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The Food-Energy-Water-Nexus and a Keynes sector in a post growth economy – learnings from a CGE model

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Abstract—

In its reports, the IPCC demands new prosperity ideas (i.e., new post-growth economic models (change of lifestyle, institutional innovations and networks of neighbourhood help [1])) to solve the climate crisis [2, 3]. Therefore a Keynes sector covering non-market economic activity is modelled in an intertemporal dynamic multinational Computable General Equilibrium model (CGE model) [4]. The CGE model consists of four countries (A, B, C, D) with three economic sectors (Food-Energy-Water (FEW)-sector, public and private service, industry) each and country D has a derived Keynes sector representing the ideas of the post growth approach [5].

We discuss the economic effects of our CGE model in a scenario where the countries' growth rates differ: Country A follows a zero-growth pathway, B and C grow by moderate rates, and country D is on a de-growth scenario. Using the CGE model, we discuss the implementation of a Keynes sector in an open economy with trade relations to the other three countries. This model approach reveals the possible socio-economic consequences and alterations of various growth models for the FEW Nexus sector, as well as the other economic sectors of the four countries.

Keywords: FEW-Nexus, CGE Model, Keynes sector

I. INTRODUCTION

In 1930 John Maynard Keynes discusses in his paper "Economic possibilities for our grandchildren [6]" the possibilities of "non-economic purposes" as new societal goals because humankind has reached a technological level that raised the living standard in such a way, that most economic problems are solved in 2030 and a fifteen-hour working-week would be quite enough. The change of societal moral codes leads also to the decline of the social importance of wealth [6, 7]. Keynes stated in 1930: "When the accumulation of wealth is no longer of high social importance, there will be great changes in the code of morals [6]." And he added: "All kinds of social customs and economic practices … we shall then be free, at last, to discard [8]."

However, the change Keynes expected has not taken place until 2021. But the current scientific [9, 10] and political discussions [7] increasingly supports and take up Keynes idea of reduced economic growth not because humanity has solved all economic problems as Keynes expected but because the global community has to cope with the threat of accelerating climate change [11], the dramatic loss of biodiversity [12] and its dramatic resource consumption [13]. The necessity and plausibility of the prevailing economic growth model [14] is challenged [14], raising instead questions as the following:

- Is climate change the consequence of constant economic growth [15]?
- In The Economist, Adam Posen and Tim Jackson discuss the central economic question of our times: Are new economic growth models a tragedy or a benediction for society [16].
- Is economic growth even a key concern or a precondition of sustainable development [17]?

Addressing this controversial debate, the objective of our model is to contribute to the discussion about the characteristics of a post growth economy, by introducing a Keynes sector, as a sectoral first institutional step towards a world without economic growth. This Keynes sector covers non-market economic activities, which are not considered in the traditional GDP. The objective of the developed model is built on the ideas of Tim Jackson [14], who demands a redefinition of prosperity "in which humans can still flourish and yet reduce their material impact on the environment" [14] and who, to do so, calls for 'networks of neighbourhood help [5, 18, 19]' as a new prosperity source [20]. Pictorially speaking, Jackson [14] and Paech [21] raise ethical concerns about the "cowboy economy" as Kenneth Boulding set it [22] (i.e., an "economy of apparently illimitable resource"), proposing as Kenneth Boulding [23] instead the transition to a "spaceman economy" (i.e., an economy "without unlimited reservoirs of anything") [22]. The remainder of this paper is structured as follows: In the Section 2, the CGE model and the different economic growth scenarios inspired by the works of Tim Jackson [14, 24], the Club of Rome [25, 26], Victor [27], Weitzman [28], D'Alisa [8, 29] and Paech [21] will be discussed. In Section 3 the model results and its consequences will be presented and in Section 4 we will summarize the findings.

II. A 4-COUNTRY-4-SECTOR-CGE-MODEL

Our model is a dynamic multinational Computable General Equilibrium model (CGE model). It is based on the model idea developed by Solow, Swan [30, 31], and Kaldor [32] as well as the Arrow-Debreu-Model [33, 34], the latter of which was used to prove the existence of equilibria [35]. It is assumed that foreign trade volume positively correlates with

growth. As we want to demonstrate the impact of negative growth for at least one country, we need to extend our analysis to four countries in order to mitigate direct effects from growth strategies to trade and in turn the growth rate of other countries via their exports. The advantage from using a CGE model is twofold: First, all economic agents are to be included and therefore, economy wide consequences can be understood. Second, the CGE model accounts for direct as well as indirect or feedback effect from decisions of our economic agents on others. Our model thus includes a representative household and a government for each of our four countries. As the Food-Energy-Water (FEW) sector plays a crucial role, each country is assumed to have a FEW sector representing the environmental system. In all, the sectors covered by our model are:

- Sector 1: Food-Energy-Water
- Sector 2: Industry production
- Sector 3: Public and private services

Additionally, a derived Keynes "de-growth" sector [36] is incorporated into our model.

1.1. Food-Energy-Water sector

In the first sector, we summarize the water, the energy and food sector in one overall Food-Energy-Water sector. The FAO assess water, energy and food as essential for human well-being, poverty reduction and sustainable development [37]. The UN-Water division believes the FEW nexus is central to sustainable development [38] but current unsustainable global development sets the core of sustainable development – food, energy, water - under stress by climate change, consumption and production patterns, and the global urbanization trends [38, 39]. Holger Hoff confirmed this view in the Bonn FEW-Nexus conference report and added that the global requirements for food, energy and water will rise in the near future caused by the key drivers of globalization: Increasing population, technological change and growth of economic activities [40].

1.2. Industry sector

The industry sector summarizes the manufacturing in the four economies. This includes beneath the manufacturing also crafts, energy industry, energy and water supply and construction. The production is material- and capital-intensive.

1.3. Public and private services sector

The public and private service sector comprises all services (trade, banking and insurance) provided by private enterprises, state and public institutions.

1.4. A Keynes sector

The derived sector in country D is introduced as Keynes sector - the reduction of the average weekly working time [6]– for non-market or as Keynes set it for non-economic activities [6]. The subsistence economy is an important characteristic of the Keynes sector and means a reduction of the average weekly working time, which would free up time resources.

Material resources for new production would be replaced by alternative economic processes [1]:

- Craft skills for self-production and life extension,
- Sharing economy (repair café),
- Bringing up children,
- Neighbourhood help.
- Care and nursing,
- Social relations for the purpose of community use and exchange of services (community garden).

The corresponding industrial deconstruction would have to be designed in such a way that of the time released from work can feed precisely those subsistence services that compensate for the decline in production [1]. This paper will take up these ideas and analyse the effect of more subsistence economy in globalized economic environment.

III. MODEL FRAMEWORK

The model is based on the Ecomod model [41] and covers a representative household that maximizes an intertemporal utility function subject to the budget constraint, as well as the government and the production sector for each of the four countries (A, B, C, D). As we model open economies, the countries trade with each other. The representative consumer maximizes its intertemporal utility as in the neoclassical consumption model [42]. Optimal savings and consumption levels are determined for each period. The government collects taxes and pays household transfers, which constitutes an equal-yield reform [41].

We assume three sectors for each of the four regions. Each sector is represented by a firm, which operates under perfect competition and constant returns to scale with a Cobb-Douglas function. Each country's production sector has several stages: Labour and capital are used to determine output, which is combined with intermediates at the next production stage according to a Leontief production function. The result is domestically produced output that can be used for either domestic or foreign consumption. A Constant-Elasticity-of-Transformation (CET) function [43] is applied to separate exports from domestically sold goods. At the next stage of production, the domestically produced goods, which are sold at domestic markets, are combined with imports of the same kind of goods according to a constant elasticity of substitution (CES) function. Here, we use the Armington assumption [44, 45] that states that domestic and foreign inputs are not perfect substitutes accounting for – amongst others – product heterogeneity [46]. A fraction of the final output is used as intermediate input. The higher the efficiency parameter of the CES function, the more productive are the factors used. Technical progress is reflected in its increase. If the production elasticities add up to one, there are constant returns to scale. In the case of constant returns to scale, the factor shares are equal to the respective elasticities of production [47, 48]. Further, in our CGE model, demand is homogenous of degree zero in the price vector and only relative prices are determined. Following Walras' Law (which determines that if n-1 markets are in equilibrium, the n^{th} market must be in equilibrium as well), we omit one of the market clearance conditions [49, 50]. Additionally it is assumed that all economic actors have perfect foresight – they have all relevant information [51] - and the investments (I) are financed through the household savings (S). The governments of the countries organize the taxes and the social transfers.

A. Social Accounting Matrix

For the status quo of our model economy, a database needs to be determined, as table 1 and 2 shows. The Social

Accounting Matrix (SAM) represents flows of all economic transactions that take place within the four economies [52].

Table 1:

Social Accounting Matrix Country A + C

	FEW	Industry	Service	Consumption	Investment	Exports	Total
FEW	0	0	0	70	5	15	90
Industry	0	0	0	120	40	20	180
Service	0	0	0	185	100	50	335
K payments	50	60	100				
L payments	20	90	200				
XD	70	150	300				
Imports	20	30	35				
Total	90	180	335				

Source: Ecomod, 2003 & authors, 2021.

A crucial requirement is that the data needs to be balanced, that is all payoff streams as well as all streams representing real goods need to be balanced. This holds true, if the Social Accounting Matrix (SAM) [53] for each country is balanced. It comprises payoff streams of all sectors and economic actors. As in the initial situation all prices are normalized to one, also the streams of real values are balanced. We assume that country A and C are small countries and their economy can be described using the social accounting matrix (table 1).

Countries B and D are assumed to be large countries with the following status quo data (table 2).

Table 2:

Social Accounting Matrix Country B + D

	FEW	Industry	Service	Consumption	Investment	Exports	Total
FEW	0	0	0	125	10	20	155
Industry	0	0	0	210	80	30	320
Service	0	0	0	415	200	35	650
K payments	100	120	200				
L payments	40	180	400				
XD	140	300	600				
Imports	15	20	50				
Total	155	320	650				

Source: Ecomod, 2003 & authors, 2021.

All social accounting matrices are balanced, which can be seen from the last row and the last column: The columns representing expenditures equal the value of the rows, which stand for incomes.

Growth Rates and Parametrization

The countries vary in the steady state growth rate (see Table 2). The underlying ideas for the growth rates are taken from the literature:

- country A is in a zero growth country based on the ideas of Maxton [25] and Jackson [24],
- country B will grow according to the Randers model [Randers & Maxton, 2016] by 1.2% per year [26],
- country C will grow conventionally by 1.9%,
- country D will contract by 1.3%, based on the ideas and models developed by Victor [27], Weitzman [28], Schumacher [54], and Paech [55].

Table 3:

Model assumptions

	Country			
	A	B	C	D
Interest rate	5.0%	5.1%	5.2%	4.9%
Time preference rate	5%	5.1%	5.2%	4.9%
Steady state growth rate	-0.001%	1.2%	1.9%	-1.3%
Labor development	0.001%	0.001%	0.001%	0.001%

Source: Authors, 2020 IEK-STE 2020

Furthermore, we assume that the countries vary in their technological abilities. This means, we use the following values for the efficiency parameter (aF) of the CES production function:

Table 4:

Technological level of the four regions

Efficiency parameter (aF)	Country A	Country B	Country C	Country D
Service	0.6651	0.5651	0.5015	0.5337
FEW-Nexus	1.1159	1.0185	0.9527	0.9864
Industry	1.1818	1.0952	1.0359	1.0664

Source: Own calculations, 2021

Table 4 shows that the service sector has in all four countries the lowest economic efficiency, followed by the FEW-Nexus sector and the best efficiency has the industry sector in all four countries, whereas the industry sector of country A has the highest efficiency value (aF).

B. Economic indicators

In the following, the results of our stylized economic growth model are presented considering different endogenous technical standards expressed in the efficiency parameters of the four countries.

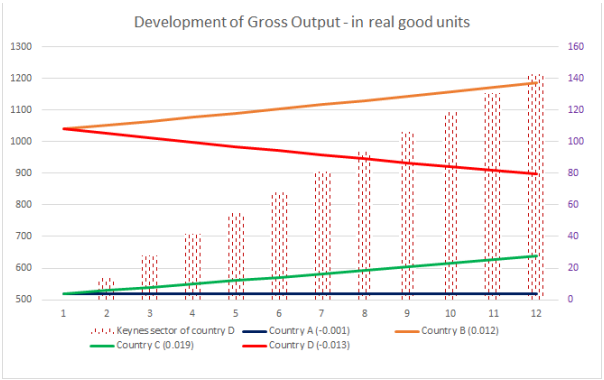

Figure 1: Gross Output

The impact of our economic framework conditions on the income, the consumption, the savings, the investments, the gross output, the trade balance, the utility level and the emissions of the countries will be shown. The gross output (GO) is the measure of total economic activity in the production of new goods and services in the observed period, as figure 1 shows for the four countries. The gross output increases in country C and B constantly over the observed period, whereas the output in country A remains more or less the same and in country D the gross output declines significantly. Country D has therefore built up a new derived Keynes sector in the observed period, which increases substantially.

Table 5 shows the model results for the development of the GDP, the capital demand and labour input of the four countries and the development of the derived Keynes sector. The GDP of country A decreases annually about -0.2%, whereas the economic performance of country B and C increases about 1.1% and 1.6% per year.

The GDP of country D decreases about 14.1% over the observed period, so that the economic pressure arises to develop new economic structures for the new Keynes sector. This new sector has to increase its performance every year of about 24% to even out the economic losses of country D. The economic performance measured by the GDP is based on the capital expenditures and the labour input in the various countries. The labour input of country A decreases over the 12-year-period about 1.1%, whereas the labour demand of country B and C increases about 14 and 23%.

Table 5:

Change of key economic indicators of the 4 countries & Keynes sector of country D

	Average annual growth	Growth over the period 1..12
GDP, real monetary units		
Country A (-0.001)	-0.19%	-2.23%
Country B (0.012)	1.09%	13.85%
Country C (0.019)	1.58%	20.69%
Country D (-0.013)	-1.26%	-14.10%
Keynes sector of country D	24.19%	984.28%
Capital, nominal monetary units		
Country A (-0.001)	0.08%	1.00%
Country B (0.012)	1.08%	13.79%
Country C (0.019)	1.74%	22.94%
Country D (-0.013)	-1.27%	-14.19%
Keynes sector of country D	23.43%	913.45%
Labour input, nominal wage		
Country A (-0.001)	-0.09%	-1.09%
Country B (0.012)	1.10%	14.02%
Country C (0.019)	1.74%	23.00%
Country D (-0.013)	-1.19%	-13.41%
Keynes sector of country D	23.63%	931.22%

Source: Own calculations, 2021

The labour needs of country D decreases in this time of more than 13%, so that the Keynes sector of country D has to increase its labour demand of nearly 24% every year to take up this labour supply. Based on the previous economic indicators the investment, savings, consumption, income and utility development of the four countries can be defined.

Table 6 shows that the development of the economic performance has increased the income of country B and C, whereas the income of country A stagnates and of country D decreases about 1.19% annually. The Keynes sector of country D has to increase its income equivalent – e.g. measured in neighbourhood help hours - about nearly tenfold over the time horizon observed in our model. The earned income can be used for direct consumption but can also be saved for future consumption. The consumption of country A decreases slight about nearly 2% in the observed time, whereas the consumption of country B and C rises of about 1 and 1.6 % per year. The consumption of country D decreases by 1.2% per annum, so that the supply of alternative consumption goods and services (neighbour help, repair café) has to increase by 931% in the 12-year period. The part of the income that is not used for consumption will be saved for future consumption and investment. The savings of country A are more or less unchanged over the observed period, while the savings of country B and C rise about 1.1% or respectively for country C about 1.74% annually. The savings of country D decline in its traditional conventional economic sectors about 1.2% per year, whereas the savings – future neighbourhood help hours - of the new Keynes sector have to increase about 23.63% per year.

The emissions – all harmful environmental effects[1] - of country A increase only about 0.69% over the analysed period, whereas the emissions of country B and C rise in the same time about 13.7% and 23.2%. The emissions of country D decline about -1.26% per year. The development of the emissions of the Keynes sector D is not yet foreseeable, because the future economic structure of the sector and its specific emissions - e.g. neighbourhood help - are currently unclear.

The development of these key economic sectors has also a direct impact on the utility level of the households of the four countries. The utility of the households of country A decreases lightly about 0.18% per year, whereas the utility of country B and C increases between 1.2 and 1.9% per annum.

The utility of country D in the de-growth strategy decreases about 1.25%, so that the Keynes sector has to provide an increasing utility level for the households of country A.

Table 6:

Change of key economic indicators of the 4 countries & Keynes sector of country D

	Average annual growth	Growth over the period 1..12
Investment, nominal monetary units		
Country A (-0.001)	-0.07%	-0.79%
Country B (0.012)	1.11%	14.13%
Country C (0.019)	1.72%	22.71%
Country D (-0.013)	-1.20%	-13.49%
Keynes sector of country D	20.46%	675.16%
Consumption, nominal monetary units		
Country A (-0.001)	-0.16%	-1.95%
Country B (0.012)	1.09%	13.83%
Country C (0.019)	1.62%	21.29%
Country D (-0.013)	-1.25%	-14.02%
Keynes sector of country D	23.96%	962.38%
Income, nominal monetary units		
Country A (-0.001)	-0.09%	-1.09%
Country B (0.012)	1.10%	14.02%
Country C (0.019)	1.74%	23.00%
Country D (-0.013)	-1.19%	-13.41%
Keynes sector of country D	23.63%	931.22%
Utility		
Country A (-0.001)	-0.18%	-2.09%
Country B (0.012)	1.09%	13.84%
Country C (0.019)	1.60%	20.99%
Country D (-0.013)	-1.25%	-14.06%
Keynes sector of country D	24.08%	973.22%
Savings, nominal monetary units		
Country A (-0.001)	-0.09%	-1.09%
Country B (0.012)	1.10%	14.02%
Country C (0.019)	1.74%	23.00%
Country D (-0.013)	-1.19%	-13.41%
Keynes sector of country D	23.63%	931.22%
Emissions, in real good units		
Country A (-0.001)	0.06%	0.69%
Country B (0.012)	1.07%	13.69%
Country C (0.019)	1.76%	23.23%
Country D (-0.013)	-1.26%	-14.10%
Keynes sector of country D	?	?

Source: Own calculations, 2021

This utility level has to increase annually by more than 24%.

C. *Sectoral development of the alternative gross output*

Figure 2 shows the possible development of the Keynes sector and its subsectors. The loss of traditional gross output of country D due to its de-growth strategy should be compensated by new non-conventional economic activities in all three subsectors: FEW-Nexus, Industry and Service.

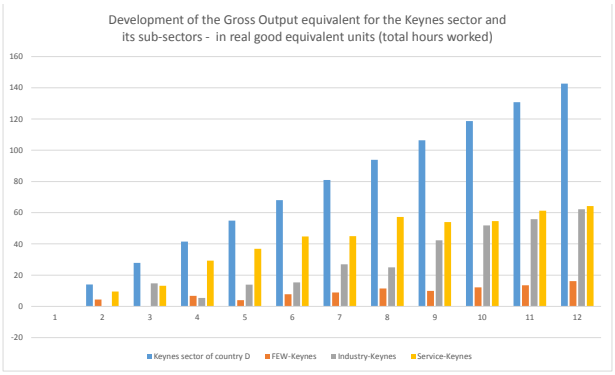

Figure 2: Gross Output Equivalent

The gross output is the traditional measure for all economic activities in the production of new goods and services, which have to be transferred in new economic indicators to measure the economic development in the new Keynes sector. An equivalent for the gross output could be the measure 'total hours worked' in the Keynes sector.

The sharp increase of the activities in the new sector of country D reveals also the need of new institutions to organize and structure the development of the Keynes sector.

[1] German Federal Immission Control Act (BImSchG) (https://www.gesetze-im-internet.de/bimschg/index.html)

D. *The need of new institutions for a mixed system*

The analysis has outlined a first framework of a Keynes sector as a starting point for a post growth society. The analysis reveals that the new Keynes sector has to take up 13% of the labour supply from country D for non-market activities such as craft, bringing up children, neighbourhood help, participation in community gardens, care and nursing, repair cafes etc. [55].

Table 7:

Development of the Keynes sector of country D

	Average growth	12-year growth
Capital	23.43%	913.45%
Investment	20.46%	675.16%
Consum	23.96%	962.38%
GDP	24.19%	984.28%
Income	23.63%	931.22%
Savings	23.63%	931.22%
Labour	23.63%	931.22%
Gross output	23.47%	916.79%
Utility	24.08%	973.22%

Source: Own calculations, 2021

The table 7 shows, that the Keynes sector is a rapidly growing sector that needs also rising capital supply and investments to increase the equivalent gross output that summarizes all the activities of the new economic sector. Through the development of the Keynes sector, country D developed a mixed economic system based on three economic sectors and a Keynes sector, as figure 3 shows. The mixed system consists of a classical monetarised sector covering 87% of its economic activities and a Keynes sector containing 13% of the original labour demand of the country D. Nobel Prize winner Douglass North defined the great importance of institutions for economic success: "Institutions are the humanly devised constraints that structure political, economic and social interaction [North, 1991]." Hence the new Keynes sector has to develop both constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights) to organize the new sector.

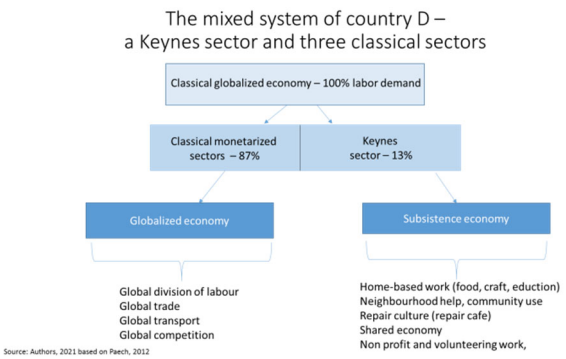

Figure 3: The mixed system

Country D has to develop institutions and formal rules to create a social order, which reduce uncertainty and building the constraints for the political, economic and social interaction that also have to take place in the new Keynes sector and in the traditional globalized economic sector. The country needs also institutions for its mixed system, which connect the institutions of the Keynes sector to the institutions of the traditional economic sectors.

IV. Conclusions

The new growth models are causing an increasing economic pressure measured by the traditional economic indicators. The model results reveal the high political pressure caused on the current institutions to organize the transformation of the current economic system without utility losses. Additionally the question has to be discussed, if this transformation process needs new institutions for the Keynes sector to organize such new institutions as repair cafés and neighbourhood help, block chain based energy prosumer [56], energy cooperatives [57-59], and the founding of water cooperatives [60]. The question has also to be discussed if the Keynes sector needs new economic indicators to measure its economic activities (working hours) or are the traditional indicators also sufficient to measure the activities of the Keynes sector. The utility decline of country D leads to the question, if the utility sacrifices of the households have to even out or can utility also been generated by renunciation.

V. References

[1] Paech N. Postwachstumsökonomik. Gabler Lexikon. 2020, May, 11. https://wirtschaftslexikon.gabler.de/definition/postwachstumsoekonomik-53487

[2] IPCC. IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems - Summary for Policymakers. Geneva: IPCC; 2019.

[3] IPCC. The Ocean and Cryosphere in a Changing Climate - Summary for Policymakers. Monaco: Second Joint Session of Working Groups I and II of the IPCC and accepted by the 51th Session of the IPCC, Principality of Monaco, 24th September 2019; 2019.

[4] Schubert S, Schnabel R. Curing Germany's health care system by mandatory health premia? *J Health Econ*. 2009;28:911-23.

[5] Woynowski B, Becker P, Bertram A, Bhandari S, Burger J, Haver M, et al. Wirtschaft ohne Wachstum? Notwendigkeit und Ansätze einer Wachstumswende. Arbeitsberichte des Instituts für Forstökonomie. Freiburg: Albert Ludwigs Universität Freiburg; 2012.

[6] Keynes JM. *Economic possibilities for our grandchildren*. In: Keynes JM, editor. *Essays in persuasion*. New York: W. W. Norton & Co; 1963(1930).

[7] Cassidy J. Can we have prosperity without growth? The New Yorker. New York2020.

[8] D'Alisa G, Damaria F, Kallis G. Degrowth: A Vocabulary for new era. New York: Routledge; 2015.

[9] Stern N. *The Economics of Climate Change. The Stern Review* Cambridge: Cambridge University Press; 2006.

[10] Stiglitz JE. It's time to retire metrics like GDP. They don't measure everything that matters. The Guardian2019.

[11] Schwalm CR, Glendon S, Duffy PB. RCP8.5 tracks cumulative CO2 emissions. *Proceedings of the National Academy of Sciences*. 2020.

[12] UNEP. Global Biodiversity Outlook 5. New York: UNEP; 2020.

[13] Elhacham E, Ben-Uri L, Grozovski J, Bar-On YM, Milo R. Global human-made mass exceeds all living biomass. *Nature*. 2020;588:442-4.

[14] Jackson T. *Prosperity without growth*. London: Earthscan; 2009.
[15] Wallace-Wells D. *The Uninhabitable Earth: Life After Warming*: Tim Duggan Books; 2019.
[16] Posen A, Jackson T. Slower growth - Disaster or blessing? A debate. The Economist. London: The Ecoomist; 2015.
[17] Higgins KL. Economic growth and sustainability – are they mutually exclusive? Striking a balance between unbounded economic growth and sustainability requires a new mindset. Elsevier connect. https://www.elsevier.com/connect/economic-growth-and-sustainability-are-they-mutually-exclusive: Elsevier; 2013.
[18] Statista Research Department. Welche wirtschaftlichen Aktivitäten zählen zur Schattenwirtschaft? Hamburg: Statista GmbH. https://de.statista.com/themen/5373/schattenwirtschaft/
[19] Folkers M, Paech N. *All you need is less*. München: Oekom; 2020.
[20] Paech N. Postwachstumsökonomie. https://wirtschaftslexikon.gabler.de/: Gabler; 2019.
[21] Paech N. *Befreiung vom Überfluss: Auf dem Weg in die Postwachstumsökonomie*. Munich: Oekom; 2012.
[22] Boulding K. *The economics of the coming spaceship earth*. In: Daly H, Townsend K, editors. *Valuing the Earth, Economics, Ecology, Ethics,*. Boston: MIT Press; 1994 (1966). p. 297-310.
[23] Jackson MC. Special issue: An appreciation of Kenneth Boulding. *Systems Research*. 1995;12:255-.
[24] Jackson T. The Post-growth Challenge: Secular Stagnation, Inequality and the Limits to Growth. *Ecological Economics*. 2019;156:236-46.
[25] Maxton G. *Change!* München: KomplettMedia; 2018.
[26] Randers J, Maxton G. *Ein Prozent ist genug*. München: Oekom Verlag; 2016.
[27] Victor PA. Growth, degrowth and climate change: A scenario analysis. *Ecological Economics*. 2012;84:206-12.
[28] Weitzman ML. On modeling and interpreting the economics of catastrophic climate change *Rev Econ Stat*. 2009;91:1-19.
[29] D'alisa G, Demaria F, Kallis G. *Introduction: degrowth*. In: D'alisa G, Demaria F, Kallis G, editors. *Degrowth - A vocabulary for a new era*. New York: Routledge; 2015.
[30] Solow RM. A Contribution to the Theory of Economic Growth. *Q J Econ*. 1956;70:65–94.
[31] Swan TW. Economic growth and capital accumulation. *Economic Record*. 1956;32:334-61.
[32] Kaldor N. A Model of Economic Growth. *The Economic Journal*. 1957;67.
[33] Arrow KJ, Debreu G. Existence of an Equilibrium for a Competitive Economy. *Econometrica*. 1954;22:265-90.
[34] Arrow KJ. General Economic Equilibrium: Purpose, Analytic Techniques, Collective Choice. *The American Economic Review*. 1974;64:253-72.
[35] Mckenzie LW. General Equilibrium. In: Durlauf SN, Blume LE, editors. The new palgrve dictionary of economics. 2 ed. London: Palgrave Macmillan,; 2008.
[36] Heinemann M. *Theorie des Allgemeinen Gleichgewichts. In: Dynamische Makroökonomik. Dynamische Makroökonomik*. Berlin, Heidelberg: Springer Gabler; 2015. p. 1-21.
[37] FAO. The Water-Energy-Food Nexus. Rome: FAO; 2014.
[38] UN Water. Water, Food and Energy. New York: United Nations. 2021, February, 2. https://www.unwater.org/water-facts/water-food-and-energy/
[39] van Leeuwen CJ, Frijns J, van Wezel A, van de Ven FHM. City Blueprints: 24 Indicators to Assess the Sustainability of the Urban Water Cycle. *Water Resources Management*. 2012;26:2177-97.
[40] Hoff H. Understanding the Nexus - Background paper for the Bonn2011 Conference: The Water, Energy and Food Security nexus. Stockholm: Stockholm Environment Institute (SEI); 2011.
[41] ECOMOD. *Practical General Equilibrium Modeling using GAMS*. Northampton, MA: EcoMod Press; 2003.
[42] Chiang AC. *Fundamental methods of mathematical economics*. Singapore: McGraw Hill; 1984.
[43] Powell AA, Gruen FHG. The Constant Elasticity of Transformation Production Frontier and Linear Supply System. *International Economic Review*. 1968;9:315-28.
[44] Armington PS. A Theory of Demand for Products Distinguished by Place of Production. *Staff Papers (International Monetary Fund)*. 1969;16:159-78
[45] Lofgren H, Cicowiez M. Linking Armington and CET Elasticities of Substitution and Transformation to Price Elasticities of Import Demand and Export Supply: A Note for CGE Practitioners *Documento de Trabajo Universidad Nacional de la Plata*. 2018;2018.
[46] Francois JF, Reinert KA. Applied Methods for Trade Policy Analysis. Cambridge: Cambridge University Press; 1997.
[47] H. Hesse, R. Linde. *Gesamtwirtschaftliche Produktionstheorie Teil I*. Heidelberg: Physica-Verlag 1976.
[48] Stobbe A. *Micro economics [in German: Mikroökonomik]*. Berlin: Springer; 1991.
[49] Shoven JB, Whalley J. *Applying general equilibrium*. Cambridge: Cambridge university press; 1993.
[50] Varian HR. *Intermediate Microeconomics*. New York, London: W. W. Norton & Company; 2003.
[51] Black J, Hashimzade N, Myles G. *A dictionary of economics*. Oxfod: Oxford University Press; 2009.
[52] Mainar-Causapé AJ, Ferrari E, McDonald S. Social Accounting Matrices: basic aspects and main steps for estimation. Brussels: European Commission; 2018.
[53] Roland-Holst DW. *Social Accounting Matrices*. In: Francois JF, Reinert KA, editors. *Applied Methods for Trade Policy Analysis*. Cambridge: Cambridge University Press; 1997.
[54] Schumacher EF. *Small is Beautiful: A Study of Economics as if People Mattered.* London: Blond and Briggs; 1973.
[55] Paech N. *Befreiung vom Überfluss*. München: Oekom; 2018.
[56] Hwang J, Choi M-i, Lee T, Jeon S, Kim S, Park S, et al. Energy Prosumer Business Model Using Blockchain System to Ensure Transparency and Safety. *Energy Procedia*. 2017;141:194-8.
[57] Heras-Saizarbitoria I, Sáez L, Allur E, Morandeira J. The emergence of renewable energy cooperatives in Spain: A review. *Renewable and Sustainable Energy Reviews*. 2018;94:1036-43.

[58] Hentschel M, Ketter W, Collins J. Renewable energy cooperatives: Facilitating the energy transition at the Port of Rotterdam. *Energy Policy*. 2018;121:61-9.
[59] Schröder C, Walk H. *Local climate governance and the role of cooperatives*. In: Knieling J, Filho WL, editors. *Climate Change Governance*. Berlin Heidelberg: Springer Science & Business Media; 2012. p. 105-18.
[60] Röttgen N. Aufbruch in ein neues Energiezeitalter. Gemeinsam auf dem Weg in eine nachhaltige Moderne. Berlin: Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU); 2011.
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