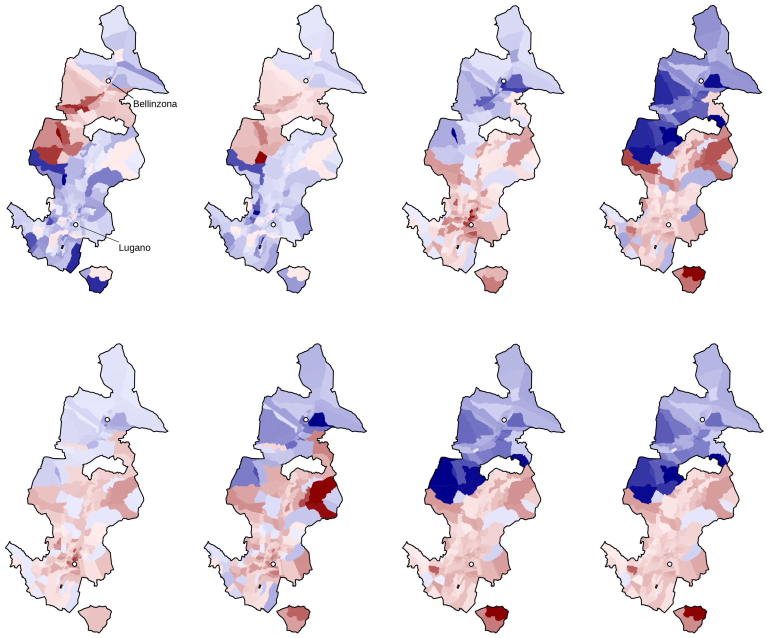

Towards a Quantitative Spatial Model for Switzerland: Prototype Implementation and Lessons Learned from Ticino

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STRC Conference Paper 2026 **May 2026**

STRC | **26th Swiss Transport Research Conference**
Monte Verità / Ascona, May 20-22, 2026

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Abstract

Quantitative spatial models (QSMs) enable general equilibrium evaluation of transport investments, yet no such model exists for Switzerland, partly because operating one at fine spatial resolution requires floorspace price data that is not publicly available. This paper proposes a *stock-inversion procedure* that recovers floorspace prices from observed building stock using the model's equilibrium conditions, bypassing this data constraint. We develop a QSM prototype for the canton of Ticino, building on Hörcher and Graham (2025), and apply it to investigate the Ceneri Base Tunnel's opening. In the Bellinzona–Lugano corridor, our model predicts employment concentration in Lugano, residential decentralisation towards Bellinzona, and agglomeration-driven productivity gains, while the average value of time declines even as total welfare rises. At the cantonal scale, the inversion produces implausible results where the observed stock reflects market forces outside the model's demand structure — such as vacation homes and retirement occupancy — revealing that the reliability of the recovered prices depends on the match between model assumptions and the forces that shaped the data. The prototype provides a foundation for a national QSM capable of evaluating how large transport investments reshape Switzerland's spatial economy.

Keywords

Ceneri Base Tunnel; floorspace prices; spatial general equilibrium; transport economics

Preferred citation

Guggisberg, D., Hörcher, D., Heinen, E. and Lapparent, M. d. (2026) Towards a Quantitative Spatial Model for Switzerland: Prototype Implementation and Lessons Learned

from Ticino, paper presented at the *26th Swiss Transport Research Conference (STRC 2026)*, Ascona, May 2026.

1 Introduction

The Ceneri Base Tunnel (CBT) opened in December 2020, cutting rail travel times between Ticino's capital, Bellinzona, and its main business centre, Lugano, by roughly half. A shock of this magnitude can be expected to change the relative attractiveness of residential and employment locations, shift land-use pressure between municipalities, and alter the economic geography of the canton.

A growing body of *quantitative spatial models* (QSMs) can evaluate such effects in general equilibrium. QSMs are a class of spatial general equilibrium models that jointly model residential and workplace location choice, wages, floorspace prices, and commuting flows from theoretically micro-founded equilibrium conditions (Redding and Rossi-Hansberg, 2017; Allen and Arkolakis, 2014). Ahlfeldt et al. (2015) developed the first QSM to study Berlin's division and reunification, whereas Heblich *et al.* (2020) applied the framework to London's historical railway expansion, and Tsivanidis (2026) extended it to evaluate bus rapid transit in Bogotá. The framework shares core features with the *spatial computable general equilibrium* (SCGE) tradition more familiar in transport research, where models such as RELU-TRAN (Anas and Liu, 2007; Anas and Chang, 2023) and the Swiss application of van Nieuwkoop (2014) integrate traffic networks with housing and labour markets. Relative to SCGE models, the methodological advantage of QSMs lies in *identification* and *transparency*: structural parameters are estimated from data using the model's own equilibrium conditions, rather than calibrated externally, and the resulting equilibria are tractable enough to make the mechanisms behind policy outcomes interpretable.

In Switzerland, SBB's SIMBA MOBi (Scherr *et al.*, 2020) and the National Passenger Transport Model [NPTM; Bundesamt für Raumentwicklung (ARE) (2026)] represent the state of the art in transport demand modelling, with land-use inputs supplied by the National Land-Use Model [FLNM; Bundesamt für Raumentwicklung (ARE) (2014)], a large-scale microsimulation *land-use/transport interaction* (LUTI) model built on FaLC (Bodenmann *et al.*, 2014). The FLNM is well established in Swiss planning practice and produces detailed demographic and land-use forecasts, but it is limited if the goal is an economic evaluation of how transport interventions reshape the spatial economy, because its behavioural models do not impose general equilibrium market-clearing conditions. Evaluating effects such as those triggered by the CBT requires a model in which transport, location choices, and the spatial economy adjust jointly — in general equilibrium. At present, no QSM exists for Switzerland, and cost-benefit analysis of major projects remains a partial equilibrium exercise that cannot account for the spatial reallocation effects that accompany large infrastructure investments.

Hörcher and Graham (2025) adapt the Ahlfeldt *et al.* (2015) framework for transport appraisal of the Elizabeth Line in Greater London. Their model extends CBA by producing general equilibrium welfare measures that account for the spatial reallocation of workers, residents, and economic activity.

This paper proposes a *stock-inversion procedure* that recovers floorspace prices from observed building stock using the QSM's equilibrium conditions. Existing QSM inversions take observed prices as an input and recover location fundamentals as residuals (Ahlfeldt *et al.*, 2015; Heblich *et al.*, 2020). Our procedure reverses the observables: under Cobb-Douglas floorspace demand, prices are identified from observed stock given the remaining equilibrium quantities. The operational contribution is the explicit invertibility criterion that links data-model compatibility to the reliability of the recovered prices, and the feasibility of running a QSM where spatially disaggregated price data is not publicly available. Building on the Hörcher and Graham (2025) framework, we construct a QSM prototype for the canton of Ticino with the CBT as the motivating transport shock. In the Bellinzona–Lugano corridor, the procedure produces well-defined equilibria. At the cantonal scale, it breaks in zones where the observed stock reflects forces outside the model's structure; the failure follows directly from the invertibility criterion and is therefore diagnostically informative.

Together, the stock-inversion procedure, the invertibility criterion, and the diagnostic use of the failure mode point toward a feasible path for developing a national QSM for Switzerland. Section 2 presents the model and the stock-inversion procedure, Section 3 reports results for the Bellinzona–Lugano corridor, Section 4 discusses model extensions that would improve inversion quality, and Section 5 concludes.

2 Model

Our prototype builds on the quantitative urban model of Hörcher and Graham (2025), itself an extension of Ahlfeldt et al. (2015). The economy consists of n discrete zones connected by a transport network and is organised in three sectors. *Households* choose where to live and work; *firms* produce a numeraire tradable good using labour and commercial floorspace as inputs; and a *construction sector* supplies commercial and residential floorspace subject to a land constraint. Full equations are in Appendix B, and complete derivations available from the above mentioned references.

A worker in zone i commuting to workplace j derives utility from leisure, consumption, and residential floorspace, subject to a Fréchet-distributed taste shock (eq. B1). The household faces two constraints: a *pecuniary budget* linking net labour income to expenditure on consumption and floorspace, and a *time budget* allocating the daily endowment between leisure, work, and commuting (eqs. B2–B3). This double-constraint structure replaces the standard iceberg treatment of transport costs, in which travel time and monetary cost cannot enter utility separately[1]. Here, both affect utility through their respective constraints, and the first-order conditions yield a pair-specific marginal value of time $v_{ij} = (w_j - \tau_{ij})/(T + t_{ij})$, where w_j is the wage at j, τ_{ij} the monetary commuting cost, T the working day, and t_{ij} commuting time. This hourly net wage varies endogenously across all origin-destination pairs. Labour supply is also pair-specific: longer commutes reduce work participation, so transport supply affects labour markets directly (eq. B4).

Location choice follows a Fréchet gravity structure governed by the composite elasticity ν (eq. B5). Floorspace is supplied by a construction sector subject to a capacity ceiling $\bar{H}_i$ that captures zoning and geographical constraints (Delventhal and Parkhomenko, 2024) (eq. B6); the quality of this ceiling's recovery depends on the floorspace price signal, as Section 3 demonstrates. The model is *invertible*: given observed data, location fundamentals are recovered as structural residuals of the equilibrium conditions (Hörcher and Graham, 2025; Allen and Arkolakis, 2014). Counterfactual analysis[2] perturbs the travel time matrix, holding fundamentals fixed, and solves for the new equilibrium. Most structural parameters are adopted from Hörcher and Graham (2025), except for the commuting elasticity ν, which has been estimated on Ticino data (Section 3). Estimation of the remaining parameters is contingent on the data and model improvements discussed in Section 4.

2.1 Stock-inversion procedure

Floorspace prices are the empirically most demanding input for this prototype. The standard QSM inversion takes observed prices as given and recovers location fundamentals (amenities, productivities, and floorspace capacity ceilings) from the equilibrium condi-

[1] In iceberg transport costs, costs are proportional to the value shipped rather than additive. This convention, originating in trade theory, means that travel time and monetary cost cannot enter the utility specification separately.

[2] A *counterfactual* scenario changes one or more model inputs while holding structural fundamentals fixed, isolating the causal effect of an intervention that may not have occurred or whose effects cannot be observed in isolation. In this paper, *scenario* refers to a counterfactual scenario unless stated otherwise.

tions (Ahlfeldt *et al.*, 2015; Hörcher and Graham, 2025). At this stage, no floorspace price index with sufficient zonal coverage could be obtained.

The prototype instead takes floorspace stock from the Federal Register of Buildings and Dwellings (RegBL) (Bundesamt für Statistik (BFS), 2019) as the observed input and recovers prices from the equilibrium demand conditions. Standard QSM inversions treat observed prices and populations as inputs and recover location fundamentals as residuals (Ahlfeldt *et al.*, 2015; Heblich *et al.*, 2020); under Cobb-Douglas floorspace demand, the rearrangement of observables from prices to stock is algebraic. The operational contribution is not the rearrangement itself but the explicit invertibility criterion derived from the supply equation, which links data-model compatibility to the reliability of the recovered prices and delivers an interpretable diagnostic where spatially disaggregated price data is not publicly available (Ahlfeldt *et al.*, 2023).

Under the Cobb-Douglas utility specification, the expenditure share on floorspace is constant, so residential floorspace demand depends only on population, the calculated mean value of time, and the price itself. The procedure rearranges this demand equation to recover residential prices from observed stock (eq. B8). Commercial floorspace prices follow a similar procedure (eq. B9). The capacity ceiling $\bar{H}_i$ recovered from the supply equation is well-defined only when floorspace prices, land area, and observed stock satisfy the model's conditions. Where this fails, the recovered ceiling contradicts its function, as Section 3 demonstrates.

3 Case study and results

3.1 Study area and data

Ticino offers a natural setting for a first prototype. The opening of the CBT in December 2020 produced a large and spatially concentrated accessibility shock: rail travel times between Locarno and Lugano fell from approximately 50 minutes to 22 minutes, and between Bellinzona and Lugano from 27 to 14 minutes.[3] Such a discrete, localised intervention is well suited to identification strategies in the QSM tradition. The canton

[3]Fastest direct service on the December 2020 timetable (SBB/TILO).

is also small enough to keep data assembly and computation manageable for a first implementation.[4] At the same time, cross-border commuters from Italy accounted for 29% of total employment in Ticino at the end of 2020, the highest share in Switzerland (Ufficio federale di statistica (UST), 2021), and the current prototype is not yet able to represent this section of the labour market.

We implement the model on the NPTM zoning system, the same spatial units used in SIMBA MOBi, so that outputs of the QSM can in principle be passed back to the respective transport models. The baseline combines employed and workplace populations, travel times, floorspace stock, and wages (see Appendix A). Data inputs are typically not reported at this fine zonal resolution, and it is here that the floorspace price problem described in Section 2 becomes binding. We report results for the 195 non-rural zones covering the Bellinzona and Lugano agglomerations, a geographically pre-specified scope that encompasses the corridor where the accessibility gain is largest. All 195 zones in this scope pass the invertibility criterion ($\Omega_i > H_i$; Appendix B). At the cantonal scale, 4 of the remaining 232 zones fail the criterion; we discuss these in Section 3.3. The baseline uses the 2017 SIMBA MOBi travel-time matrix (pre-CBT); the counterfactual replaces it with the 2023 matrix, which reflects the post-CBT timetable. All fundamentals are held fixed.

3.2 Results for the Bellinzona–Lugano corridor

Our model predicts that the CBT strengthens Lugano's role as the central business district while Bellinzona specialises as a residential location.[5] In aggregate, the Lugano agglomeration gains approximately 3,200 workers (+5%) and loses roughly 500 residents (-1%); the Bellinzona agglomeration shows the mirror image, gaining about 500 residents (+2%) while losing approximately 3,200 workers (-14%). This pattern is consistent with the standard prediction of urban economic models: a commuting cost reduction strengthens the dominant employment centre while enabling residential decentralisation. Heblich, Redding, and Sturm (2020) demonstrate this mechanism empirically for the London underground expansion.

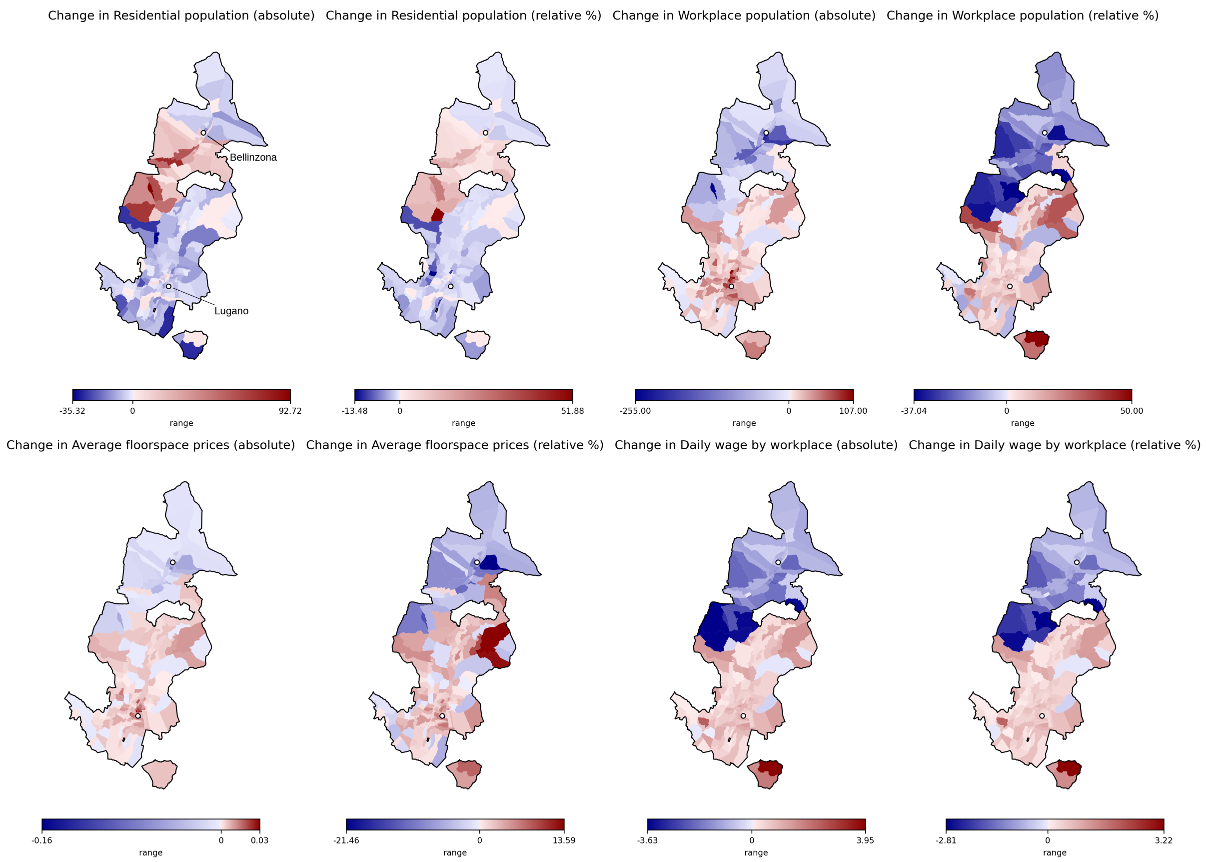
Figure 1 shows the spatial distribution of changes across the four main outcome vari-

[4] Ticino comprises 427 NPTM transport analysis zones; the national zoning system has almost 8,000 within Switzerland.

[5] Results are conditional on structural parameters largely adopted from the London case of Hörcher and Graham (2025) and should be interpreted directionally rather than as precise predictions.

ables: residential population, workplace population, average floorspace prices, and wages. Wages decline slightly across both agglomerations (Bellinzona -1.4% on average, Lugano -0.8%), reflecting the increase in effective labour supply at each workplace as commuting costs fall. Average floorspace prices across residential and commercial uses rise in Lugano (+2.0%), where the concentration of economic activity increases demand, and fall in Bellinzona (-7.1%), where the loss of productive activity reduces commercial floorspace demand by more than the residential gain from new residents. The spatial reallocation of workers also feeds back into productivity through agglomeration externalities: total factor productivity rises in Lugano (+0.3%) as employment concentrates, and falls in Bellinzona (-0.9%) as it thins out — a channel that reinforces the initial concentration effect.

Figure 1: Bellinzona–Lugano corridor: predicted changes in residential and workplace population, floorspace prices, and wages following the Ceneri Base Tunnel opening.



The average value of time experienced by commuters falls from 17.7 to 17.4 CHF/h, driven by two channels: the general equilibrium wage decline documented above, which lowers v_{ij} directly through the numerator, and a compositional shift as workers sort into longer-commute pairs that carry a lower v_{ij}. This decline does not imply a welfare loss. Following the money-metric welfare decomposition in Hörcher and Graham (2025), the model yields a welfare gain of approximately CHF 25,100 per day, or CHF 0.33 per commuter per day.[6] For comparison, Hörcher and Graham report a per-commuter welfare gain of approximately CHF 1.06 per day for the Elizabeth Line in London.[7] Workers voluntarily sort into pairs with lower v_{ij} because the overall utility on the new pair is higher. The divergence between the average VoT decline and the positive structural welfare gain connects to the theoretical literature on the value of travel time savings (Jara-Díaz, 2007). For a detailed comparison of QSM welfare with standard CBA measures, see Hörcher and Graham (2025).

3.3 Where the model breaks

At the cantonal scale, the results are less well-behaved. Alpine and peripheral zones exhibit implausible responses to the accessibility shock. The root cause lies in the stock-inversion itself: when the procedure recovers prices from building stock that reflects forces the model does not represent, the resulting prices and derived capacity ceilings become economically meaningless.

In Ticino, floorspace stock does not always reflect commuter-driven market conditions. The RegBL is a reliable register of the physical building stock, but it records structures regardless of their economic function: retired-owner occupancy, vacation homes, and unmaintained buildings all contribute to the recorded stock. In zones where such non-market occupancy is prevalent, the recorded stock exceeds what the model would predict from the local commuter-driven economic fundamentals alone. The inversion then assigns a low price to a large stock. The well-definedness condition $\Omega_i > H_i$ fails, and the recovered capacity ceiling $\bar{H}_i$ turns negative. In the counterfactual scenario, the negative ceiling enters the supply equation (eq. B6) via the congestion term $\phi_i = 1 - H_i/\bar{H}_i$. Designed to shrink the effective land input as stock approaches the ceiling, ϕ_i instead exceeds unity when $\bar{H}_i < 0$. The term then *expands* the effective land supply, favouring construction in zones where none is actually warranted. Where stock is overstated without crossing the sign threshold, the model does not break as dramatically, but a proportional

[6] The money-metric consists of an income-equivalent component (CHF 23,800/day) and a land-rent component (CHF 1,300/day). The commuting elasticity $\nu = \gamma\epsilon = 14.5$, estimated on Ticino data is high relative to the commuting gravity literature, so the welfare figure should be read as directional.

[7] London figure converted at the 2018 annual average rate of 1 GBP = 1.3056 CHF and divided by $N \approx 2.93$ million. The London counterfactual also includes a two-percent relaxation of floorspace constraints around selected stations, which the CBT calculation does not.

bias still arises.

This failure is informative. It reveals that the stock-inversion procedure is sensitive to the match between the data and the model's assumptions about what drives floorspace demand. The RegBL faithfully records the physical stock; the problem is that the current model specification generates all floorspace demand through the commuting economy and cannot account for demand outside it. An initial attempt to address the problem by replacing geographical area with developable area derived from planning zone boundaries did not resolve it but accentuated it: restricting L_i to developable land reduces Ω_i directly, pushing more zones past the failure threshold. The issue is upstream, it originates in the gap between the model's demand structure and the forces that shaped the observed stock. An alternative approach would attempt to isolate the commuter-driven component of the stock directly, filtering out vacation homes, retirement-occupied dwellings, and other non-market units before running the inversion. The RegBL records building attributes that could partially support such filtering, but the classification is imperfect and would introduce its own source of measurement error.

4 Discussion

A QSM formulation capable of capturing a broader set of market forces would produce better inverted prices from the same stock data. A *constant elasticity of substitution* (CES) consumption formulation would allow trade costs between regions to generate spatial price variation, following Monte et al. (Monte *et al.*, 2018) and Anas and Liu (Anas and Liu, 2007); this is necessary both for a national model, where the free-trade assumption within the study area no longer holds, and for remote regions where the current specification sets $p_i = 1$ uniformly despite generally higher goods prices. Explicit mode choice via a nested Fréchet structure would represent the demand response of travellers switching between road and rail, a channel that the current model cannot capture, as otherwise modelled by Herzog et al. (2024) and Tsivanidis (2026). Endogenous congestion would close the feedback loop between transport demand and travel times, as in Barwick et al. (2024) and Allen and Arkolakis (2022). An agglomeration elasticity in the floorspace production function would allow construction productivity to vary with local density, a channel through which land-use responds endogenously to economic concentration. A CES formulation and explicit mode choice would also extend the model's spatial reach, better accommodating longer-distance travel and non-urban regions where the current specification struggles. Each of these extensions changes the equilibrium price structure and therefore the conditions under which the stock-inversion yields well-defined results. A separate challenge is floorspace demand that originates outside the commuting economy entirely — retirement migration, second-home ownership, tourism — which none of the above extensions addresses and which would require additional demand channels in the model.

The stock-inversion retains practical value despite these limitations. No publicly available floorspace price index covers Swiss zones at the resolution required by QSMs, even in urban areas where the model's assumptions are well-matched. The procedure offers a feasible path for urban QSMs in Switzerland. An improved formulation does not, however, eliminate the need for better price data. The standard QSM inversion, taking observed prices as input, remains preferable when reliable data exists. Constructing a micro-geographic price index along the lines of Ahlfeldt, Carozzi, and Makovsky (Ahlfeldt *et al.*, 2023), and improving public access to spatially disaggregated transaction records, would benefit any spatially explicit economic model of Switzerland. Finally, scaling to a national model usable in practice would also require an adequate representation of cross-border labour markets, which are economically significant in several parts of the country.

5 Conclusion

This paper has developed the first quantitative spatial model for a Swiss region, a prototype applied to the Ceneri Base Tunnel in the Bellinzona–Lugano corridor. The proposed stock-inversion procedure recovers floorspace prices from observed building stock when disaggregated price data is unavailable. Where it works, the model produces general equilibrium predictions consistent with urban economic theory; where it breaks, the failure reveals that inversion quality depends on the match between the model's demand structure and the forces that shaped the data.

The prototype demonstrates that a parsimonious, theory-grounded model can produce spatially disaggregated predictions that current Swiss modelling infrastructure does not provide. The next stage of the project addresses the obstacles documented above: extending the model formulation to capture demand channels beyond the common urban commuting economy, improving transport realism, constructing a micro-geographic price index, and estimating structural parameters on Swiss data.

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A Data sources

Table A1 summarises the data inputs used in the Ticino prototype.

Table 1: Data inputs for the Ticino prototype. Baseline period: 2017–2019, pre-Covid. Employed and workplace populations are constructed from the BFS commuter matrix (published 2020, reference year 2018, pre-CBT) (Bundesamt für Statistik (BFS), 2023), observed at commune level and disaggregated to NPTM zones using the synthetic population marginals (Bundesamt für Raumentwicklung (ARE), 2019). Travel times represent the shortest travel time between public transport and road for each origin-destination pair, taken from SIMBA MOBi outputs. In a model without explicit mode choice, the minimum across modes approximates the generalised cost faced by each commuter — a simplification consistent with Ahlfeldt et al. (Ahlfeldt *et al.*, 2015), who similarly use mode-aggregated commuting times. Floorspace stock is taken from the Federal Register of Buildings and Dwellings (RegBL) as of 2019 (Bundesamt für Statistik (BFS), 2019). Wages combine BFS sectoral wage averages for Ticino with STATENT job counts by sector and zone, so they capture differences in sector composition across zones but not local within-sector wage premia. This introduces a potential bias in zones dominated by a single high-paying employer, where the cantonal sectoral average understates the actual local wage.

Input	**Source**	**Notes**
Employed population	BFS commuter matrix 2020	By NPTM origin zone
Workplace population	BFS commuter matrix 2020	By NPTM destination zone
Travel times	SIMBA MOBi 2017 and 2023	Shortest time across modes, by OD pair
Floorspace stock	RegBL 2019	Buildings existing pre-Covid
Wages	BFS wages by NOGA sector for Ticino + STATENT jobs by sector and zone	Captures sector mix, not within-sector wage differences

B Model equations

This appendix collects the model equations summarised verbally in Section 2; notation and derivations follow Hörcher and Graham (Hörcher and Graham, 2025) and Ahlfeldt et al. (Ahlfeldt *et al.*, 2015).

Household utility. A worker residing in i and working in j derives utility from leisure L_{ij}, consumption C_{ij}, and residential floorspace H^R_{ij}, subject to an idiosyncratic taste shock z_{ij}:

$$U_{ij} = \left(\frac{L_{ij}}{1-\gamma}\right)^{1-\gamma} \left(\frac{K_{ij}}{\gamma}\right)^{\gamma} z_{ij}, \qquad K_{ij} = \left(\frac{C_{ij}}{\beta}\right)^{\beta} \left(\frac{H^R_{ij}}{1-\beta}\right)^{1-\beta}. \tag{B1}$$

Budget constraints. The pecuniary budget links net labour income to expenditure:

$$x_{ij}(w_j - \tau_{ij}) = p_i C_{ij} + q_i H^R_{ij}, \tag{B2}$$

where x_{ij} is individual labour supply, w_j the wage at j, τ_{ij} monetary commuting cost, and p_i, q_i the prices of goods and floorspace at i. The time budget allocates the daily endowment $\bar{L}$:

$$\bar{L} = L_{ij} + x_{ij}(T + t_{ij}). \tag{B3}$$

Labour supply and value of time. The first-order conditions yield the marginal value of time $v_{ij} = (w_j - \tau_{ij})/(T + t_{ij})$ (eq. 1 in the main text) and individual labour supply:

$$x_{ij} = \frac{\gamma \bar{L}}{T + t_{ij}}. \tag{B4}$$

Commuting gravity. With Fréchet-distributed taste shocks (shape ϵ, location-specific scales X_i, E_j), the share of workers living in i and working in j is:

$$\lambda_{ij} = \frac{X_i E_j \left[\frac{v_{ij}}{p_i^{\beta} q_i^{1-\beta}}\right]^{\gamma\epsilon}}{\sum_{r,s} X_r E_s \left[\frac{v_{rs}}{p_r^{\beta} q_r^{1-\beta}}\right]^{\gamma\epsilon}}. \tag{B5}$$

In the discrete choice literature, the location-specific scales X_i and E_j play the same role as alternative-specific constants in logit models. The Fréchet distribution belongs to the Type II extreme value family and produces choice probabilities consistent with the McFadden random utility framework (McFadden, 1974).

The composite exponent $\nu = \gamma\epsilon$ governs the sensitivity of commuting flows to transport costs. Residence and workplace populations are $N_i^R = N \sum_j \lambda_{ij}$ and $N_j^W = N \sum_i \lambda_{ij}$.

Floorspace supply. Total floorspace $H_i = H_i^R + H_i^W$ is produced from capital Z_i and land L_i:

$$H_i = Z_i^{1-\psi} \left(\phi_i(H_i)\, L_i\right)^{\psi}, \qquad \phi_i(H_i) = 1 - H_i/\bar{H}_i, \tag{B6}$$

where $\bar{H}_i$ is a capacity ceiling (Delventhal and Parkhomenko, 2024).

Production and wages. Firms produce a tradable good with Cobb-Douglas technology in effective labour $M_j^W = \sum_i \lambda_{ij} x_{ij} N$ and commercial floorspace H_j^W, scaled by productivity A_j. Free trade within the study area normalises $p_i = 1$. The zero-profit condition gives:

$$w_j = \alpha\, A_j^{1/\alpha} \left(\frac{1-\alpha}{Q_j}\right)^{(1-\alpha)/\alpha}. \tag{B7}$$

Stock-inversion procedure. When floorspace prices are not observed, they can be recovered from observed stocks by inverting the demand conditions. The residential price follows from the floorspace demand equation:

$$q_i = \frac{(1-\beta)\,\gamma\,\bar{L}\,N_i^R\,\overline{v}_i}{H_i^R}, \tag{B8}$$

where $\overline{v}_i = \sum_j \lambda_{j|i}\, v_{ij}$ is the mean value of time for residents of zone i. The commercial price follows from the cost-share condition:

$$Q_j = \frac{(1-\alpha)}{\alpha}\, w_j\, \frac{M_j^W}{H_j^W}. \tag{B9}$$

An apparent circularity arises because the joint commuting probabilities λ_{ij} (eq. B5) depend on q_i. However, the residential inversion uses the *conditional* workplace choice probabilities $\lambda_{j|i} \propto E_j\, v_{ij}^{\gamma\epsilon}$, which condition on residence and do not depend on q_i. The mean value of time $\overline{v}_i$ is therefore computable from workplace amenities E_j and bilateral values of time alone. The procedure is sequential: (1) estimate workplace amenities E_j and ϵ from the commuting gravity equation; (2) compute $\overline{v}_i$ from conditional probabilities; (3) invert residential prices via eq. B8; (4) estimate residential amenities X_i; (5) compute joint probabilities λ_{ij} and mean labour supply $\bar{x}_j$; (6) invert commercial prices via eq. B9. The residential inversion is algebraic, not iterative, and the overall pipeline is sequential rather than a fixed point in q_i.

The capacity ceiling $\bar{H}_i$ recovered from the supply eq. B6 is well-defined only when $\Omega_i = [(1-\psi)\bar{q}_i]^{(1-\psi)/\psi} \cdot L_i > H_i$, where $\bar{q}_i$ is the average floorspace price and H_i the observed total stock. In the Bellinzona–Lugano corridor (195 zones), all capacity ceilings are well-defined. At the cantonal scale, 4 of 427 zones yield negative $\bar{H}_i$; these are the zones discussed in Section 3.

Equilibrium and inversion. Given fundamentals $\{X_i, E_j, A_j, \bar{H}_i\}$ and cost matrices $\{\tau_{ij}, t_{ij}\}$, a spatial general equilibrium simultaneously clears the labour, goods, and floorspace markets. The model is *invertible*: given observed data in a baseline year, location fundamentals are recovered as structural residuals of the equilibrium conditions (Hörcher and Graham, 2025). Counterfactual analysis perturbs the travel time matrix, holding fundamentals fixed, and solves for the new equilibrium.