The spatial effect of changes in regional characteristics

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Overview

Definition

Regional characteristics:

properties of geographical regions which may influence the residential **location choice** of households.

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Examples:

- city districts
- counties
- federal states
- nations (of a confederation such as the EU)

Basics

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Overall utility:

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$\hookrightarrow$ utility maximizing location choice **probabilities**:

$$\pi_{hr} = \frac{\exp(\lambda U_{hr})}{\sum_{r'} \exp(\lambda U_{hr'})}$$

The deterministic utility

The assumed form of the (deterministic) utility function is:

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Remarks:

- Inc_{hr} denote per household income levels
- px_{hr} denote price indices
- The above formulation is usually called indirect utility function
- q_{hr} denote inherent location attractiveness parameters
  $\hookrightarrow$ calibration

Calibration of household location choice

Given:

- $\bar{Inc}_{hr}$ per household income levels (benchmark)
- $\bar{\pi}_{hr}$ household location choice probabilities (benchmark)
- N_h number of households of type h

Note: $N_h \cdot \bar{\pi}_{hr}$ is the number of households of type h in region r in the benchmark.

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Wanted:

$$\pi_{hr} = \frac{\exp(\lambda U_{hr})}{\sum_{r'} \exp(\lambda U_{hr'})} = \frac{\exp(\lambda(\bar{Inc}_{hr} + q_{hr}))}{\sum_{r'} \exp(\lambda(\bar{Inc}_{hr'} + q_{hr'}))} \stackrel{!}{=} \bar{\pi}_{hr}$$

Since the income levels are given, only the parameters q_{hr} can be used to calibrate the location choice probabilities.

Example

Let us assume the following:

- Only one household type, two regions $R = \{1, 2\}$
- $I\bar{n}c_1 = 5.2$ and $I\bar{n}c_2 = 3.7$
- Free parameter $\lambda = 1$
- $\bar{\pi}_1 = \bar{\pi}_2 = 0.5$

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Problem: There is generally no unique solution!

Solution 1: Solution 3: ...

Selecting unique parameter values

Unique parameter values are selected with the help of a constrained optimization procedure:

$$\text{for all } h:$$
$$\min \sum_r q_{hr}^2$$
$$\text{subject to } \bar{\pi}_{hr} = \frac{\exp(\lambda(\bar{Inc}_{hr} + q_{hr}))}{\sum_{r'} \exp(\lambda(\bar{Inc}_{hr'} + q_{hr'}))}$$

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Interpretation: Find, among all feasible values, those with the smallest sum of squares.

Note that the first order condition on the objective function implies that $\sum_r q_{hr} = 0$ for all h.

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Back to the example:
$q_1 = -0.75$ and $q_2 = 0.75$.

Explaining the location choice

The example gave $q_1 = -0.75$ and $q_2 = 0.75$.

$\hookrightarrow$ There must be characteristics of region 2, apart from income, which cause a higher attractiveness for households to reside there (compared with region 1).

Explaining the location choice

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$\hookrightarrow$ There must be characteristics of region 2, apart from income, which cause a higher attractiveness for households to reside there (compared with region 1).

Generally, a way to find out is to regress the q_{hr} on available regional characteristics g_{br}.

$$q_{hr} = \mu_h + \sum_{b \in B} \delta_{bh} \cdot g_{br} + \nu_{hr}$$

Note that:

- Other, possibly non-linear regression functions are allowed
- $|B| \ll |R|$ to obtain meaningful estimates

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- Here: $\delta = \frac{q_1 - q_2}{g_1 - g_2} = 0.3$ and $\mu = q_1 - \delta \cdot g_1 = -23.5$

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Now, it is possible to simulate how changes in g_r affect q_r and thus, the population distribution π_r.

Welfare function

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The evaluation criterion will be the following welfare function, which, technically, is the expected maximum utility (Anas/Xu, 1999):

$$W_h = \left(\sum_r \pi_{hr} \cdot U_{hr} \right) - \frac{1}{\lambda_h} \sum_r \pi_{hr} \cdot \ln \pi_{hr}$$

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The direct welfare impact

Assume the regional characteristics take new values $\tilde{g}_{br}$.
These affect the location attractiveness parameters:

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These affect the location attractiveness parameters:

$$\tilde{q}_{hr} = \mu_h + \sum_{b \in B} \delta_{bh} \cdot \tilde{g}_{br} + \nu_{hr},$$

Only the location choice probabilities are affected directly:

$$\tilde{\pi}_{hr} = \frac{\exp\left(\lambda(Inc_{hr} + \tilde{q}_{hr})\right)}{\sum_{r'} \exp\left(\lambda(Inc_{hr'} + \tilde{q}_{hr'})\right)}$$

The new welfare level containing the direct effect is:

$$\tilde{W}_h^{dir} = \left(\sum_r \tilde{\pi}_{hr} \cdot (Inc_{hr} + \tilde{q}_{hr}) \right) - \frac{1}{\lambda_h} \sum_r \tilde{\pi}_{hr} \cdot \ln \tilde{\pi}_{hr}$$

Example: Direct welfare impact

Again the example:

Benchmark welfare level:

$$W^{bm} = 0.5(5.2 - 0.75) + 0.5(3.7 + 0.75) - (0.5\ln(0.5) + 0.5\ln(0.5))$$
$$= 5.143$$

Assume that the air quality index in region 2 drops by 1 point:
$\tilde{g}_2 = g_2 - 1 = 79$, $\tilde{g}_1 = g_1 = 75$:

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Assume that the air quality index in region 2 drops by 1 point: $\tilde{g}_2 = g_2 - 1 = 79$, $\tilde{g}_1 = g_1 = 75$:

$\hookrightarrow \tilde{q}_2 = 0.45$
$\hookrightarrow \tilde{\pi}_2 = 0.426$
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Counterfactual welfare level (only including the direct effect):

$$\begin{aligned} \tilde{W}^{dir} =& 0.574(5.2 - 0.75) + 0.426(3.7 + 0.45) - \\ & (0.574\ln(0.574) + 0.426\ln(0.426)) \\ =& 5.004 \end{aligned}$$

The total welfare impact

The total welfare impact consist of the direct and indirect impact:

The indirect impact includes changes of Inc_{hr} and px_{hr} resulting from a **spatial shift** of economic activity.

This shift depends on how households interact with **other sectors** and how these sectors interact with each other.

In this multiregional model, **multiregional** I-O tables describe those interactions.

Data basis

Data basis: Interregional social accounting matrix (IRSAM)

		region 1					region 2				
		sector 1	sector 2	sector 3	sector 4	households	sector 1	sector 2	sector 3	sector 4	households
region 1	sector 1	0.6	0.4	0	0	1.6	0.2	0.2	0	0	0.8
	sector 2	0.2	0.5	0	0	1.6	0.1	0.3	0	0	1.2
	sector 3	1.1	1.6	0	0	0	0	0	0	0	0
	sector 4	1.5	1	0	0	0	0	0	0	0	0
	households	0	0	1.8	1.5	0	0	0	0.8	1.1	0
region 2	sector 1	0.3	0.2	0	0	0.8	0.3	0.1	0	0	0.5
	sector 2	0.1	0.2	0	0	1.2	0.1	0.8	0	0	1.2
	sector 3	0	0	0	0	0	0.6	1.5	0	0	0
	sector 4	0	0	0	0	0	0.9	0.7	0	0	0
	households	0	0	0.9	1	0	0	0	1.3	0.5	0

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Method to derive intraregional I-O relations (FLQ formula) and interregional I-O relations (gravity model) from national tables:

Jahn, M. (2016): Extending the FLQ Formula: A Location Quotient-based Interregional Input-Output Framework, *Regional Studies*, doi: 10.1080/00343404.2016.1198471.

The aggregate model (1)

The household expenditure from the IRSAM is used to calibrate a CES utility function:

$$U_{hr} = A_{hr} \left(\sum_{m \in M, s \in R} \beta_{mhsr} \cdot C_{mhsr}^{\rho_h} \right)^{1/\rho_h}$$

with

- A_{hr} ($A_{hr} > 0$) scale parameter
- C_{mhsr} quantities demanded by a household of type h located in region r from final sector m ($m \in M$) in region s. Interpretation $C_{m \to h}^{s \to r}$
- β_{mhsr} ($\beta_{mhsr} \geq 0$; $\sum_{m,s} \beta_{mhsr} = 1$) share parameters
- ρ_h ($-\infty < \rho_h < 1$) elasticity of substitution parameter

Note that the CES function can be written as $U_{hr} = {}^{Inc_{hr}}/_{px_{hr}}$.

The aggregate model (2)

Other supply and demand functions can be calibrated from the IRSAM:

- Factor supply functions of households
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The location choice is included in the **general equilibrium** through the market clearing equations (here for primary factors $f \in F$ in region r):

$$\sum_{h \in H, s \in R} N_h \cdot \pi_{hs} \cdot S_{hfsr} = \sum_{m \in M, s \in R} Y_{fmrs}$$

Interpretation of the individual household supply: $S_{h \to f}^{s \to r}$

Interpretation of the primary input demands: $Y_{f \to m}^{r \to s}$

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- Thereof direct welfare impact: 2.776 billion €

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Extensions:

- Household types $h = \{s, r\}$, i.e. simultaneous choice of zone of residence and zone of work ($\rightarrow$ commuting)
- Introduce sectoral emissions intensities and their effect on air quality ($\rightarrow$ regional integrated assessment model)
- Introduce time t ($\rightarrow$ e.g. long-term impacts of climate change)

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