Koen Declercq** : Professor of quantitative economics, labor economics
  - **Hélène Latzer** : Professor of macro-econonomics, policy evaluation

- Post-doctoral researchers
  - **Francesco Pascucci :** statistics, Beamm.brussels
  - **Alexandre Jacquemain** : Inequality analysis, statistics
  - **(Elisabeth Leduc** : Labor and education, public policy evaluation)

- Doctoral students :
  - **Arnaud Dorsimont** : Macroeconomic effects of fiscal policy
  - **Hugues Annoye** : Machine learning, statistics
  - **Carlos Rodriguez Ameal :** Machine learning, statistics
  - **Jean Paul Madrigal Rodriguez** : Transport-beamm, transport economics
  - **Rory Green** : Beamm, labour market
  - **David J. Sonnewald** : Beamm.brussels - labor market modelling
  - **Audric De Bevere** : Consumption modelling, carbon taxes
  - **Astrid Adam** : Transport-beamm.brussels - transport economics
  - **Daniel Coppens d'Eeckenbrugge** : ETR, progressivity, redistribution
  - **(Tom Van Zeebroeck** : tax design and family dynamics)
  - **François Meuwissen** : Tax design, environmental economics
  - **Soufiane Amzur** : Social policy, poverty
  - **Léa Jacquet** : Tax design and family dynamics
  - **Mathilde Pourtois** : labor market, public policy evaluation
- + Research associates : Willem Sas, Malka Guillot

beamm

Today's menu

1. **Beamm : motivation and intro**
2. Presentation beamm : model
3. Next steps

Beamm.brussels : motivation

- "No taxation without representation"
- How to raise taxes, how to redistribute → cornerstones of role state & democracy

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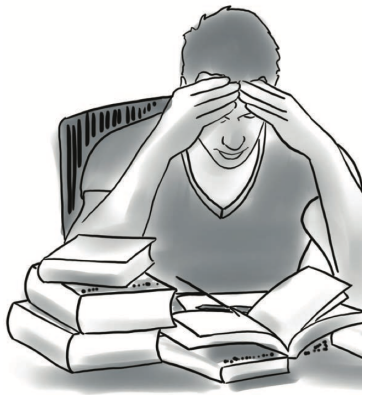
Beamm.brussels : motivation



- BUT : assessing taxes, benefits, public policies = difficult !

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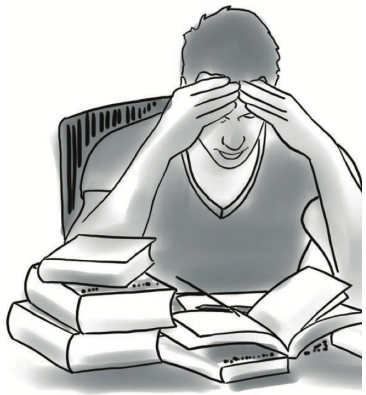

- BUT : assessing taxes, benefits, public policies = difficult !
- technicality, institutional complexity, lack of accessible data & analytical skills
  $\rightarrow$ difficult to assess impact, see full picture
  $\rightarrow$ for policy makers, civil society, citizens
  $\rightarrow$ weakens democratic debate, hinders efficient policy making

Beamm ?

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- *Beamm $\rightarrow$ 21th century technology for detailed & reliable impact assessments of public policy reforms, freely available to policy makers, civil society, citizens, media...*

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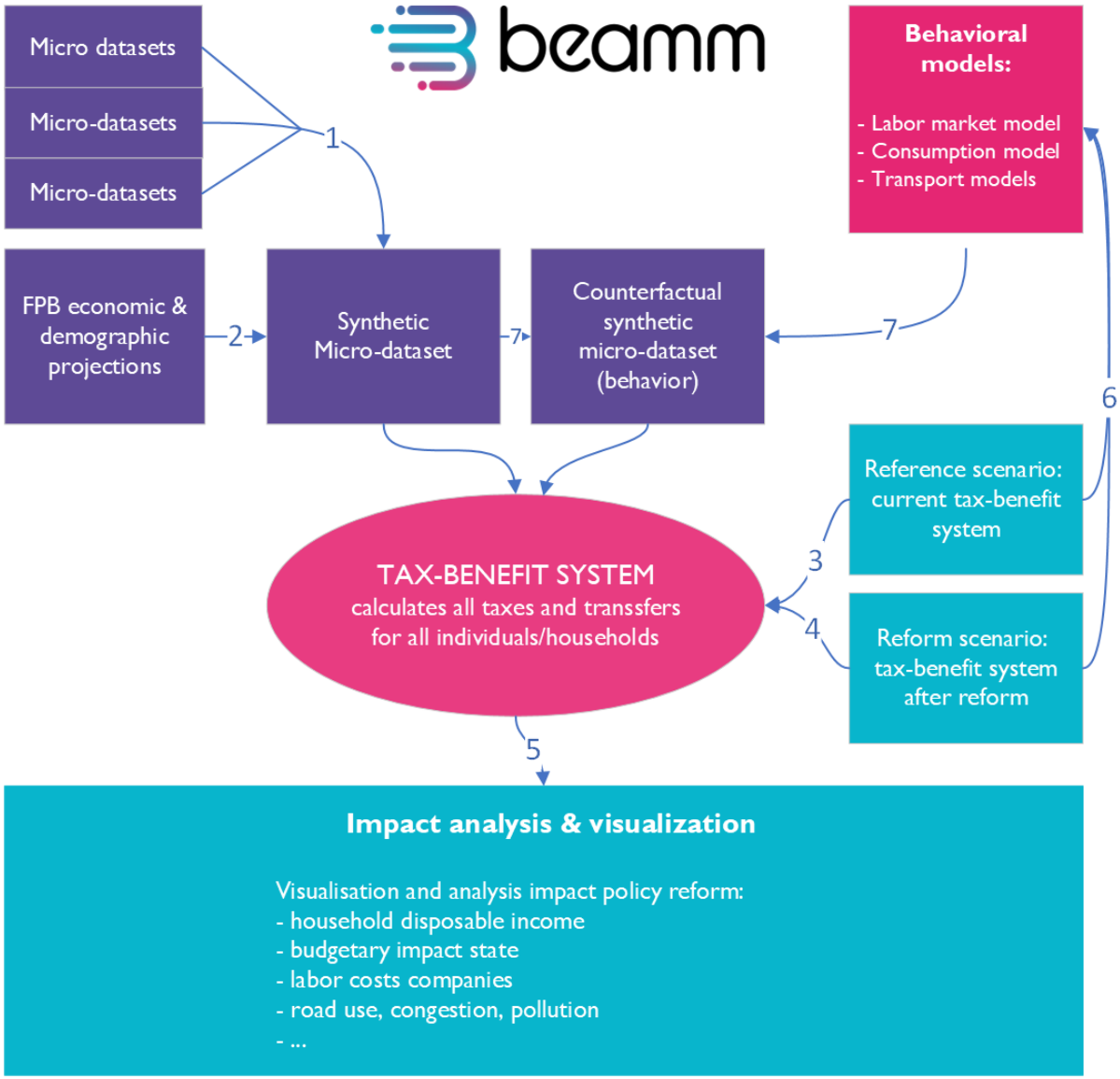
Model logic


Micro datasets
Micro-datasets
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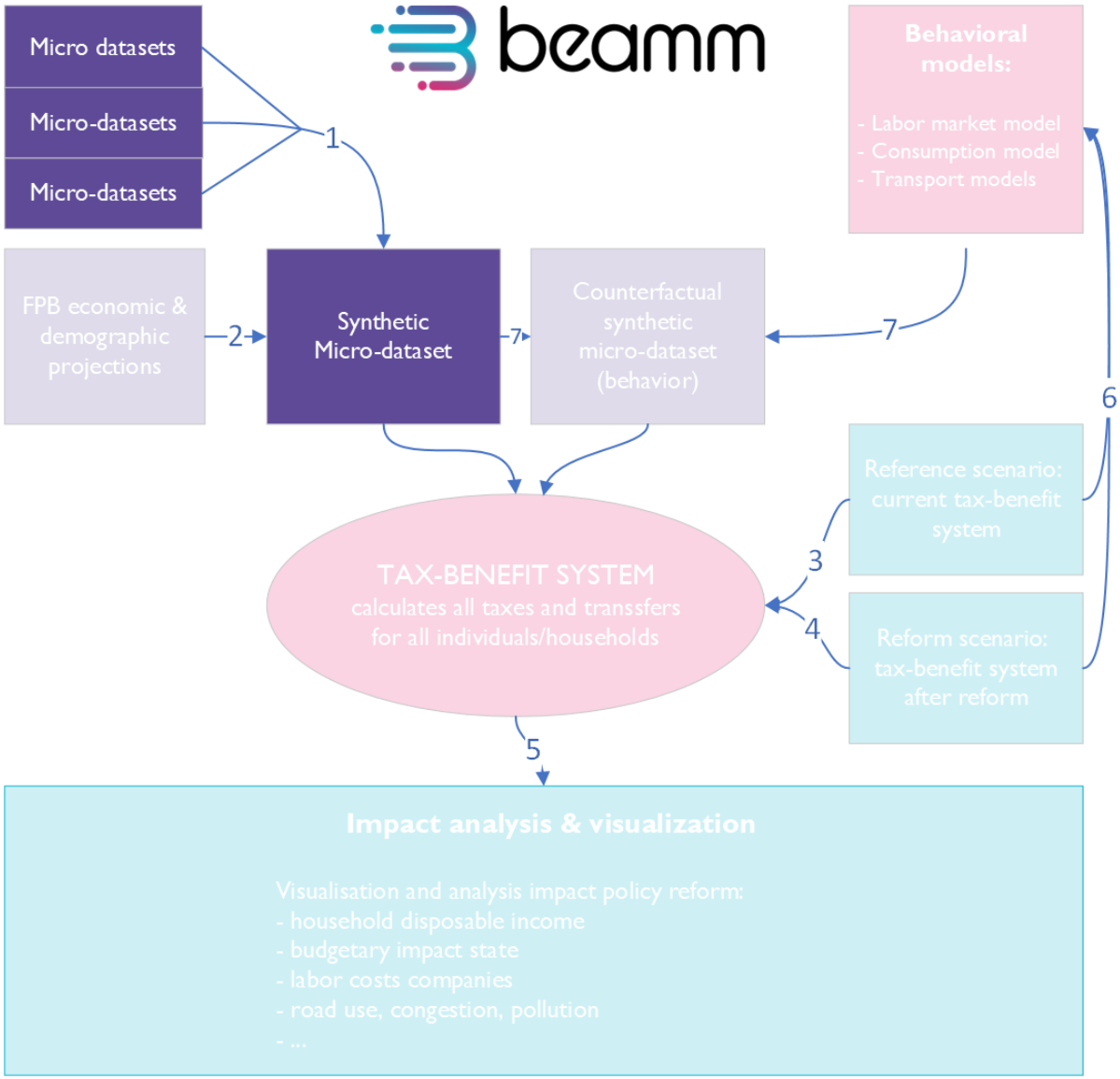
1
FPB economic & demographic projections
2
Synthetic Micro-dataset
7
Counterfactual synthetic micro-dataset (behavior)
7
Behavioral models:
- Labor market model
- Consumption model
- Transport models
6
Reference scenario: current tax-benefit system
3
TAX-BENEFIT SYSTEM
calculates all taxes and transsfers for all individuals/households
4
Reform scenario: tax-benefit system after reform
5
Impact analysis & visualization
Visualisation and analysis impact policy reform:
- household disposable income
- budgetary impact state
- labor costs companies
- road use, congestion, pollution
- ...

Step 1 : data - digital twin



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- Challenge 1 : How to combine information different anonymous micro-datasets ?
- Challenge 2 : How to use highly sensitive data in online applications ?
- Solution : machine learning algorithms - AI
  - Statistical matching → Statistically correct at aggregate level - fictitious at individual level
  - GAN : generation of 100% fictitious but very realistic data

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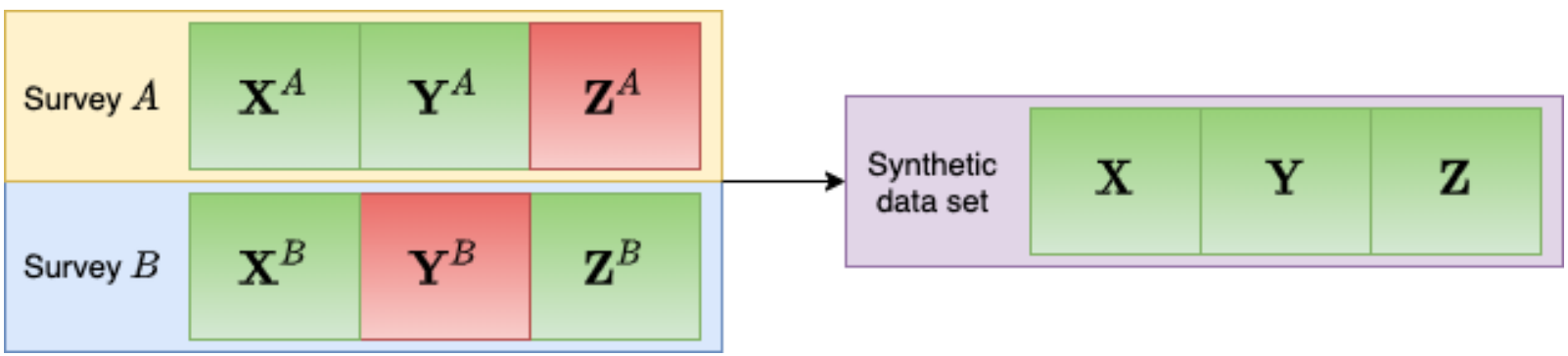
Step 1 : data - digital twin

- Statistical matching $\rightarrow$ Development machine learning algorithms - AI
  - (Kernel Canonical Correlation Analysis, Super-Organizing Maps and Autoencoders-Canonical Correlation Analysis)
  - Statistical matching $\rightarrow$ Statistically correct at aggregate level - fictitious at individual level



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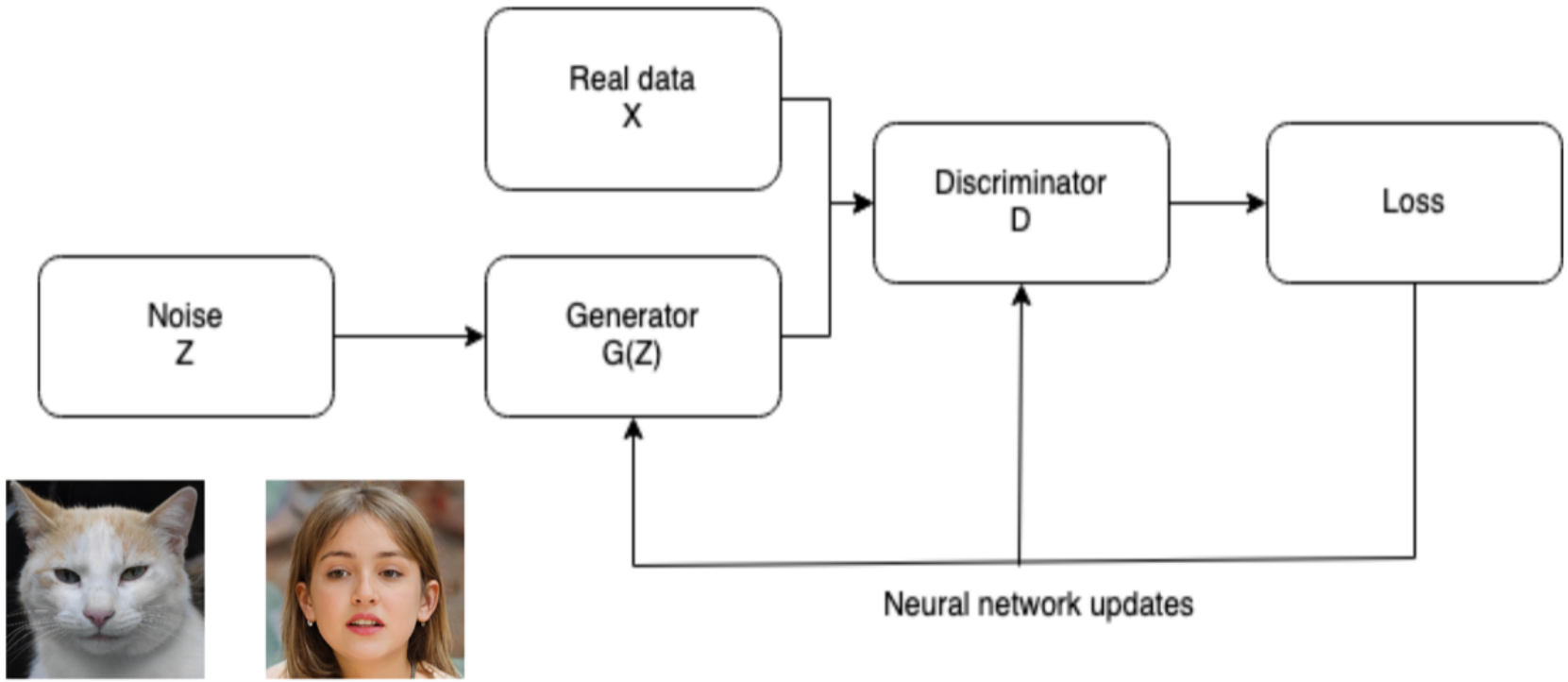
- Generation fictitious datasets : Wasserstein Generative Adversarial Networks (WGAN)



Results : Statistical matching

Measure	KCCA	A-CCA	Super-OM	CCA	MMLP	HD	REG
RwsMSE aver. cont. var.	0.60	0.64	0.62	0.63	0.63	1.23	0.58
RwsMSE aver. cat. var	0.95	0.94	0.95	0.94	0.90	1.03	0.87
RwsMSE aver. all var.	0.87	0.87	0.87	0.86	0.83	1.08	0.80
Multivariate R^2 (Jones)	0.63	0.58	0.59	0.59	0.58	-1.05	0.64
Average $\widetilde{\mathrm{CVM}}$ NC	1.18	1.17	2.43	1.78	3.06	0.67	9.85
Average $\widetilde{\mathrm{CVM}}$ Mixed	0.67	0.64	1.39	0.94	1.67	0.82	5.42

Table – Results (average over five folds) of the different statistical matching techniques applied to the SILC dataset only. KCCA : Kernel Canonical Correlation Analysis ; A-CCA : Autoencoders Canonical Correlation Analysis ; Super-OM : Super organizing maps ; CCA : Canonical Correlation Analysis ; MMLP : Multi-output Multilayer Perceptron ; HD : Distance Hot-deck ; REG : Multi-output regression. aver. cont. var., average for all continuous variables ; aver. cat. var., average for all categorical variables ; aver. all var., average for all variables.

Results : Generation fictitious datasets

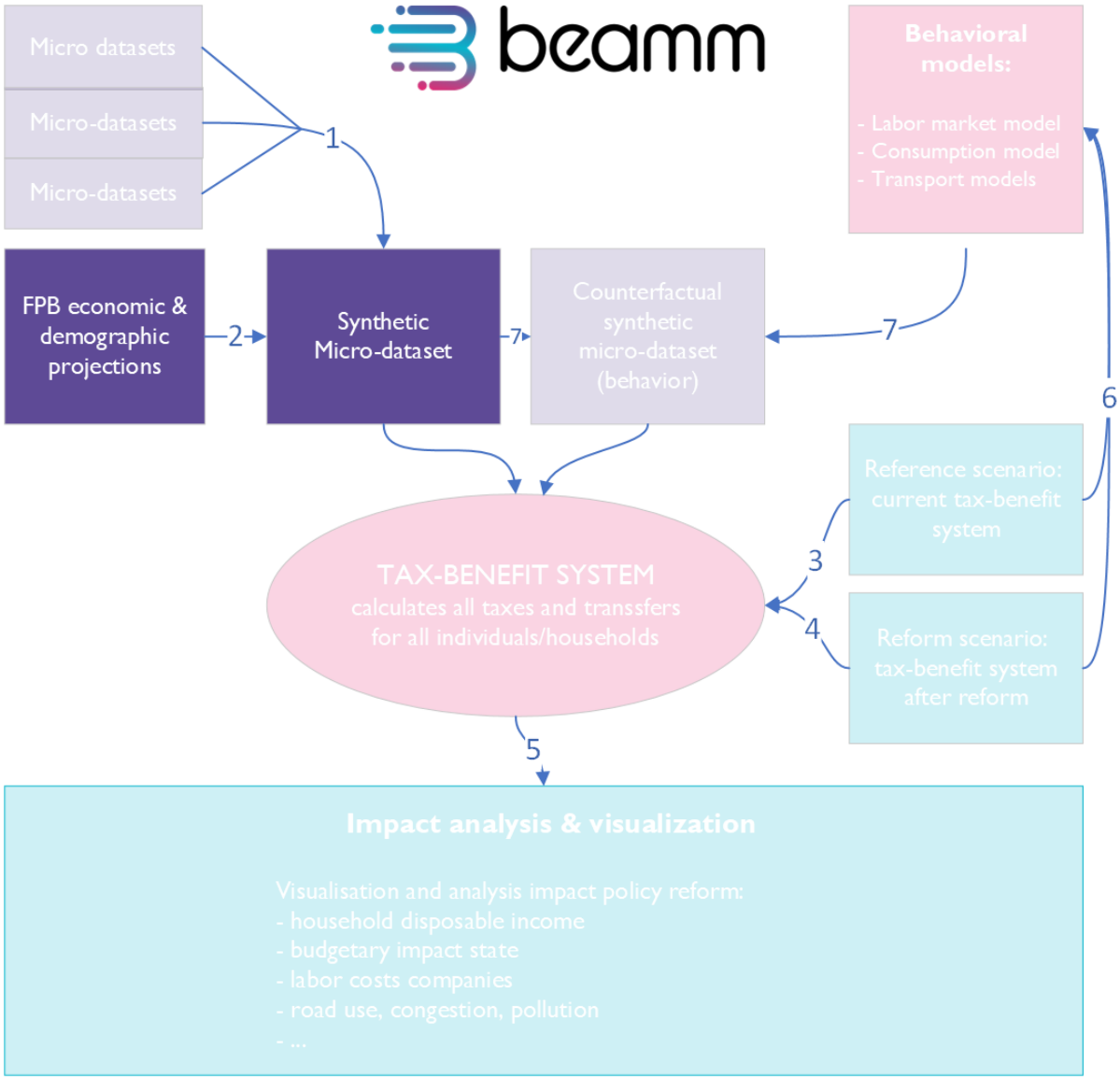
- Here we can find the results for the validation set for each method using the best hyperparameters.

	WGAN with GP	WGAN with WC	SDV (CopulaGAN) [1]
Wasserstein distance	**5.6116**	6.5685	8.352
Relative difference of the radius of a SVDD	**0.00098**	0.00652	0.01654
Time [2]	**2h**	2h	25h

- The absolute value of the difference of correlations between all the variables is for more than 90% of the couples of variables smaller for WGAN with GP than for SDV (CopulaGAN).

1. SDV is a python package that provides functions to create synthetic datasets. CopulaGAN is one of their most advanced functions that combines GAN models with Copulas.
2. for one combination of hyperparameters

Step 2 : projecting data



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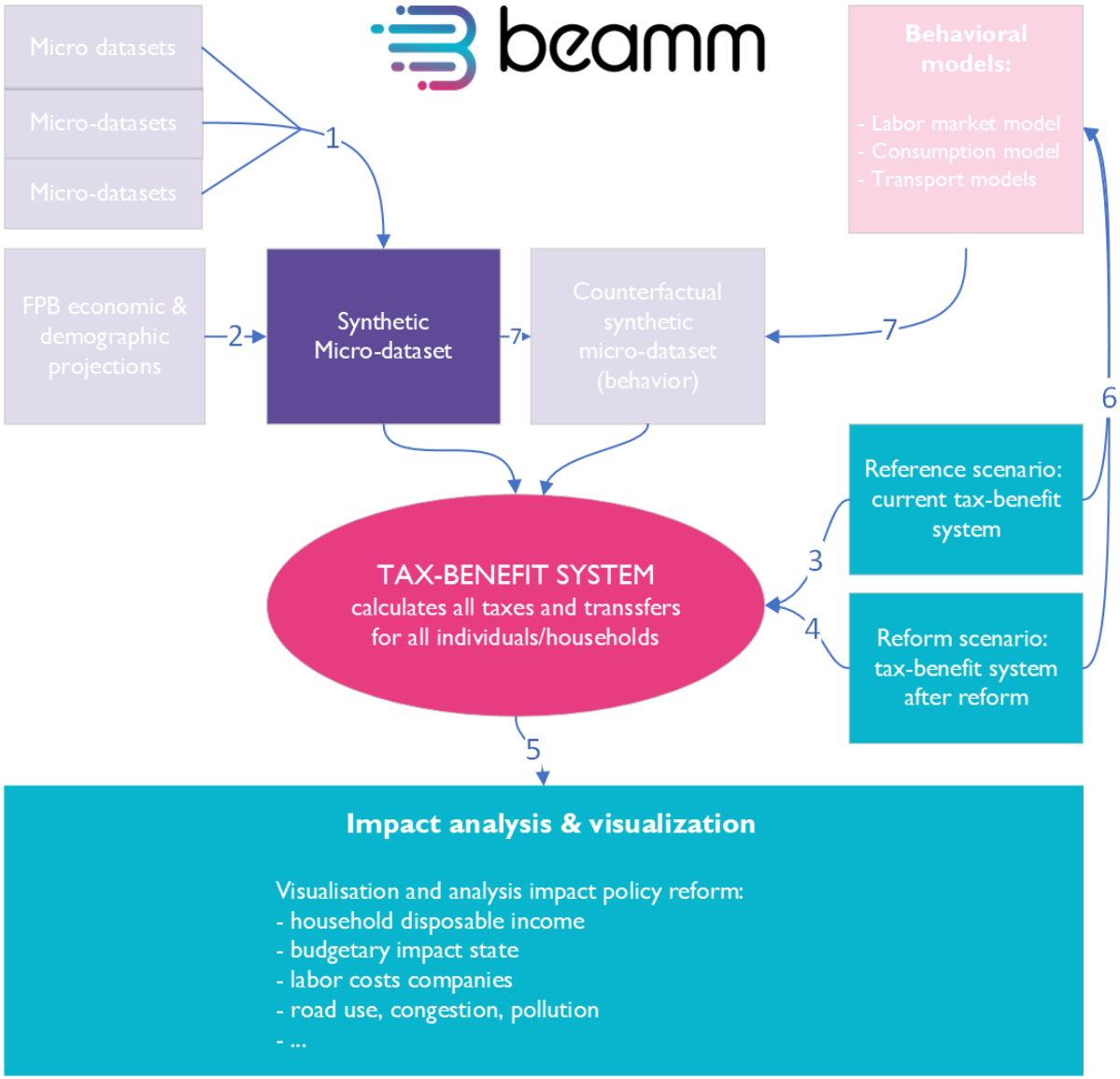
- (Work-in-progress $\rightarrow$ now : Fantasi-D, AI later)

Step 3 : micro-simulation Model



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- Documentation tax-benefit system $\rightarrow$ plan : integration figures from data

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  - Allow users to specify tax-benefit reforms
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- Server side
  - Public cloud server $\rightarrow$ kubernetes cluster to dynamically adapt server capacity

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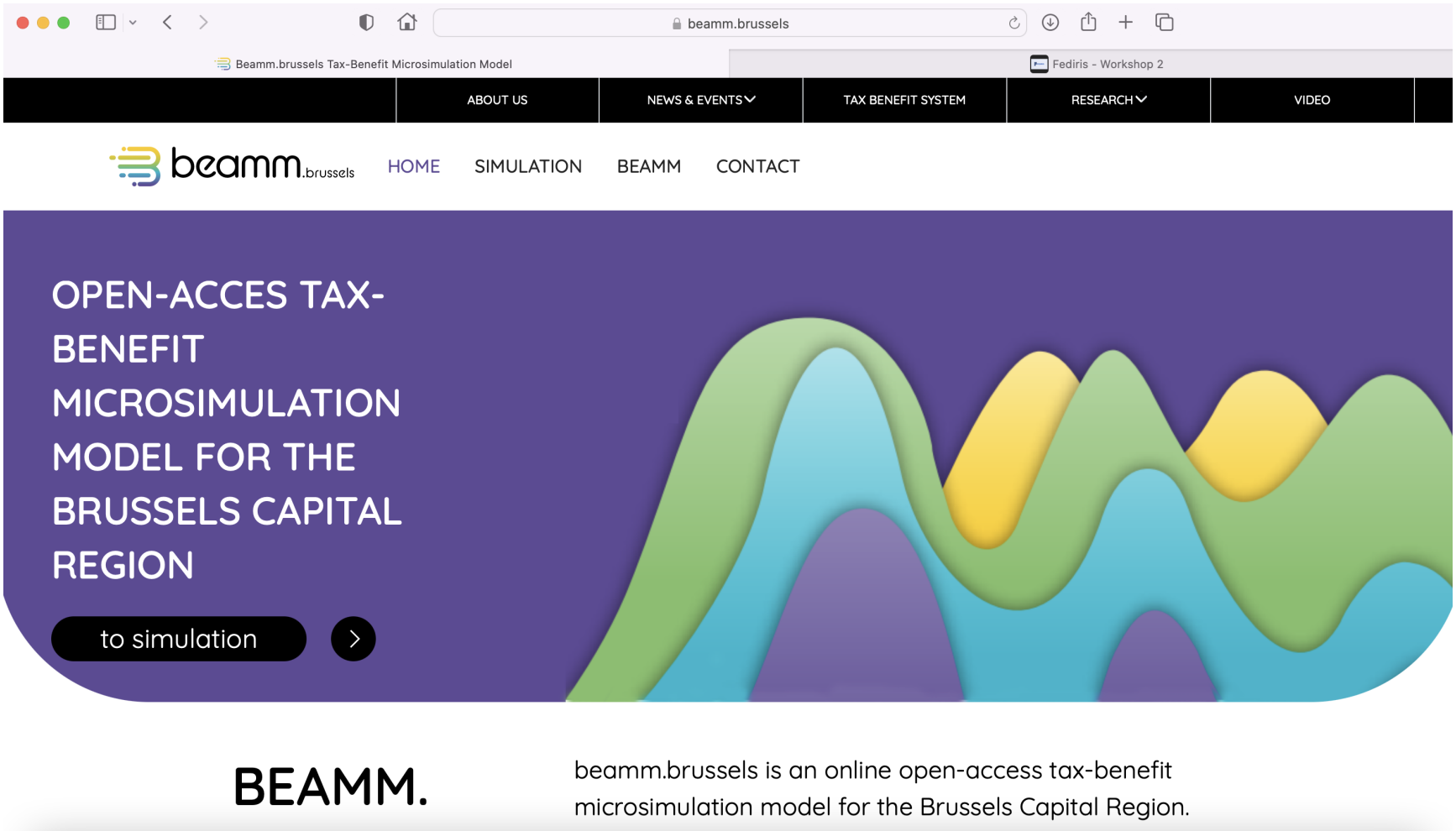

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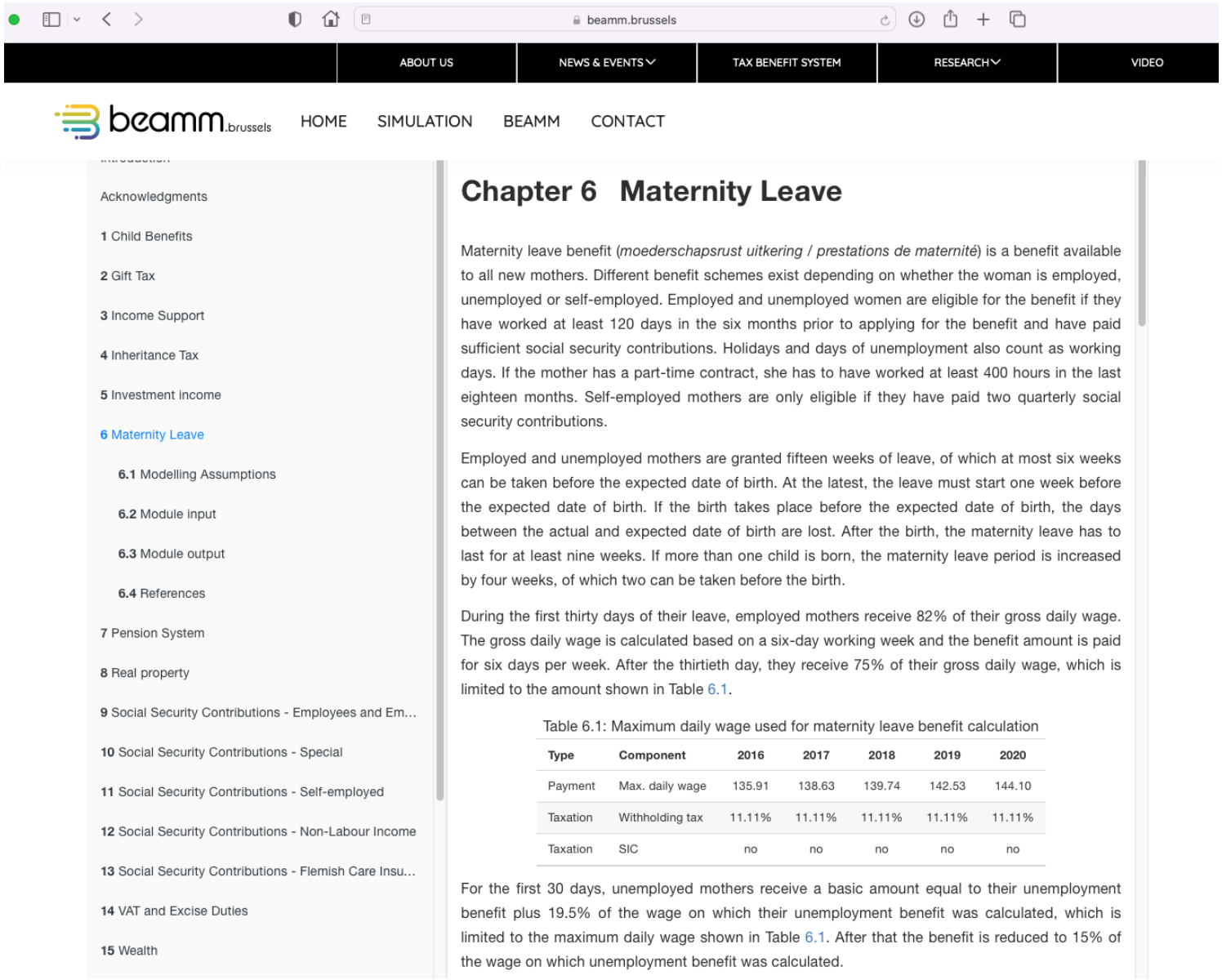

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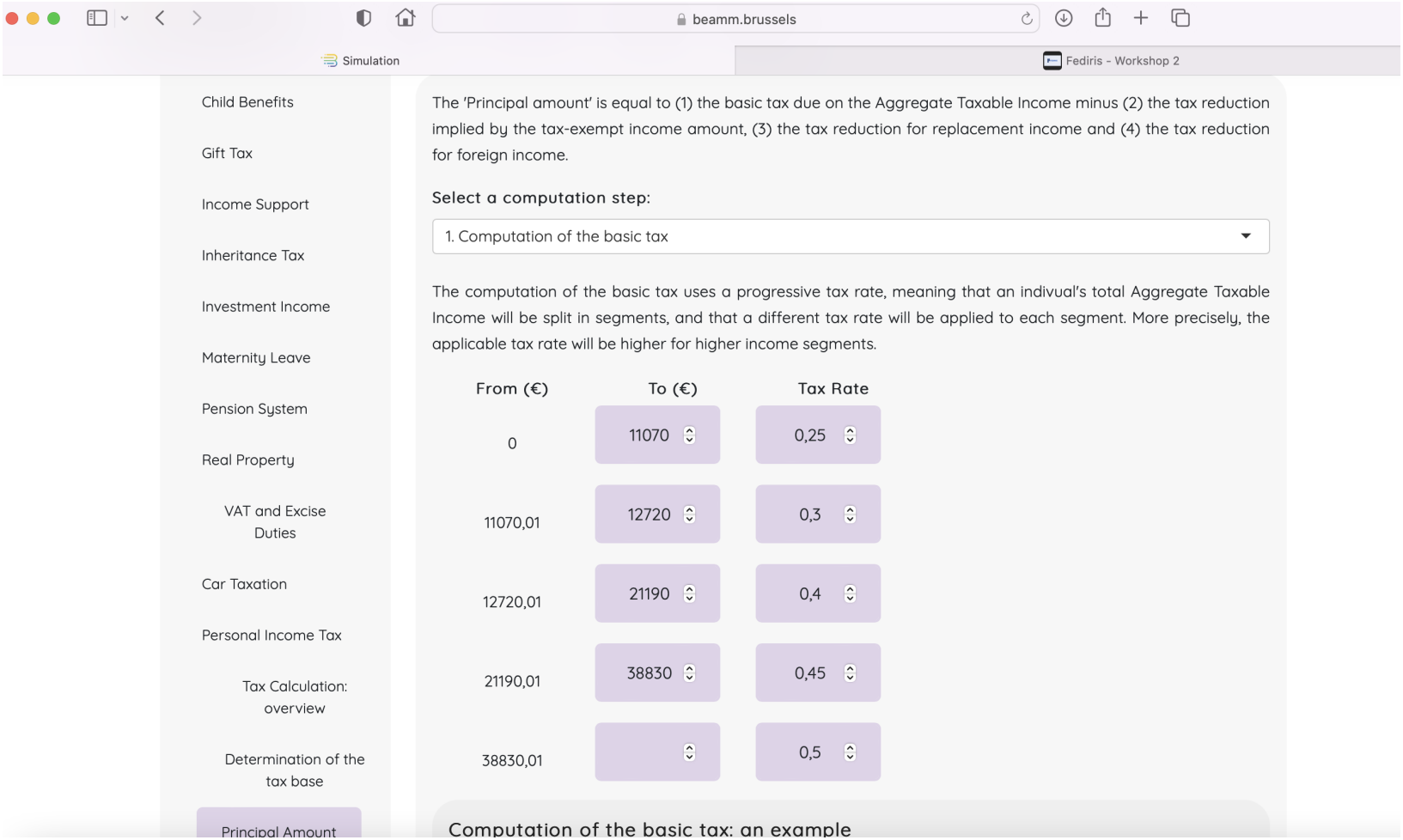

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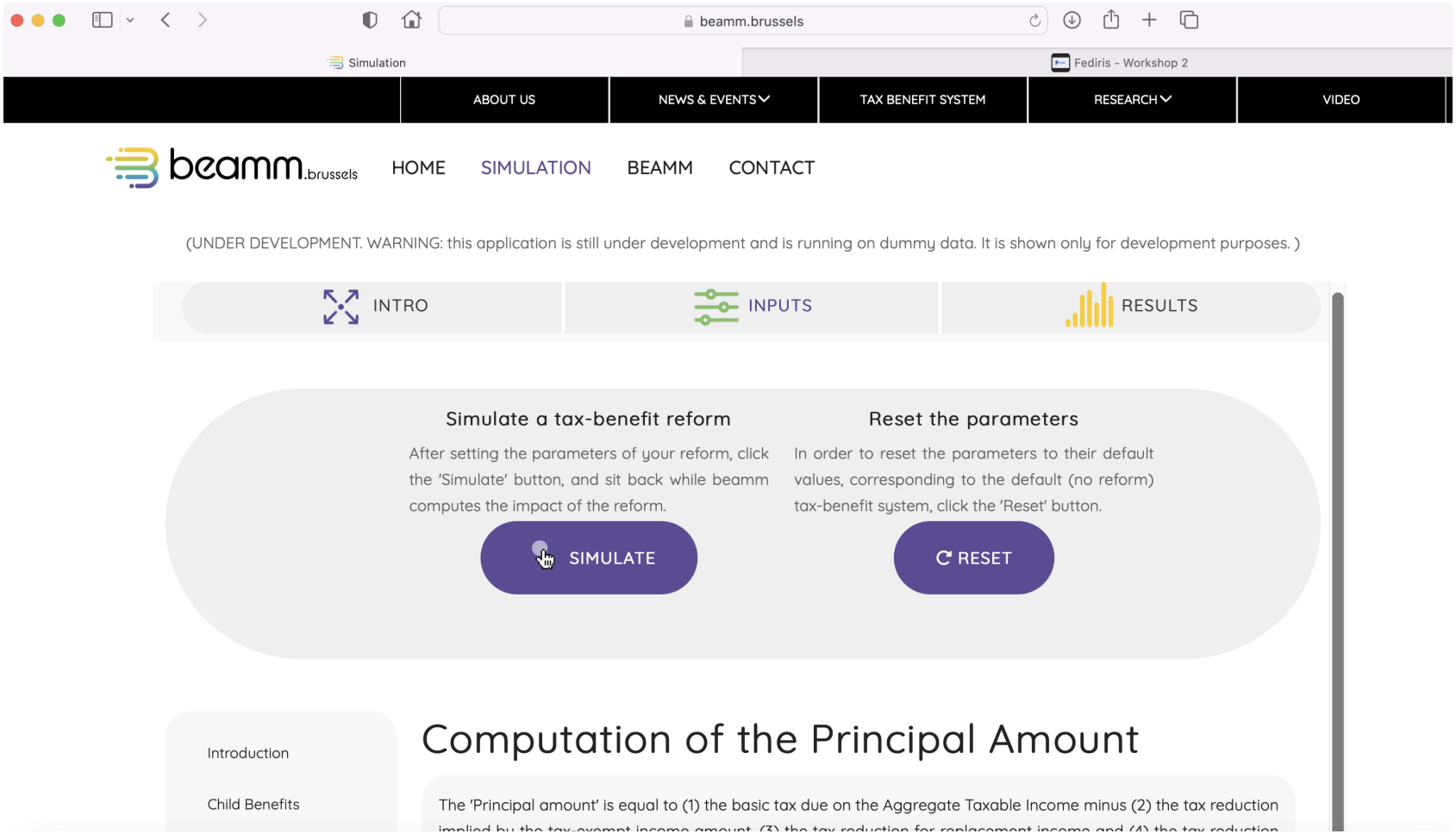

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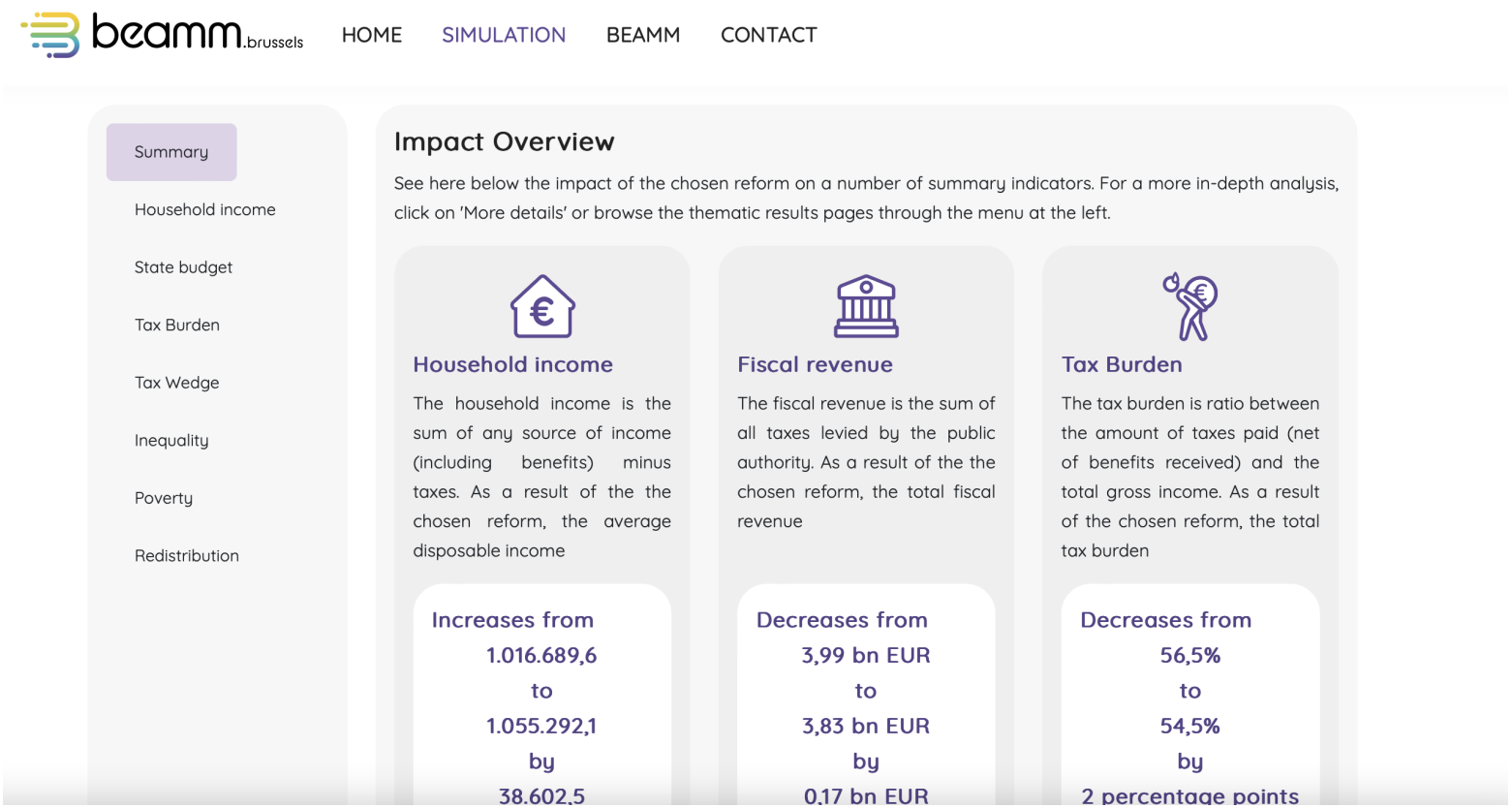

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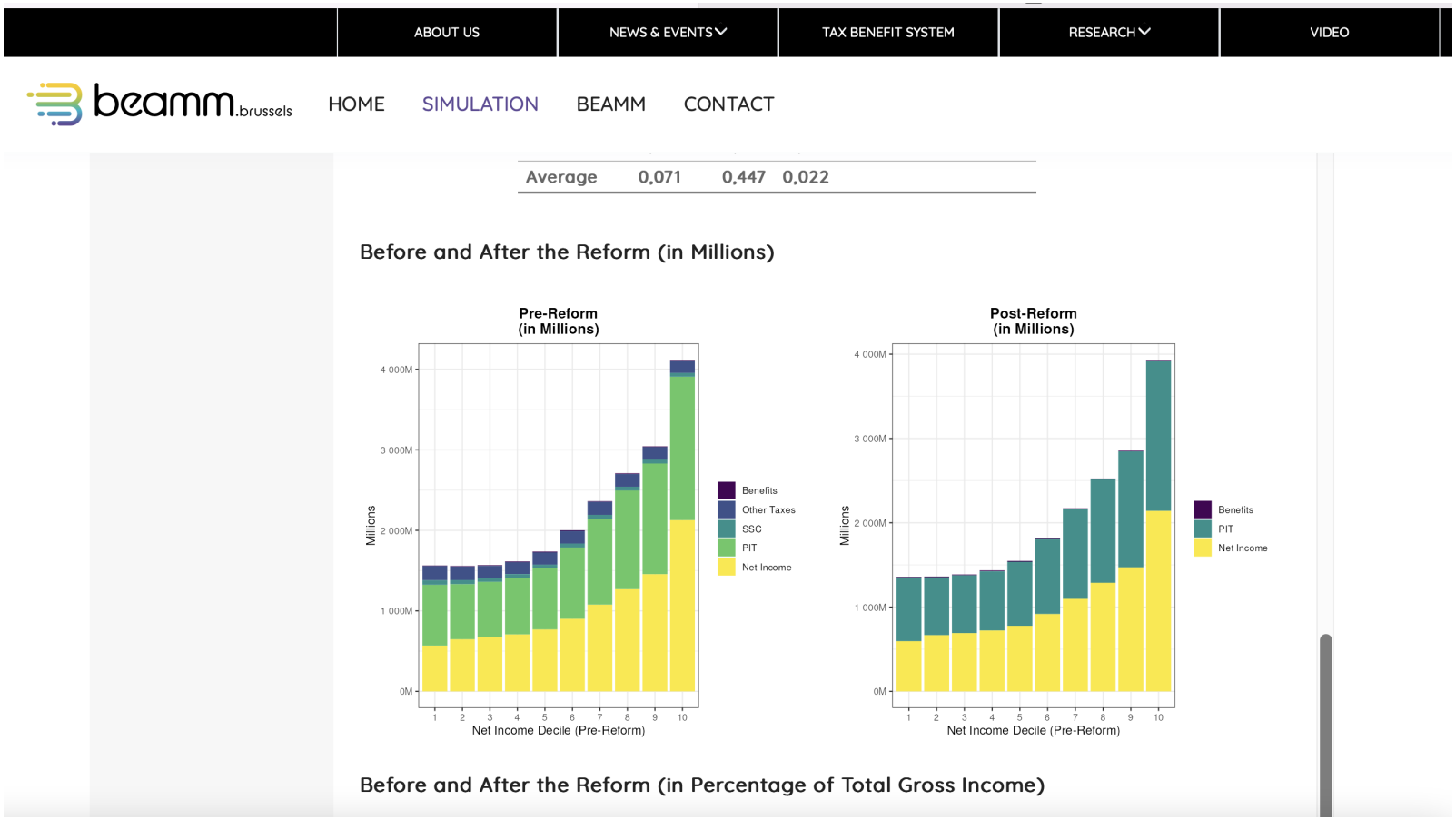

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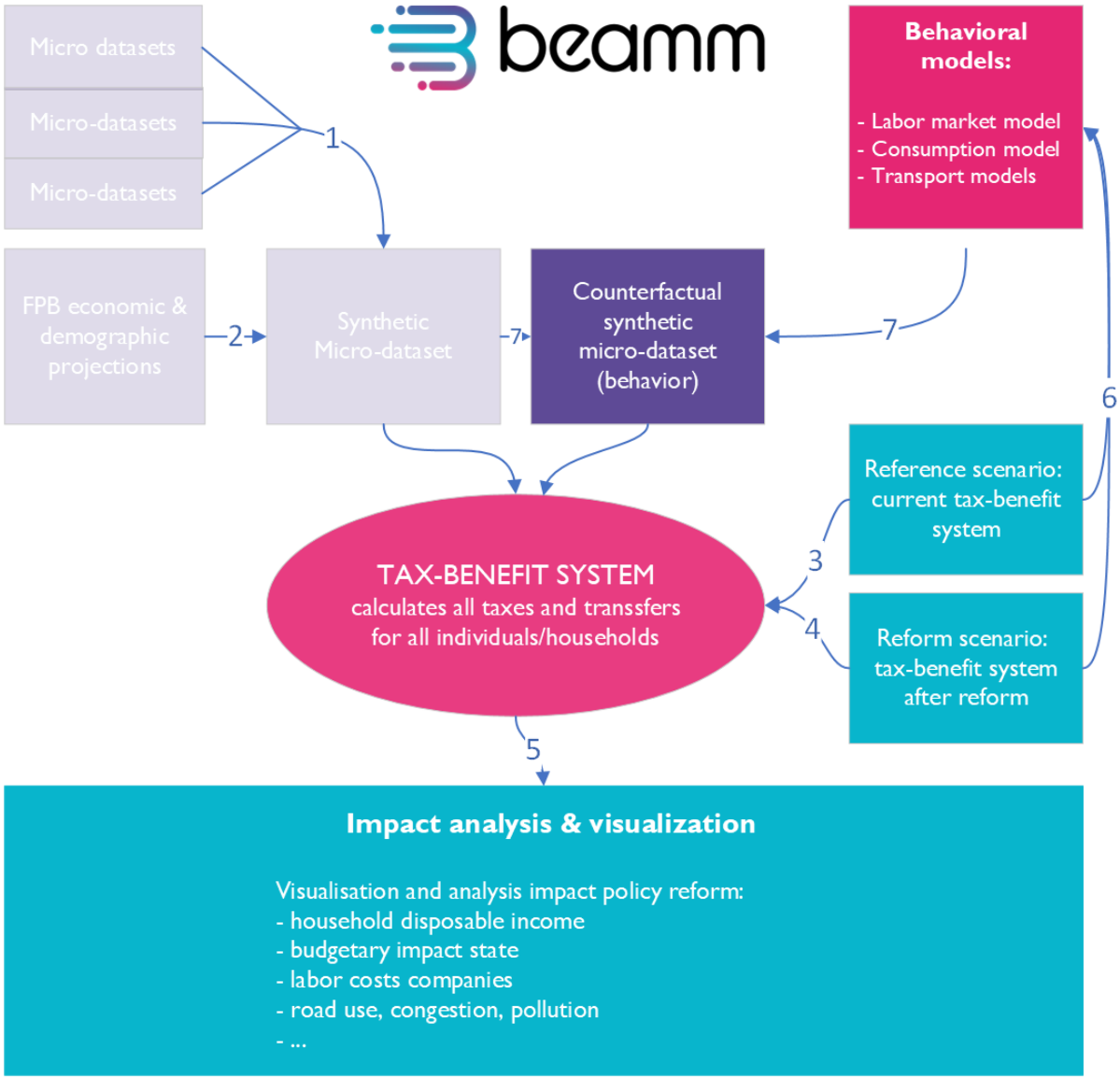

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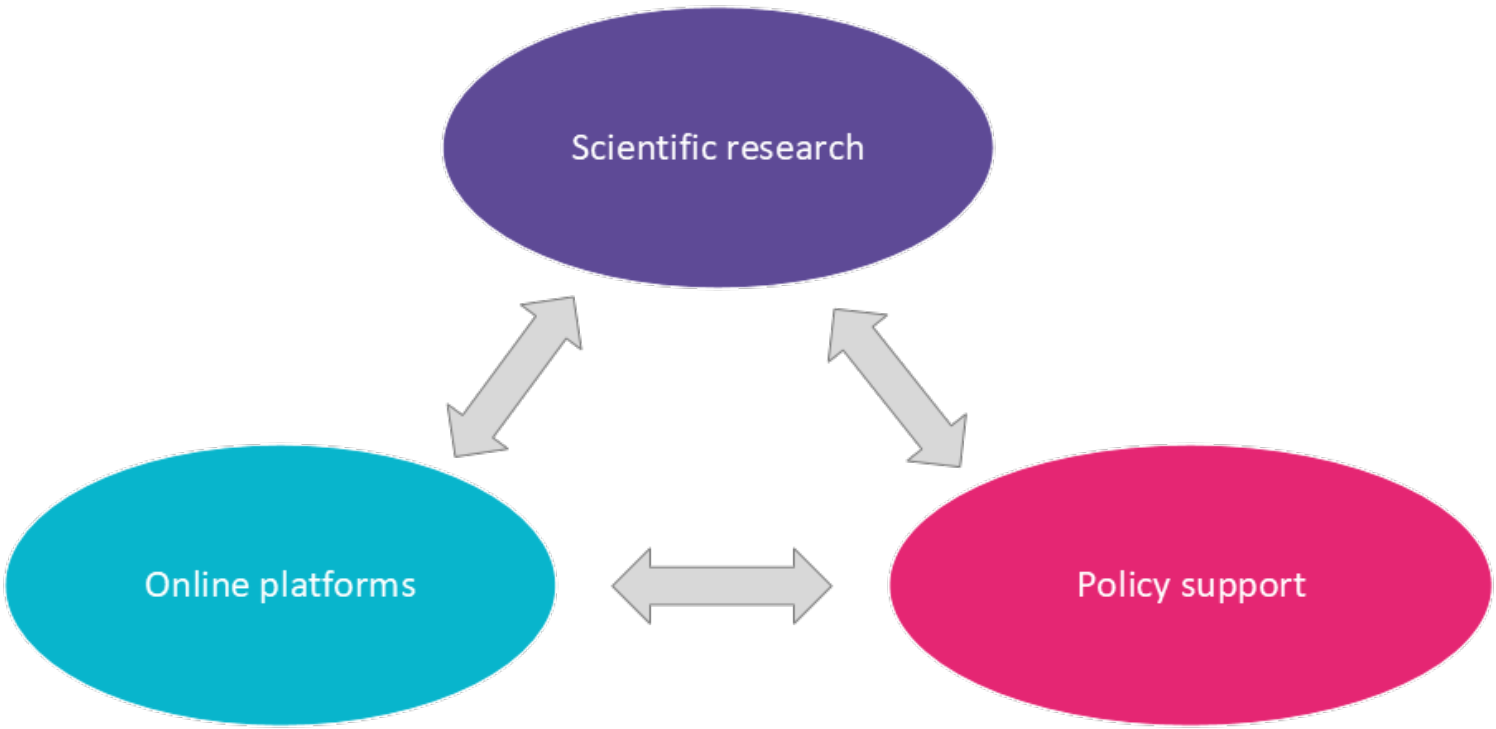
- Beamm = long term project → continued investment/development over coming years/decades..

Beamm Trinity



And finally..

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  - Longer term : networked simulation platforms
- In that light : Vlaamse Overheid and CAPE
  - Open for further collaboration, reciprocity
  - Participate or present in our workshops ?
  - Feel free to reach out !

Questions ? Interested ?

Contact us :

tom.truyts@uclouvain.be

cape-slb@uclouvain.be

Sites : Tom Truyts, CAPE

Use cases : examples (1)

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  - Estimation of behavioral responses
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  - Calculation elasticity of taxable income, calculation elasticity labor supply
- Socio-economic impact carbon taxes
  - Distributional impact, compensating measures,
  - Estimation behavioral reactions $\rightarrow$ consumption and investment in durables

Use cases : examples (2)

- Tax design and family dynamics TAXFAM ARC project
  - Impact assessment, budgetary costs reform scenarios, distributional impact...
  - What is the fiscal unit : household vs individual ?
  - Costs of living couples vs singles $\rightarrow$ fairness fiscal unit
  - Behavioral models of household dynamics : childcare and labor supply, divorce

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- Fantasi project
  - Development Fantasi - microsimulation model Personal Income Tax
  - With Financiën en Begroting, Vlaamse Overheid
- Calculation Interregional Financial Transfers
  - For Treasury Flanders
- (IBSA-BISA support, Spending reviews, budget predictions ; participatory democracy,...)