Exiopol Summerschool
Venice, July 2010

Prof.dr. Jan Oosterhaven, session 1:

- Demand-driven models & single-region IO
- Interregional IO spillovers and feedbacks
- IRIOS: additional variables and extra relations
- IO prices and the supply-driven IO model
Demand-driven models: general principle

Exogenous demand shock $D$

Endogenous output/income/employment impact $Y$

Multiplier process = $1*D + a*D + a^2*D + a^3*D + … = (1 - a)^{-1} *D$

Direct output impact $1*D$

Thus: endogenous impact $Y = Y$- multiplier of $D$ * exogenous shock $D$

Fig. 4.1 Keynesian income-expenditure multiplier model
IO model: data from IO table

<table>
<thead>
<tr>
<th></th>
<th>Agriculture</th>
<th>Manufacturing</th>
<th>Services</th>
<th>Cons Invest</th>
<th>Gov’t</th>
<th>Export</th>
<th>Σ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td>Total output</td>
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<td><strong>Agri</strong></td>
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<td><strong>Man</strong></td>
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<tr>
<td><strong>Imp GDP</strong></td>
<td>Primary inputs = matrix V</td>
<td>Primary inputs of final demand</td>
<td>M</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(imports and value added)</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Σ</strong></td>
<td>Total input = total output = x’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C I G E</td>
</tr>
</tbody>
</table>

IO sectorally desaggregates the macro identity \( Y = C + I + G + E - M \)
**Standard (Leontief) IO model**

(1) Total demand => total output = total input per sector:
- \( x_i = \sum_j z_{ij} + \sum_q f_{iq} \)  \( (x = Z i + F i) \)
- **row** total of intermediate & final demand => output = input

(2) Total input => demand per purchasing sector:
- \( z_{ij} = a_{ij} x_j \) and \( v_{pj} = c_{pj} x_j \)  \( (Z i = A x \text{ and } V i = C x) \)
- total input => intermediate, primary & EE inputs per **column**

(3) **Solution** by substitution of \( z_{ij} = a_{ij} x_j \) into (1) =>
- \( x_i = \sum_j a_{ij} x_j + f_i \)  \( (x = A x + f) \)
Solution standard IO model

again: \( x = Ax + f \Rightarrow (I - A)x = f \)

(4) Premultiply with \( L = (I - A)^{-1} \) (Leontief-inverse):

\[ \Rightarrow x = (I - A)^{-1}f \quad \text{and} \quad Vi = Ci (I - A)^{-1}f \]

or: \( x_i = \sum_j l_{ij} f_j \quad \forall i \quad \text{and} \quad \sum_i v_{pi} = \sum_i \sum_j c_{pi} l_{ij} f_j \quad \forall p \)

• production \( i = \) Leontif-row \( i \ast \) final demand column

• final demand \( \Rightarrow \) total input \( \Rightarrow \) imports, value added & EE !
Causality standard IO model

Exogenous final demand: \( f \)

Endogenous total input: \( x \)

Endogenous primary inputs and EE: \( C \times x \)

Endogenous intermediate inputs: \( A \times x \)

\[ x = (I + A + A^2 + A^3 + \ldots) \]

\[ f = L \ f \quad \text{(direct + indirect)} \]

\[ v = C \times x = C \times L \ f \quad \text{(direct + indirect)} \]
Endogenous IO consumption

Exogenous final demand → Intermediate inputs → Gross output → Value added, jobs, EE

Labour incomes

Consumption expenditures = Q x

\[ v = C x = C (I - A - Q)^{-1} f \ (direct + indirect + induced) \]
### Bi-regional IO table in symbols

<table>
<thead>
<tr>
<th>$Z^{rr}$</th>
<th>$Z^{rs}$</th>
<th>$F^{rr}$</th>
<th>$F^{rs}$</th>
<th>$e^r$</th>
<th>$x^r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z^{sr}$</td>
<td>$Z^{ss}$</td>
<td>$F^{sr}$</td>
<td>$F^{ss}$</td>
<td>$e^s$</td>
<td>$x^s$</td>
</tr>
<tr>
<td>$m^r$</td>
<td>$m^s$</td>
<td>$m^r_f$</td>
<td>$m^s_f$</td>
<td>-</td>
<td>$M^{nat}$</td>
</tr>
<tr>
<td>$V^r$</td>
<td>$V^s$</td>
<td>$V^r_f$</td>
<td>$V^s_f$</td>
<td>-</td>
<td>$Y^{nat}$</td>
</tr>
<tr>
<td>$x^r$</td>
<td>$x^s$</td>
<td>$C^r$</td>
<td>$I^r$</td>
<td>$G^r$</td>
<td>$E^{nat}$</td>
</tr>
</tbody>
</table>

Note macro-economic accounting identity:

$$Y^{nat} = \sum_r C^r + \sum_r I^r + \sum_r G^r + E^{nat} - M^{nat}$$
Causal change in IO model when going interregional

Smaller exogenous final demand

Formerly exogenous intermediate exports become endogenous

Larger multipliers to maintain the same output

\[ y^r = f^r (+ Z_{rsi}) \]
\[ y^s = f^s (+ Z_{sri}) \]

\[ Z^{rr} \rightarrow x^r \rightarrow Z^{sr} \rightarrow x^s \rightarrow Z^{ss} \]
Solution bi-regional IO model

• Output follows the split-up in demand:
  \[ x^r = Z^{rr} i + Z^{rs} i + f^r = A^{rr} x^r + A^{rs} x^s + f^r \]
  \[ x^s = Z^{sr} i + Z^{ss} i + f^s = A^{sr} x^r + A^{ss} x^s + f^s \]

• Solution: math identical, economics different
  \[ x = A^* x + f \Rightarrow x = (I - A^*)^{-1} f = L^* f \]

| \( L^{rr} \) | \( L^{rs} \) |
| \( L^{sr} \) | \( L^{ss} \) |

\[ L^{rr} = [ I - A^{rr} - A^{rs} (I - A^{ss})^{-1} A^{sr} ]^{-1} = \]
old intra-region effect \( rr \) + interregional feedbacks
(= spillover \( rs \) * old intra-region effect \( ss \) * spillover \( sr \))

\[ L^{sr} = A^{sr} [ I - A^{rr} - A^{rs} (I - A^{ss})^{-1} A^{sr} ]^{-1} = \]
spillover \( sr \) * new larger intra-regional effect \( rr \)
Interregional spillovers and feedbacks

Feedback R-to-R = Spillover R-to-O * Intra-effect O * Spillover O-to-R
Interregional Input-Output Software

Downloadable at: www.REGroningen.nl/irios
Purpose: easy and flexible

• Easy data input & model output
  – exchangeable with other software

• Usable for all types of i-o tables:
  – interregional, but also single-region and national IOTs

• All standard i-o analyses covered:
  – descriptive statistics, linkage analyses
  – additional variables, flexible model extensions
  – multiplier and impact analyses
Basic characteristics

- no table construction
- no fancy stuff you can do elsewhere (graphics)
- Table files (.tbl) = only the basic i-o table
- Model files (.mdl) = all extra information you add yourself to build your model
- generalized Dimensions, no size restrictions
- generalized endogenous Variables, no feedback
- generalized endogenous Relations, with feedback
Generalized Dimensions

- \( r \) = regions
- \( i \) = sectors
- \( f_1 \) = regional final demand categories
  - regional origin and regional destination
- \( f_2 \) = other final demand categories
  - only regional origin, no regional destination
- \( k \) = primary costs categories
  - only regional destination, no regional origin
- **flexible Aggregation** of:
  - i-o table, e.g. from interregional to national
  - i-o statistics, multipliers and impacts
An IRIOS table in Spreadsheet format

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
| 1 | 2 | 4 | 2 | 3 | 5 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 2 |   |   |   |   |   | table name |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 3 | reg1 | reg1 | reg1 | reg2 | reg2 | reg2 | reg1 | reg1 | reg2 | reg2 |   |   | Total |   |   |   |   |   |   |   |   |   |   |   |
| 4 | sec1 | sec2 | sec3 | sec4 | sec1 | sec2 | sec3 | sec4 | fin1 | fin2 | fin1 | fin2 | ofin1 | ofin2 | ofin3 |   |   |   |   |   |   |   |   |   |   |   |
| 5 | reg1 | sec1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 6 | reg1 | sec2 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 7 | reg1 | sec3 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 8 | reg1 | sec4 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 9 | reg2 | sec1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 10 | reg2 | sec2 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 11 | reg2 | sec3 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 12 | reg2 | sec4 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 13 |   |   | other | pc1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 14 |   |   | other | pc2 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 15 |   |   | VA | pc3 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 16 |   |   | VA | pc4 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 17 |   |   | VA | pc5 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 18 | Total |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

- **red** = obligatory
- **blue** = optional for explanatory purposes
- **other** = optional

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Basic model + Extra Variables

Standard Leontief model for total output:
\[ x = (I - A)^{-1} f \]

Standard extra Variables for primary cost:
\[ v = \langle c \rangle x = \langle c \rangle (I - A)^{-1} f \]

Add other extra Variables yourself, with:
\[ c' = \text{employment coefficients, emission coefficients, etc. (per unit of output)} \]
Basic model + Extra Relations

Extra Variables: \( v = <c> ( I - A )^{-1} f \)
    have NO feedback on output

Extra Relations: \( x = ( I - A - Q )^{-1} f_{ex} \)
    DO have a feedback on output

\( Q = \) expenditure coefficients per unit of output
    (can be constructed from the IO table)
Example with data of IO table

Interregional Q: without commuting

\[
\begin{array}{c|c|c|c|c}
& r1 & r2 & c1 & c2 \\
\hline
Q1 & & & & \\
\hline
Q2 & & & & \\
\hline
0 & & & & \\
0 & & & & \\
\end{array}
\]
Adding savings and tax ratios

Single-region: \[ q_{ij}^{rrr} = p_i^{rrr} (1 - s^{rr})(1 - t^{rr}) w_j^{rr} \]

Outcommuters: \[ q_{ij}^{rrs} = p_i^{rrs} (1 - s^{rs})(1 - t^{rs}) w_j^{rs} \]

- \( w_{rj}^{s} \) = per unit wages of people living in region \( r \) earned in region \( j \) in region \( s \)
- \( t^{rs} \) = tax rate on wages people living in region \( r \) working in region \( s \)
- \( s^{rs} \) = savings rate of people living in region \( r \) working in region \( s \)
- \( p_i^{rrs} \) = share of products from sector \( i \) in region \( r \) per unit of consumption of people living in region \( r \) working in region \( s \)

(Note that \( p \) here is split-up in the IO Syllabus in \( p \) and \( t \).)
Causal change of adding cons. relation to bi-regional IO model

Smaller exogenous final demand

Formerly exogenous consumption becomes endogenous

Larger multiplier effects to maintain the same output

\[ f_r = f_r^{ex} ( + c_{rr} + c_{rs}) \]

\[ f_s = f_s^{ex} ( + c_{sr} + c_{ss}) \]
Overview possible extra Relations

production => wages => consumption => production (so-called Type II multipliers)

production => wages => (-) unemployment benefits => consumption => production (so-called Type III multipliers)

production => tax revenues => government expenditures => production (balanced budget mult.)

production => cash flow => gross investments => production
Extra Relations continued

Effects of extra Relations on extra Variables:
\[ v = <c + q_c> \quad x = <c + q_c> \left( I - A - Q \right)^{-1} f^x \]

Unique for IRIOS: besides *indirect* effects via output on Variables, also *direct* effects on Variables, e.g. of endogenous consumption on EE

\[ q_c = \text{primary cost and EE coefficients for endogenous expenditures per unit of output} \]
General IRIOS equation

\[ V_{111} + ... + V_{\text{ief}} + ... + V_{\text{IEF}} = \langle \hat{c}_1 + ... \hat{c}_i + ... \hat{c}_l \rangle \]

\[ (I - A - Q_1 - ... Q_e - ... Q_E)^{-1} < \hat{y}_1 + ... \hat{y}_f + ... \hat{y}_F \rangle \]

\( V_{\text{ief}} \) = interregional endogenous **effect** matrix for variable \( i \) through relation \( e \) of impuls \( f \),
\( \hat{c}_i \) = diagonal **coefficients** matrix for (additional) variable \( i \),
\( A \) = interregional intermediate input **coefficient** matrix,
\( Q_e \) = interregional **coefficient** matrix for extra endogenous relation \( e \),
\( \hat{y}_f \) = diagonal final demand **impulse** matrix for impuls \( f \)
Exiopol Summerschool

Venice, July 2010

Prof.dr. Jan Oosterhaven, session 2

• IO prices and the supply-driven IO model
• the Exiopol international supply/use table
• calculating direct and indirect EE impacts: multiplier versus impact analysis
• what other uses of EE-IO data?
Back to IO theory

- Where are the prices in these IO models?
- IO = corner-solution type CGE model with two independent submodels, with the values of the IO transactions as common denominator:
  - Standard demand-driven IO quantity model
  - Dual cost-push IO price model, with:
    - Value final demand = value primary inputs:
      \[ p'y = p'v'C'L'y = p'v'y \]
      , with:
      \[ p' = \text{transposed column = row with prices} \]
Standard IO quantity model and its cost-push dual price model (Leontief)

Quantities: total output = intermediate demand + exogenous final demand:
\[ x = A x + f \Rightarrow x = (I - A)^{-1} f \]

Prices: output prices = intermediate input prices + exogenous primary input prices:
\[ p' = p_v' C + p' A \Rightarrow p' = p_v' C (I - A)^{-1} \]

Source: Southern Economic Journal, 1996
Backward & Forward linkages

From demand-driven model

Exogenous final demand $f$

Gross output $x$ → Intermediate inputs $(A \times x)$

$x = (I + A + A^2 + A^3 + \ldots) f$
$= L f$ (direct + indirect)
Columns $L - I =$ backward

From supply-driven model

Exogenous primary cost $k'$

Gross input $x'$ → Intermediate outputs $(x' B)$

$x' = v' (I + B + B^2 + B^3 + \ldots)$
$= v' G$ (direct + indirect)
Rows $G - I =$ forward links
Markets in both IO models

Leontief P- en Q-model:

Ghosh P- en Q-model:

Source: Southern Economic Journal, 1996
Plausibility of both IO models

Leontief, demand-driven:
– Homogeneous output, i.e. full substitutability along the rows of the IO table
– Heterogenous inputs, full complementarity in columns
– No supply constraints
– Primary cost price increases are fully passed on to final output according to cost shares

Ghosh, supply-driven:
– Homogeneous input, i.e. full substitutability along columns of the IO table
  • Cars without gas
  • Factories without labour
– Heterogenous outputs, full complementarity in rows
– No demand constraints
– Final demand price increases are fully passed on to primary inputs according to revenue shares
Linkages example: Northern Netherlands

National backward linkages (from IRIOS) = \( i'\text{L} - i' = \) horizontal
National forward linkages (from IRIOS) = \( G_i - i = \) vertical

Size circles = % value added (from IRIOS)
Exiopol IO database issues

• Choice for an international supply-use table (SUT)
  – Less theoretical assumptions needed for database
  – Larger availability compared to national IO tables
  – Environmental data and trade data often product related (not presently used in EXIOPOL)

• Role of the Groningen: trade-linking of national SUTs

Supply table

Use table

● = all countries of the world

o = all countries except S
Valuation issues

- National supply tables in basic prices
- National use tables in purchaser prices
- IO theory requires basic prices by country of origin
  - Basic price info is lacking for imports

<table>
<thead>
<tr>
<th>Country</th>
<th>Domestic valuation</th>
<th>International trade (exports by R/imports by S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Basic prices R</td>
<td>Basic prices R (Supply table)</td>
</tr>
<tr>
<td>R</td>
<td>+ Valuation layer: taxes and subsidies</td>
<td>+ Valuation layer: taxes and subsidies</td>
</tr>
<tr>
<td>R</td>
<td>+ Valuation layer: trade and transport</td>
<td>+ Valuation layer: trade and transport</td>
</tr>
<tr>
<td>R</td>
<td><strong>Purchaser prices R</strong></td>
<td>= <strong>Exports f.o.b. R</strong></td>
</tr>
<tr>
<td>International</td>
<td><strong>Not possible at national level</strong></td>
<td>+ Valuation layer: international trade and transport and import margins</td>
</tr>
<tr>
<td>S</td>
<td><strong>Basic prices S</strong></td>
<td>= <strong>Imports c.i.f S</strong> (Use table)</td>
</tr>
<tr>
<td>S</td>
<td>+ Valuation layer: taxes and subsidies</td>
<td>+ Valuation layer: taxes and subsidies</td>
</tr>
<tr>
<td>S</td>
<td>+ Valuation layer: trade and transport</td>
<td>+ Valuation layer: trade and transport</td>
</tr>
<tr>
<td>S</td>
<td><strong>Purchaser prices S</strong></td>
<td><strong>Purchaser prices S</strong></td>
</tr>
</tbody>
</table>
National re-pricing of use table only reallocates domestic margins

With trade and transport margins attributed to sectors that produce the margins
National SUTs are split up

1. Between domestic and foreign products
2. Between the different origins & destinations

Domestic Supply Table
Export Supply Table
National Supply Table
National Use Table
Import Use Table
42x Export Ratios
42x Import Ratios

42 bilateral import use tables
Establishing consistency

- **Inconsistencies** are due to:
  - Different sources of trade data: SUT and trade data
  - Export data ≠ import data (valuation differences etc.)

- **Accounting identities** that should hold are:
  - Sum over columns of all import use tables = exports of products
  - Sum over rows of all export supply tables = import of products
  - Products exported by A to B = products imported by B from A

- **Solution**: apply an extended generalized RAS algorithm (Junius and Oosterhaven, 2003) to regain consistency
  - This (implicitly) re-prices imports from c.i.f. to f.o.b.
Using Exiopol IOTs with IRIOS

- Two files: Model (.mdl) & Table (.tbl)
- IRIOS specifies a *model* based on a *table*
- Open/Model: table is already included
- New/Model: choose a table to work with
- Save/Model: table is saved with the model
  - This stores all info added to the table, thus:
    Additional variables & Extra relations & Exogenous impulses
Standard versus normalized multipliers

**Normalized** multiplier = **Standard** multiplier / **Direct** coëfficiënt

- advantage: normalized multiplier is **dimensionless** (jobs/jobs, joules/joule, kg/kg etc.), and therefore **more stable over time**!

- example:
  \[1,5 = 18 / 12 = \left( \sum_s c_s^R l_{si}^{RR} \right) / c_i^R\]
  with:

  - \(1,5\) = **normalized EE multiplier** of sector \(i\) in \(R\)
  - \(18\) = **standard EE multiplier** of sector \(i\) in \(R\) = total (direct + indirect) EE impact in regio \(R\) per mln exogenous final demand of \(i\) in \(R\)
  - \(12\) = **direct EE coefficient** of sector \(i\) in \(R\) = direct EE impact in sector \(i\) in \(R\) per mln output of \(i\) in \(R\)
Impact analysis with IRIOS

• Simply define a series of exogenous impulses as columns $f^{ex}$
• IRIOS then calculates production effects:
  $x = (I - A)^{-1} f^{ex}$
  and
  variable effects (e.g. EE impacts):
  $v = C x = C (I - A)^{-1} f^{ex}$

OKAY: let’s try it
Overview IO analysis in practice 1

• **Direct and indirect everything**
  – Exports, employment, energy, CO$_2$, prices
  – Based on the analysis of multipliers

• **Analysis of structure and change**
  – Clusters & forward and backward linkages,
  – Done with descriptive statistics in IRIOS
  – Decomposition of structural change
    – Comparative static use of IO solution equation
  – Decomposition of factor productivity growth
    – Growth accounting, e.g. by Groningen G&D Centre
Overview IO analysis in practice 2

- **Impact studies of projects and sectors**
  - Type I to IV demo-economic models: danger of overestimation, because of inelastic supply

- **Projections of entire economies**
  - Econometric IO models, with consumption, export, import and production functions

- **Optimisation analyses**
  - e.g. minimal pollution given final demand $\mathbf{f}$ and Leontief technology $\mathbf{A}$
Finally: interindustry beyond IO

• Realistic markets need CGE modelling
  – Extended IO tables are indispensible (i.e. SAMs = social accounting matrices are indispensible)
• Base case: Cobb-Douglas, price elasticity of demand = -1 => constant value IO model
• International CGE: Base plus Armington assumption
• Spatial CGE: plus monopolistic competition
  – Interregional SAMs are indispensible
  – Cobb-Douglas at top level, e.g. KLEM function
  – Dixit-Stiglitz variety type of CES at industry level
    => Paul Krugman (1991) style agglomeration economies
Thanks for your attention!