Circular economy in a simplified input-output stock-flow consistent model

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– Increasing interest in economy-ecosystem nexus and CE

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  1) To show how a super-simplified IO-SFC model can be developed from scratch
  2) To test a simple CE innovation

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- Solution: numerical simulations

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Nominal value of assets and liabilities

Table 1: Balance sheet in $t = 20$ (baseline)

	Households	Firms	Government	Central Bank	Total
Money	25.65	0	0.0	-25.65	0
Bills	2.85	0	-28.5	25.65	0
Net financial wealth	-28.50	0	28.5	0.00	0
Total	0.00	0	0.0	0.00	0

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Money transactions and changes in stocks

Table 2: Transactions-flow matrix in $t = 20$ (baseline)

	Households	Firms	Government	Central Bank	Total
Consumption	-25.86	25.86	0.00	0.00	0
Government spending	0.00	9.55	-9.55	0.00	0
Output	0.00	[35.41]	0.00	0.00	0
Wages and salaries	35.41	-35.41	0.00	0.00	0
Taxes	-7.08	0	7.08	0.00	0
Interest payments	0.05	0	-0.05	0.00	0
Change in money stock	-2.27	0	0.00	2.27	0
Change in bills	-0.25	0	2.52	-2.27	0
Total	0.00	0	0.00	0.00	0

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Model equations: (1)-(3)

- Total "real" consumption (constant prices) is:

$$c = \alpha_1 \cdot \frac{YD_{-1}}{p_{A,-1}} + \alpha_2 \cdot \frac{V_{-1}}{p_{A,-1}} \qquad (1)$$

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- Let us consider a 2×2 production. The final demand vector is:

$$\mathbf{d} = \begin{pmatrix} d_1 \\ d_2 \end{pmatrix} = \mathbf{b} \cdot c + \mathbf{s} \cdot g = \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix} \cdot c + \begin{pmatrix} \sigma_1 \\ \sigma_2 \end{pmatrix} \cdot g \tag{2}$$

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$$\mathbf{x} = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \mathbf{A} \cdot \mathbf{x} + \mathbf{d} = (\mathbf{I} - \mathbf{A})^{-1} \cdot \mathbf{d} \tag{3}$$

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where: $\mathbf{A} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}$

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Model equations: (4)-(6)

- The nominal net product of the economy is:

$$Y_n = \mathbf{p}^T \cdot \mathbf{d} \tag{4}$$

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- The employment level is determined by firms' demand for labour:

$$N = \mathbf{x}^T \cdot \left[\begin{pmatrix} 1 \\ 1 \end{pmatrix} \oslash \mathbf{pr} \right] = \mathbf{x}^T \cdot \mathbf{l} \tag{5}$$

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- If firms use a mark-up rule, the price vector is:

$$\mathbf{p} = w \cdot \mathbf{l} + \left[\begin{pmatrix} 1 \\ 1 \end{pmatrix} + \mathbf{m} \right] \odot \mathbf{A} \cdot \mathbf{p} \tag{6}$$

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Model equations: (7)-(10)

- The deflator for household consumption is:

$$p_A = \mathbf{p}^T \cdot \mathbf{b} \tag{7}$$

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- Total tax revenue is:

$$T = \theta \cdot (Y_n + r \cdot B_{h,-1}) \tag{9}$$

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- Households' disposable income is:

$$YD = Y_n + r \cdot B_{h,-1} - T \tag{10}$$

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Model equations: (11)-(14)

- The supply of government bills is:

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- The supply of cash is:

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- The net wealth of households is:

$$V = V_{-1} + YD - c \cdot p_A \tag{14}$$

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Model equations: (15)-(16)

- The private demand for bills is:

$$\frac{B_h}{V} = \lambda_0 + \lambda_1 \cdot r - \lambda_2 \cdot \frac{YD}{V} \qquad (15)$$

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- Model IO-SIM is complete.

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Figure 1. Sankey diagram of TFM

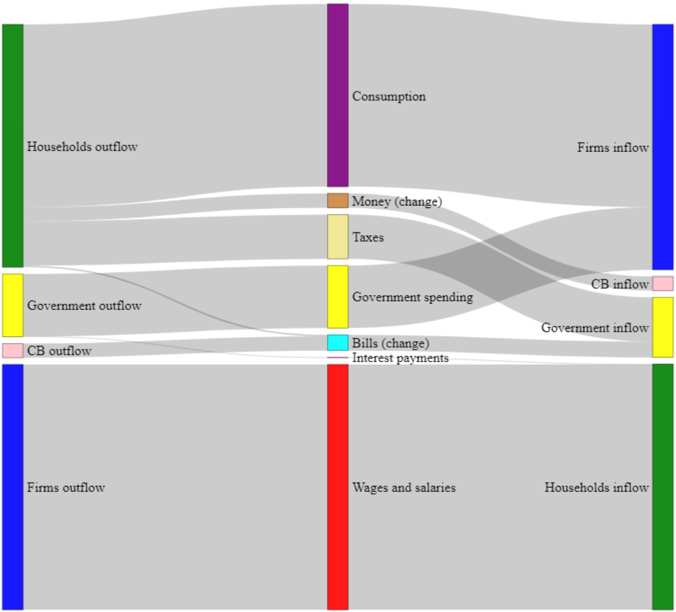
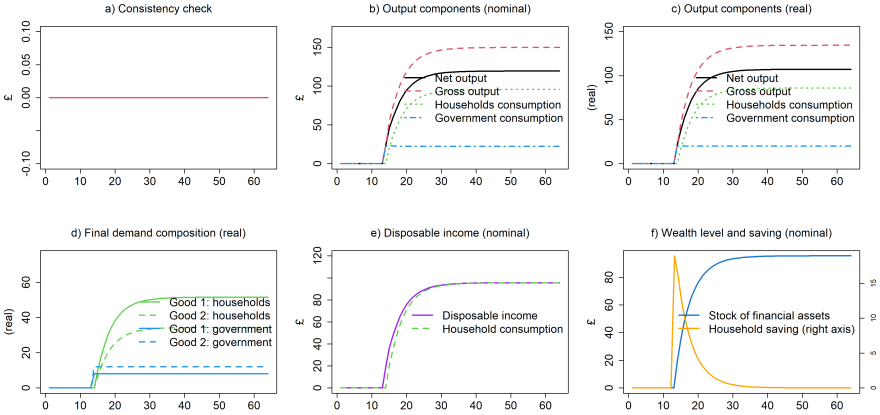


Figure 2. Model dynamics: baseline



Incomplete adjustment of output

- Eq. (3) assumes that output fully adjusts to final demands

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- Eq. (3) assumes that output fully adjusts to final demands
- We can relax this assumption by noticing that the Leontief inverse can be expressed as a sum of power series:

$$(\mathbf{I}-\mathbf{A})^{-1}=\mathbf{I}+\mathbf{A}+\mathbf{A}^2+\mathbf{A}^3+\ \dots\ +\mathbf{A}^t+\ \dots\ =\sum_{t=0}^{\infty}\mathbf{A}^t$$

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- An incomplete adjustment of production to demand conditions can be obtained using:

$$\mathbf{x} = \sum_{t=t_0}^{n-t_0} \mathbf{A}^t \cdot \mathbf{d} \qquad (3B)$$

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Output gaps and prices

- Eq. (3B) shows that the output vector adjusts gradually to demand shocks as the time goes by

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- We can assume that industry gross mark-ups depend on output gaps:

$$\mathbf{m} = \mathbf{m}_0 + \mathbf{m}_1 \odot (\mathbf{x}^* - \mathbf{x}) \qquad (17)$$

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- This captures temporary demand pressures on supply conditions

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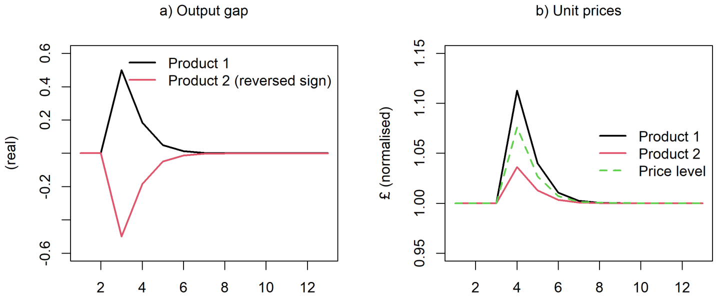
Figure 3. Output and price changes after a demand shock



The circular economy

- CE = policies that aim at reusing, repairing, sharing, and recycling products and resources to create a closed-loop system, thus minimising waste, pollution and CO_2 emissions

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- Consider a 3-sector economy: 2 goods + waste. If waste is not recycled, the matrix of technical coefficients is:

$$\mathbf{A} = \begin{pmatrix} a_{11} & a_{12} & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & 0 \end{pmatrix}$$

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- CE implies a change in technical coefficients

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Figure 4. Production structure without CE

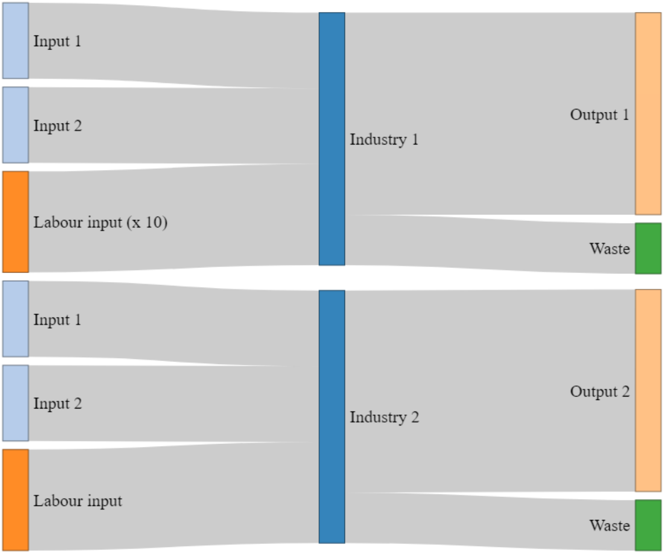
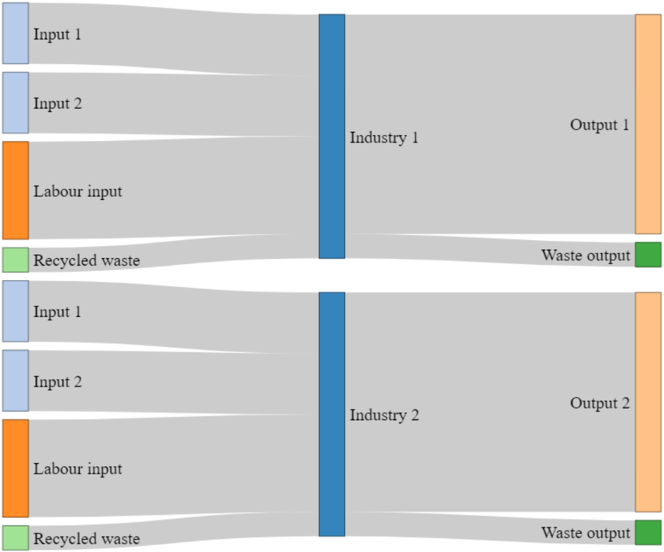


Figure 5. Production structure with (partial) CE



The circular economy (cont'd)

- The new matrix will be:

$$\mathbf{B} = \begin{pmatrix} b_{11} \leq a_{11} & b_{12} \leq a_{12} & b_{13} \geq 0 \\ b_{21} \leq a_{21} & b_{22} \leq a_{22} & b_{23} \geq 0 \\ b_{31} \geq a_{31} & b_{32} \geq a_{32} & 0 \end{pmatrix}$$

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- CE entails a reduction in coefficients defining the quantities of good 1 and good 2 used as inputs (•)

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The circular economy (cont'd)

- The new matrix will be:

$$\mathbf{B} = \begin{pmatrix} b_{11} \leq a_{11} & b_{12} \leq a_{12} & b_{13} \geq 0 \\ b_{21} \leq a_{21} & b_{22} \leq a_{22} & b_{23} \geq 0 \\ b_{31} \geq a_{31} & b_{32} \geq a_{32} & 0 \end{pmatrix}$$

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- CE entails a reduction in coefficients defining the quantities of good 1 and good 2 used as inputs (•)
- Waste now enters the production of goods 1 and 2 (•)
- The increase in waste efficiency entails an increase in the related technical coefficients (•)
- Mind the rebound effect!

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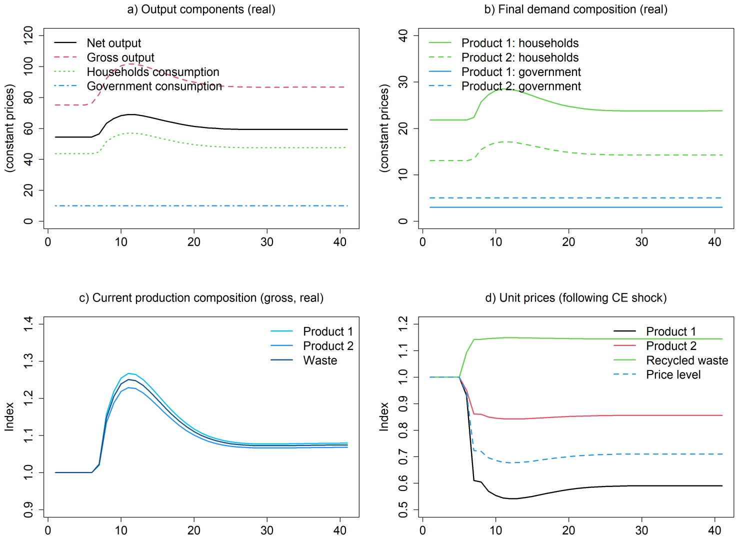
Figure 6. CE policy in a "2-industry + waste" model



Final remarks

- Simplified though it is, IO-SIM provides the base for more sophisticated models

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Final remarks

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- Ecosystem-related variables can be easily factored in

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- Technical coefficients can be linked with demand, finance, ecosystem, etc.

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Final remarks

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- Ecosystem-related variables can be easily factored in
- Technical coefficients can be linked with demand, finance, ecosystem, etc.
- A variety of feedback effects can be considered
- The main issue seems to be the consistency and availability of data...

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Thank you

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