

DTU



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Insights from e-bike adoption in Denmark: A 10-year synthetic pseudo-panel analysis

Motivation & Aim

- E-bikes are **increasing** worldwide.
- Surveys in Denmark show as that: [1,2]
 - Around **14%** of Danes used an e-bike in 2022, increasing **to 24%** in 2025.
 - Main **reasons** for using an e-bike were:
 - More exercise
 - Less strenuous
 - Longer distance

[1] Det Nationale Videnscenter for Cykelfremmes (2022). Elcyklers udbredelse i Danmark.

[2] Det Nationale Videnscenter for Cykelfremmes (2026). Endnu mere strøm på cykelstien.



Motivation & Aim

Using once

≠

Adoption

- Show who **used an e-bike**, but not how **adoption develops over time**.
- Consequently, it is difficult to identify:
 - Which **groups drive** adoption?
 - Which **modes lose** demand over time?
 - Whether **growth comes** from more travel or modal substitution?

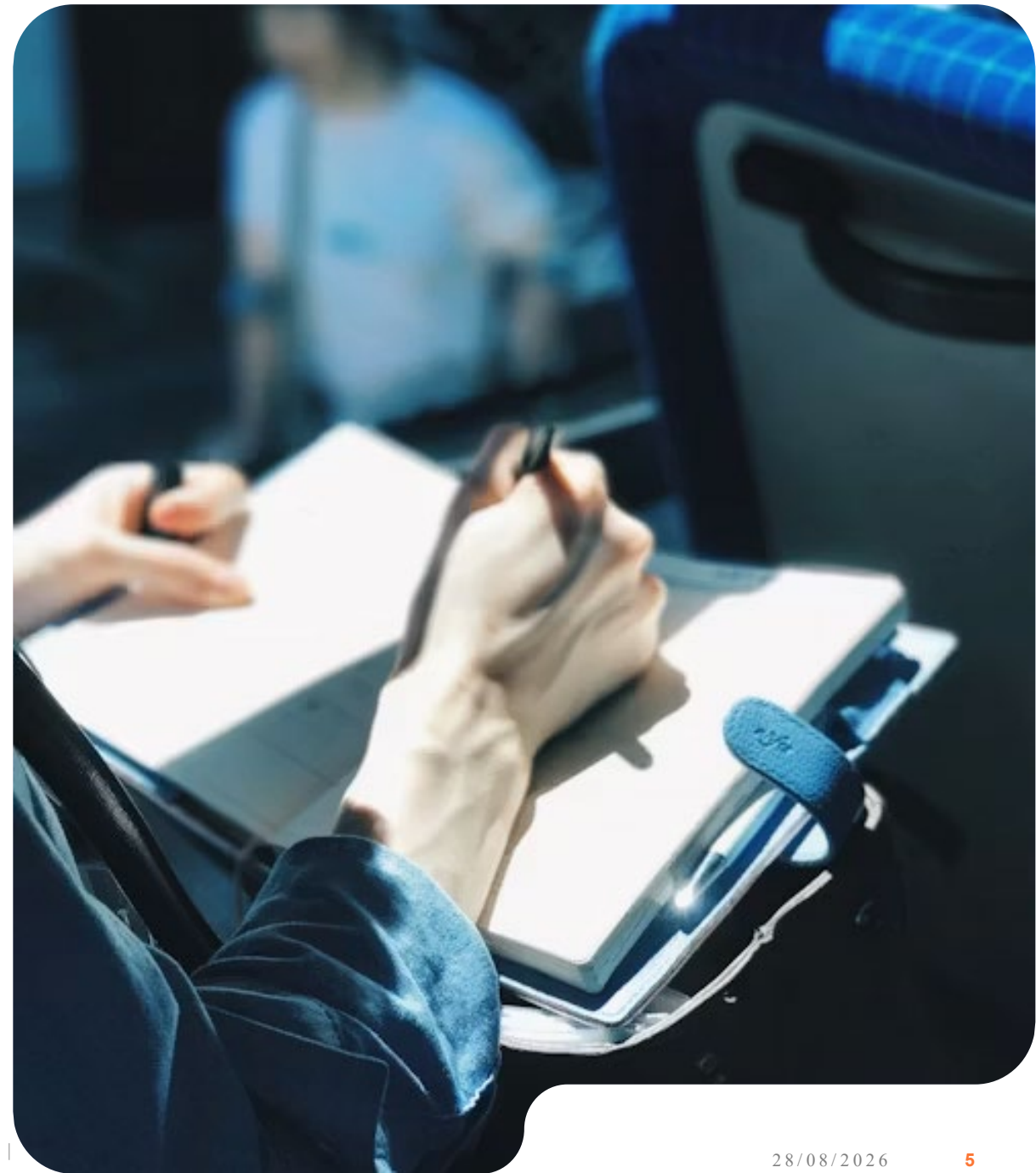


Data

What data can we use to study adoption over time?

- Longitudinal data.
 - observing the same individuals over time.
 - rarely available at scale.
- Continue cross-sectional data.
 - Danish National Travel Survey (TU). [3]
 - One-day travel diaries since 2006.
 - Conducted with the same method.
 - Distinguishes e-bike trips since 2014.

[3] Christiansen, H., & Anderson, M. K. (2025). The Danish National Travel Survey-variables.



Method

How can we use **continue cross-sectional data** to study adoption over time?

Approach	Limitation
Annual TU statistics	Mix behavioural change with socio-demographic change.
Pseudo-panels for segments	Aggregation bias and unstable estimates for small groups.
Moving averages	Reduce noise but cannot control population composition.
Regression models	Estimate effects but do not reconstruct adoption trajectories.



Method

How can we use **continue cross-sectional data** to study adoption over time?

- **Generative modelling** can address these limitations. (Borysov and Rich, 2021)
- Separate demographic and behavioural change.
 - Reconstruct a stable population.
 - Preserve heterogeneity through latent variables.
 - Enable adoption and mode reallocation analysis.

Borysov, S. S., & Rich, J. (2021). Introducing synthetic pseudo panels: application to transport behaviour dynamics. *Transportation*, 48(5), 2493–2520.



Method

Extract data

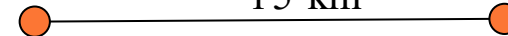
- **Daily trip records (Y)** are constructed, i.e. purpose, no. trips and average distance.



2 X



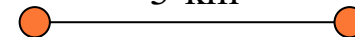
15 km



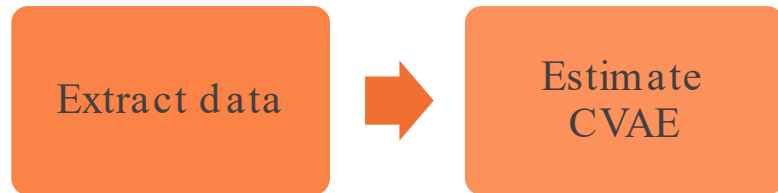
2 X



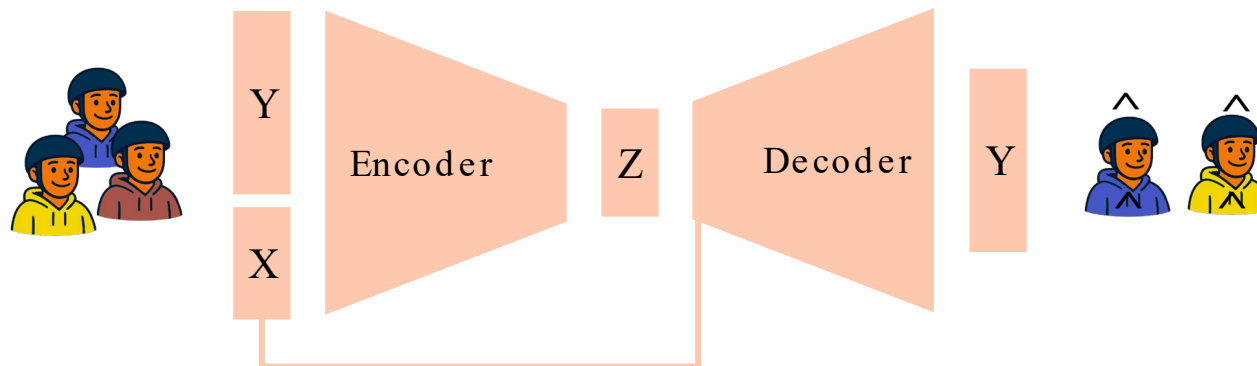
3 km



Method



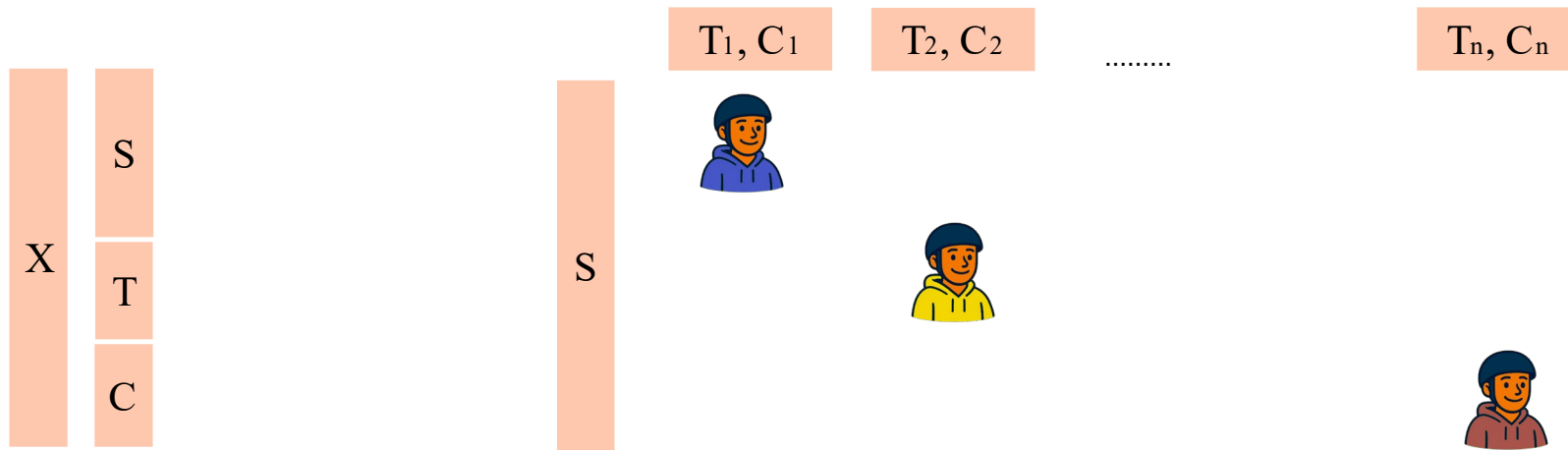
- A Conditional Variational Autoencoder (CVAE) is estimated for Y .



Method



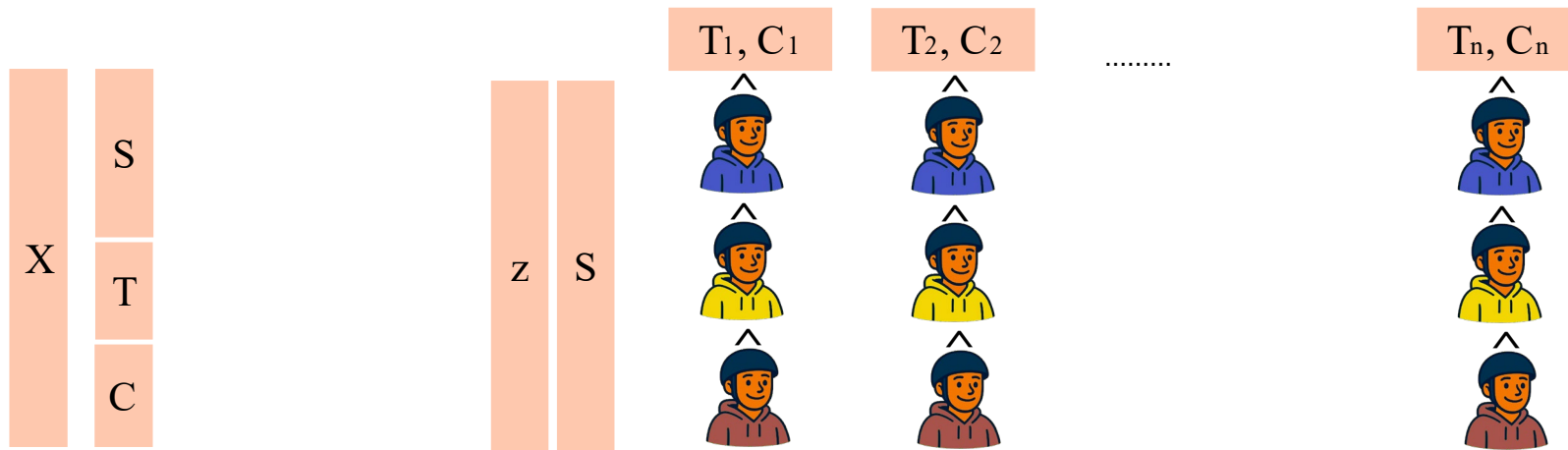
- **Synthetic individuals** are generated across years, i.e. a synthetic pseudo-panel (SPP).



Method



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Method

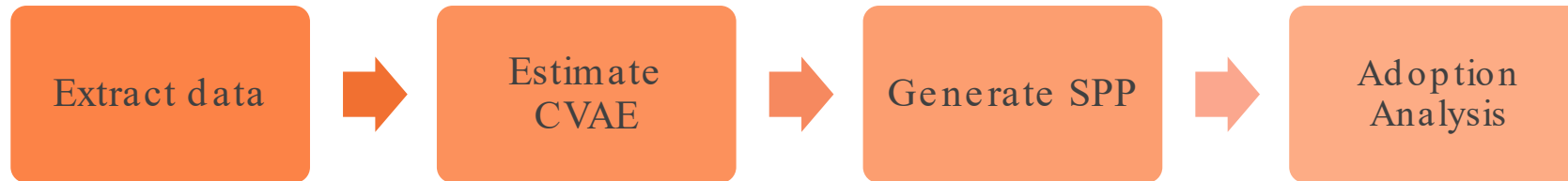


- **Synthetic individuals** are generated across years, i.e. a synthetic pseudo-panel (SPP).



e.g. young females

Method



- **Adoption** is analysed i.e. **mileage changes based on** number of trips and average distance changes.



e.g. young females

Method

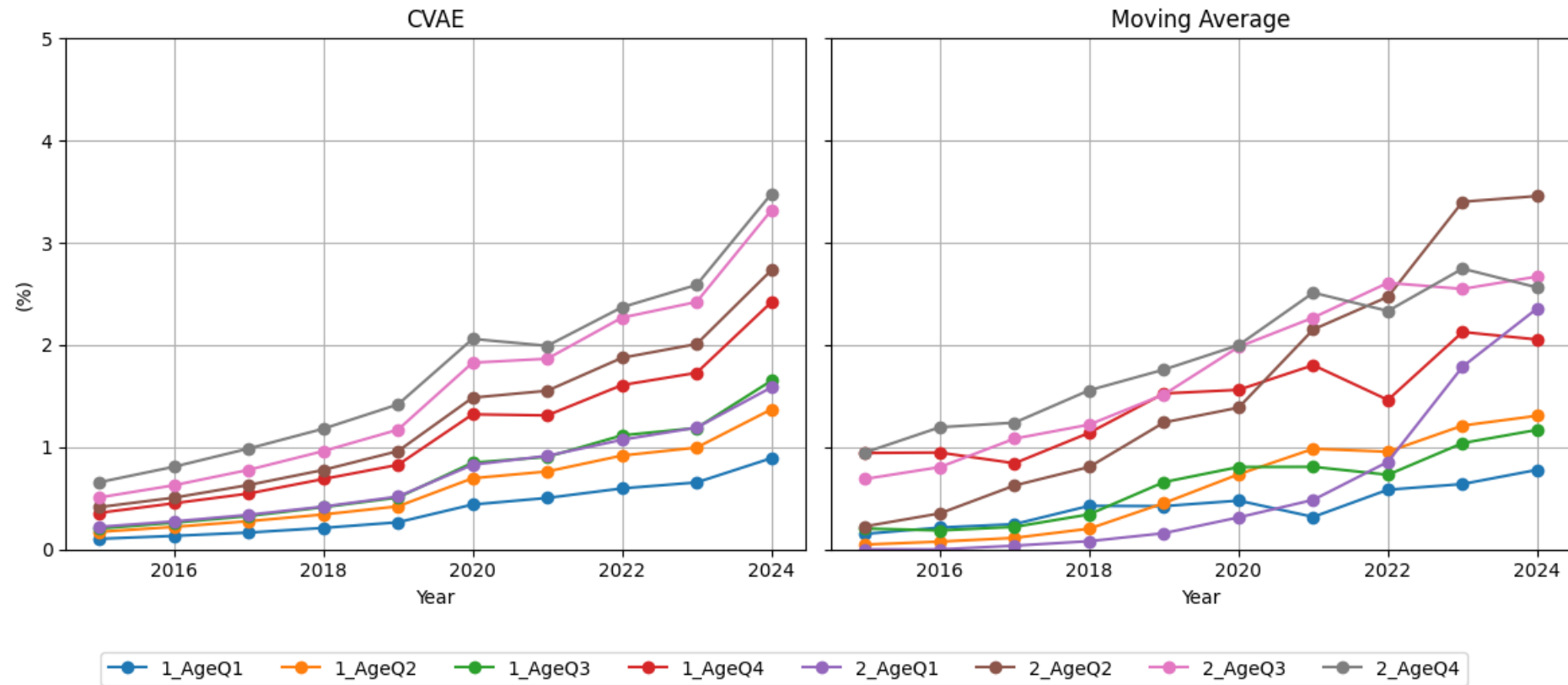


- Mode **reallocation** is calculated.



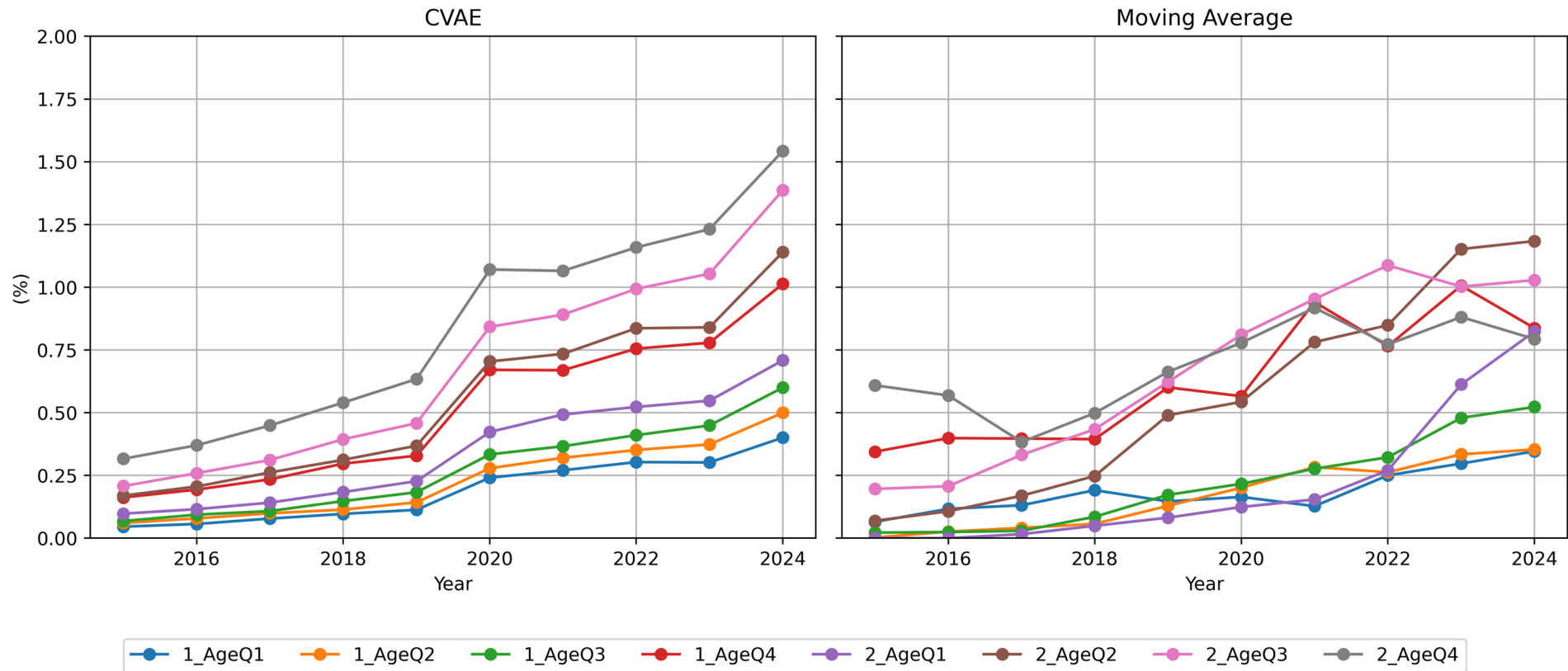
Results | SPP vs TU

Percentage of e-bike **trips** for males (1), females (2) and across age quartiles (Q1-Q4).



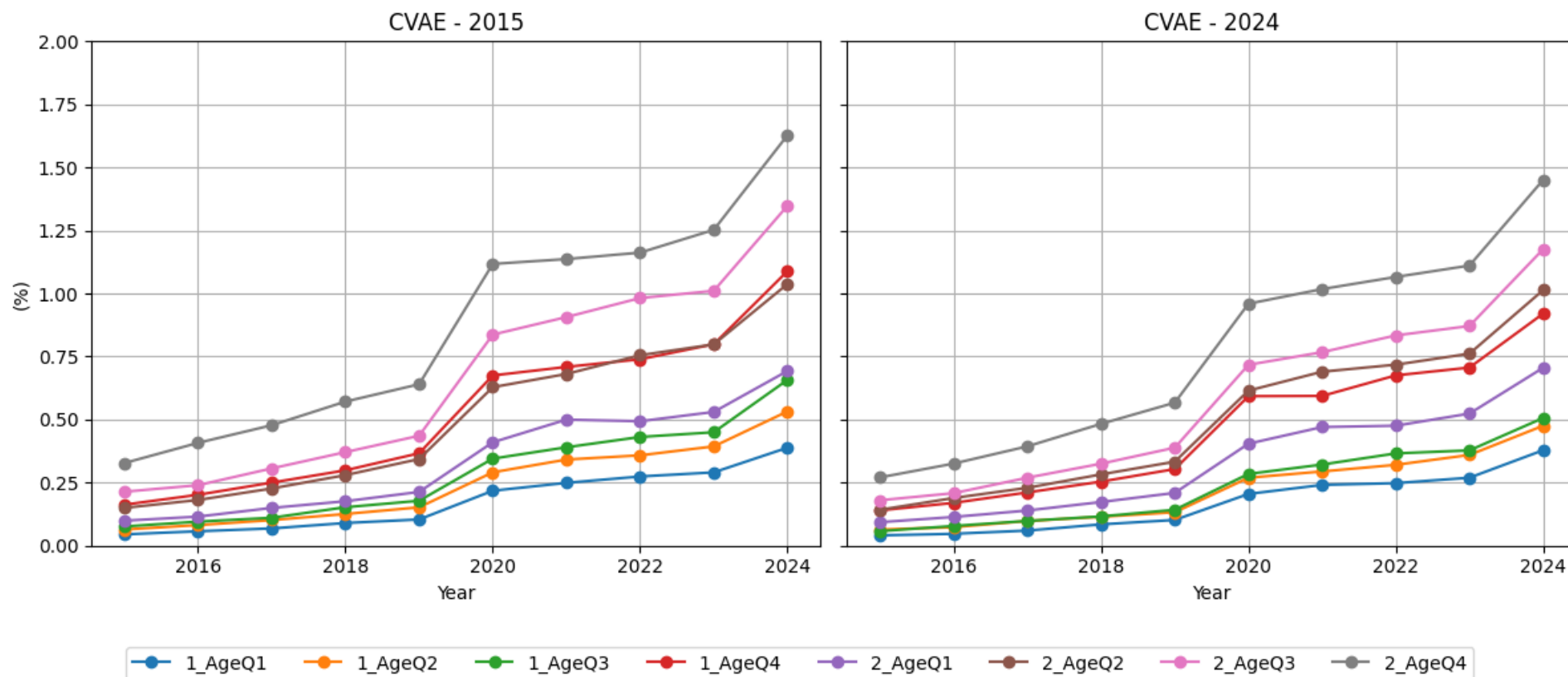
Results | SPP vs TU

Percentage of e-bike **mileage** for males (1), females (2) and across age quartiles (Q1-Q4).

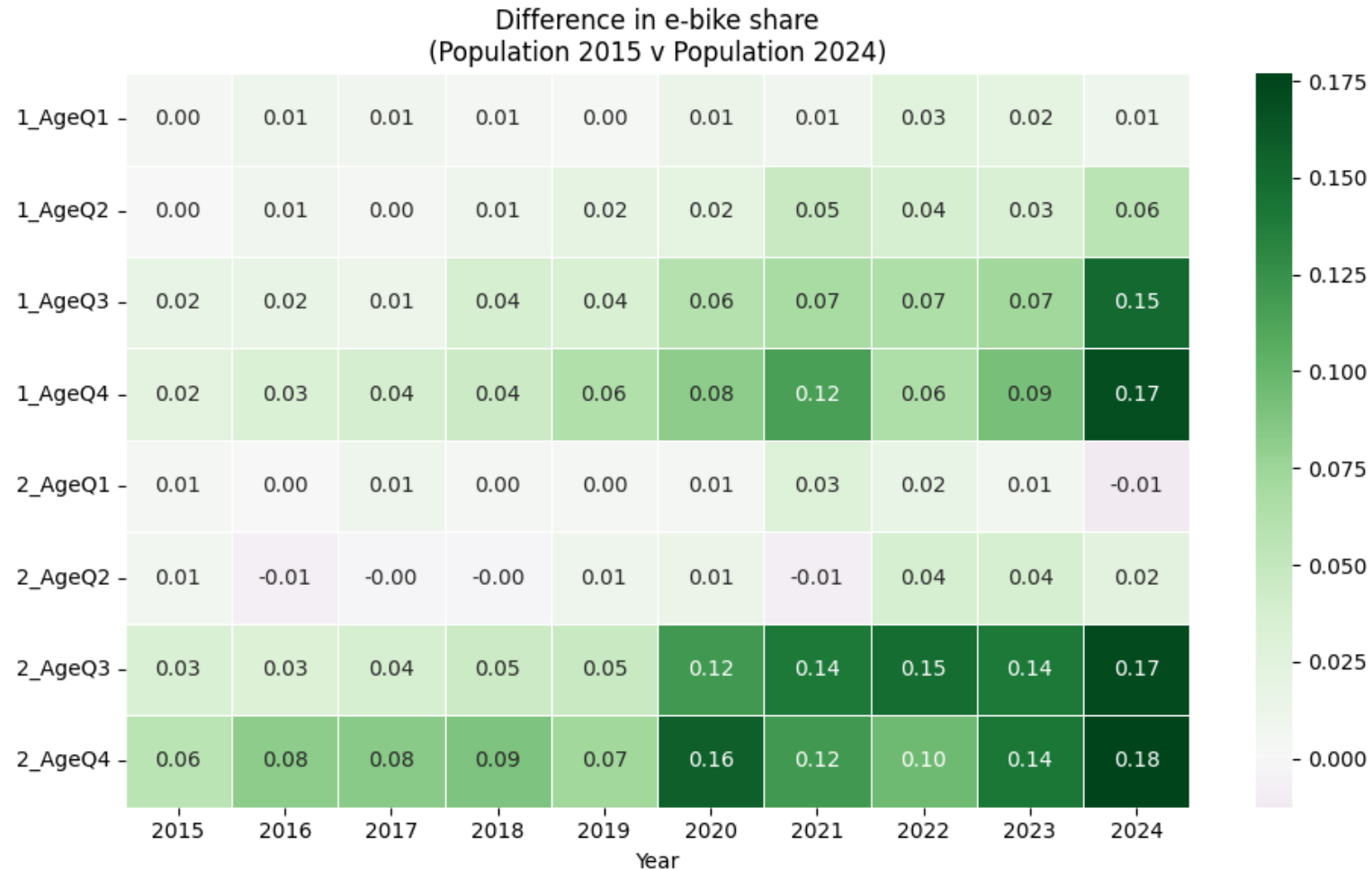


Results | SPP for different populations (2015 vs 2024)

Percentage of e-bike **mileage** for males (1), females (2) and across age quartiles (Q1-Q4).

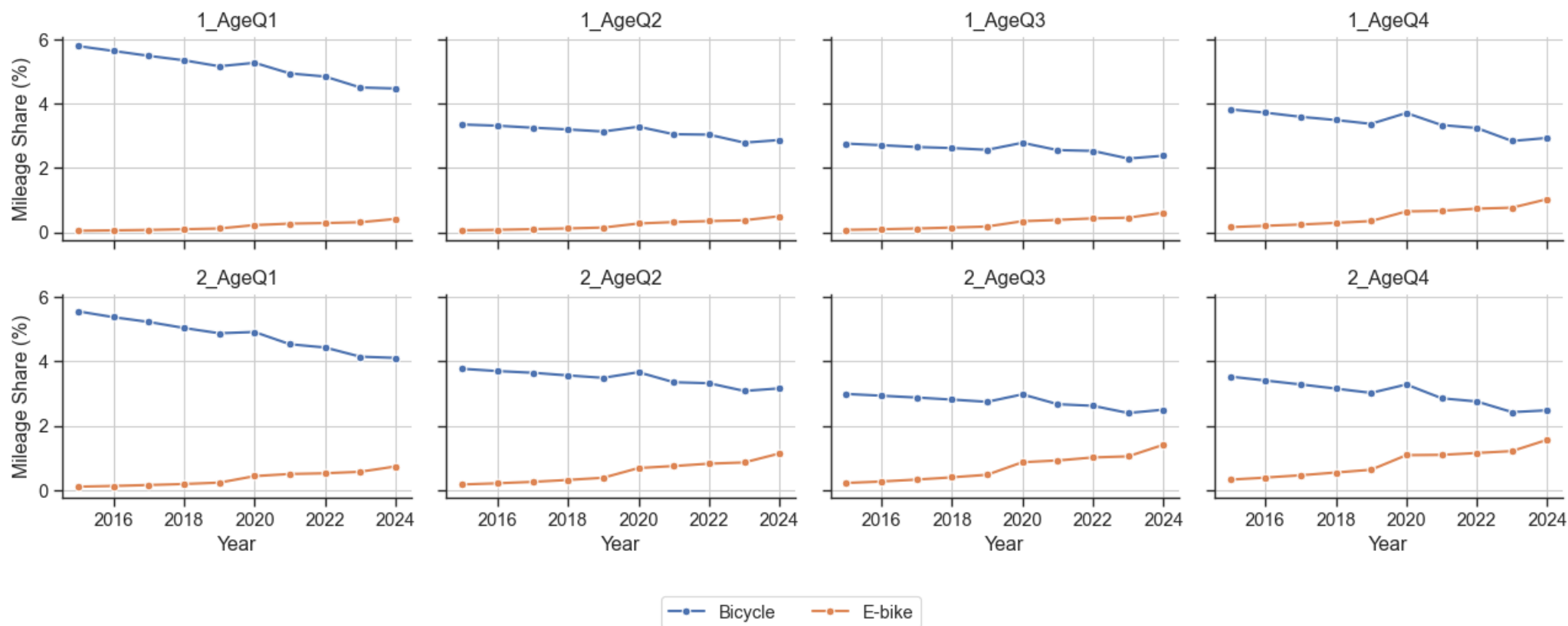


Results | SPP for different populations (2015 vs 2024)



Results | SPP – E-bikes vs Bicycles

Percentage of **mileage** for males (1), females (2) and across age quartiles (Q1-Q4).

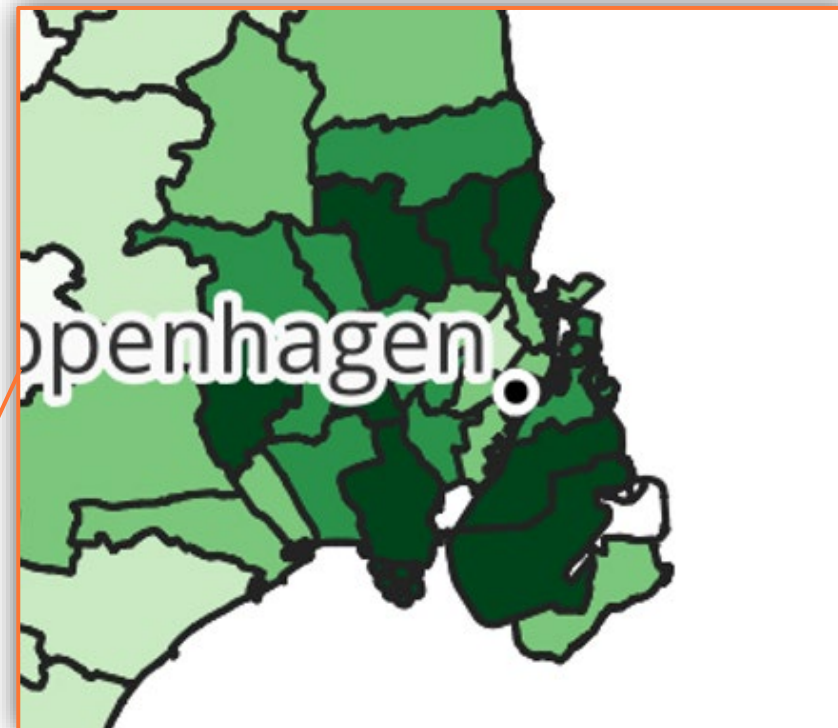
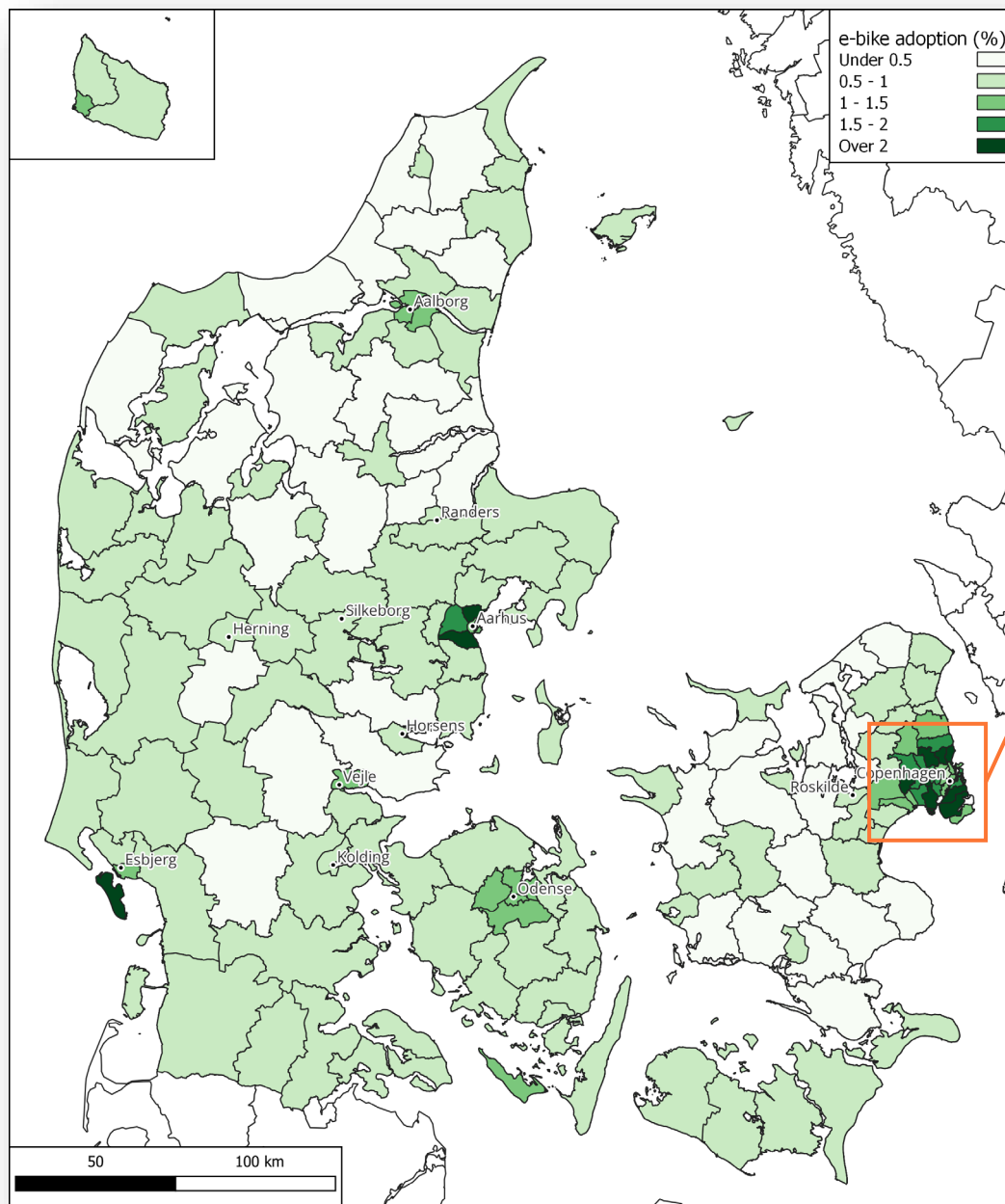


Results | SPP

Table 2: E-bike adoption (% share of total mileage) across different population segments.

	2015 (SD)		2024 (SD)		Increase		2015 (SD)		2024 (SD)		Increase	
Gender												
Male	0.08	(0.01)	0.61	(0.02)	0.53	Female	0.19	(0.01)	1.19	(0.02)		1.00
Age												
Q1	0.07	(0.01)	0.56	(0.03)	0.49	Q3	0.13	(0.01)	0.95	(0.03)		0.82
Q2	0.11	(0.01)	0.77	(0.02)	0.67	Q4	0.23	(0.02)	1.26	(0.04)		1.04
Income Family												
Q1	0.19	(0.02)	1.09	(0.04)	0.90	Q3	0.11	(0.01)	0.78	(0.03)		0.67
Q2	0.13	(0.01)	0.87	(0.03)	0.73	Q4	0.11	(0.01)	0.82	(0.03)		0.71
Home Car Ownership												
0	0.40	(0.03)	2.19	(0.07)	1.79	2	0.06	(0.01)	0.43	(0.02)		0.38
1	0.17	(0.01)	1.11	(0.03)	0.95	3+	0.04	(0.01)	0.30	(0.03)		0.26
Accessibility (car)												
Q1	0.10	(0.01)	0.64	(0.02)	0.54	Q3	0.12	(0.01)	0.81	(0.03)		0.69
Q2	0.11	(0.01)	0.76	(0.03)	0.65	Q4	0.21	(0.02)	1.43	(0.04)		1.22
Purpose												
Work/Edu.	0.11	(0.01)	0.84	(0.02)	0.72	Other	0.14	(0.01)	0.88	(0.02)		0.75

Results | SPP

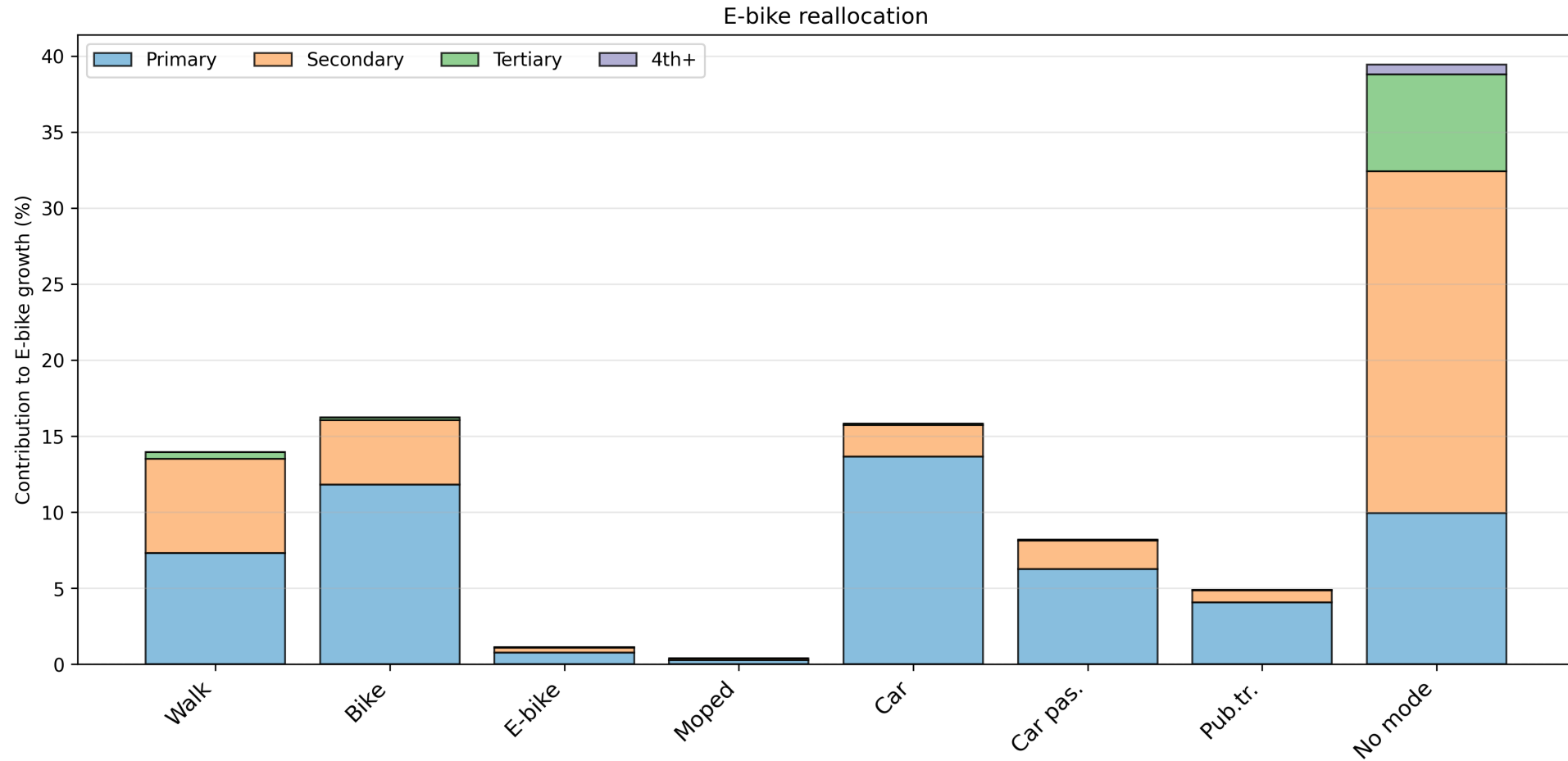


Results | SPP

- E-bike adoption.
 - Females.
 - Elderly.
 - Lower income.
 - High accessibility (urban, sub-urban).
 - No car.



Results | SPP & Reallocation (2015 to 2024)



Results | SPP & Overall market

What changed in Denmark's **transport market** given a **fixed** population over the years?

- E-bike: **increasing** in km/person
- Car: **declining** in km/person
- Bicycle: **declining** in km/person
- PT: **increasing** in km/person
- Walking: **increasing** in km/person

Total number of trips are dropping.

Average length changes are relatively small.



Sum Up

- Synthetic pseudo-panels offer a **temporal consistent approach** for adoption analysis.
- Helps understand **who adopts** e-bikes and **control** for population changes.
 - Our results indicate that e-bike growth reflects a broader shift of the transport market rather than only a shift from conventional bicycles.
- The framework could be adapted to other **emerging technologies**.

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Trafikdage 2026

Thank you!