

***CAN THE INTERDEPENDENCE BETWEEN ENERGY AND  
MATTER RESOURCES LEAD TO AN ECONOMIC COLLAPSE?***

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# Can the interdependence between energy and matter resources lead to an economic collapse?

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## Why is this interdependence an issue?

The increasing scarcity of energy and matter leads to a vicious circle (1):

- More energy is needed to extract metals
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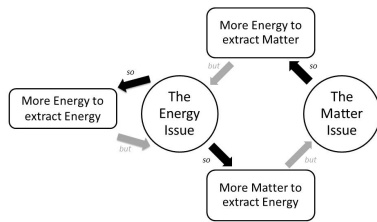


Fig. 1: The vicious circle

The issue is not about the quantity of resources available, but about how to extract it. Limits to growth would not be related to the stock of resources (which will only be an issue in the very long term), but a **medium-run problem in the coupled flow of energy and matter needed for growth**.

### What is the effect of this interdependency on the economy?

#### Aim of this study

Modeling this interdependency in a dynamic macroeconomic model and predicting the qualitative evolutions of the economic variables.

## The macroeconomic model

We develop an extension of the Goodwin-Keen model (2) which is a dynamic macroeconomic model describing the evolution of the employment rate, the wage ratio and the private debt.

The extension we propose consists in using an **Input-Output approach** to model production, in order to catch **inter-sectoral frictions**.

We model a simplified economy where production is divided in four sectors:

- consumption goods (c)
- capital goods (k)
- final energy (e)
- matter (m)

The Input-Output matrix is the following:

$$A(t) = \begin{pmatrix} a_{cc} & a_{ck} & a_{ce} & a_{cm} \\ a_{kc} & a_{kk} & a_{ke} & a_{km} \\ a_{ec} & a_{ek} & a_{ee} & a_{em} \\ a_{mc} & a_{mk} & a_{me} & a_{mm} \end{pmatrix}$$

#### The mass balance equation: net and gross production

$$\begin{pmatrix} Y_c \\ Y_k \\ Y_e \\ Y_m \end{pmatrix} = [I_4 - A(t)] \cdot \begin{pmatrix} Z_c \\ Z_k \\ Z_e \\ Z_m \end{pmatrix}$$

The gross production is directly determined by the investments made in each sector, which are decided depending on the profits.

The evolution of the employment rate is determined by gross production growth and labor productivity.

The dynamics of the wage ratio in the GDP is deduced thanks to the empirical curve linking wages to employment.

The growth in private debt is the difference between investment and profits.

**We obtain a dynamic system of 8 differential equations, which can be numerically simulated to have the evolution of the different variables.**

## Modeling the resources interdependency

The inter-sectoral frictions are set by the matrix coefficients:

$$a_{em} \rightarrow +\infty \text{ when } R_m \rightarrow 0 \quad R_m \text{ is the matter reserve.}$$

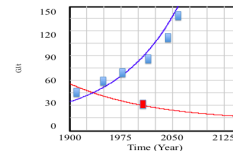


Fig. 2: Blue line: evolution of the energy consumption for 1 Mt of copper (O. Vidal, (3))

$$a_{me} \rightarrow +\infty \text{ when } R_e \rightarrow 0 \quad R_e \text{ is the energy reserve.}$$

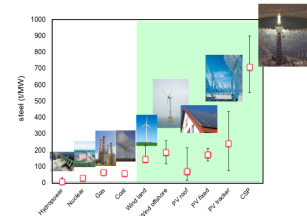


Fig. 3: Steel use in different energy sources (O. Vidal (3))

$$EROI = \frac{1}{a_{ee}} \rightarrow 1 \text{ when } t \rightarrow +\infty$$

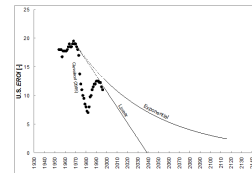


Fig. 4: US EROI evolution (Heun et al (4))

## Results & Conclusions

We perform numerical simulations in order to determine the long-run equilibria of the dynamic system.

**We observe several cases where the production falls, leading to a deep crisis : the employment rate and wage ratio decrease dramatically, and the debt explodes.**

#### Conclusion of the study

Our predictions confirm that under certain conditions, the coupling between energy and matter can precipitated the "limits to growth".

#### Further work

- Implementing a quantitative approach
- Studying the impact of the government intervention

## References

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