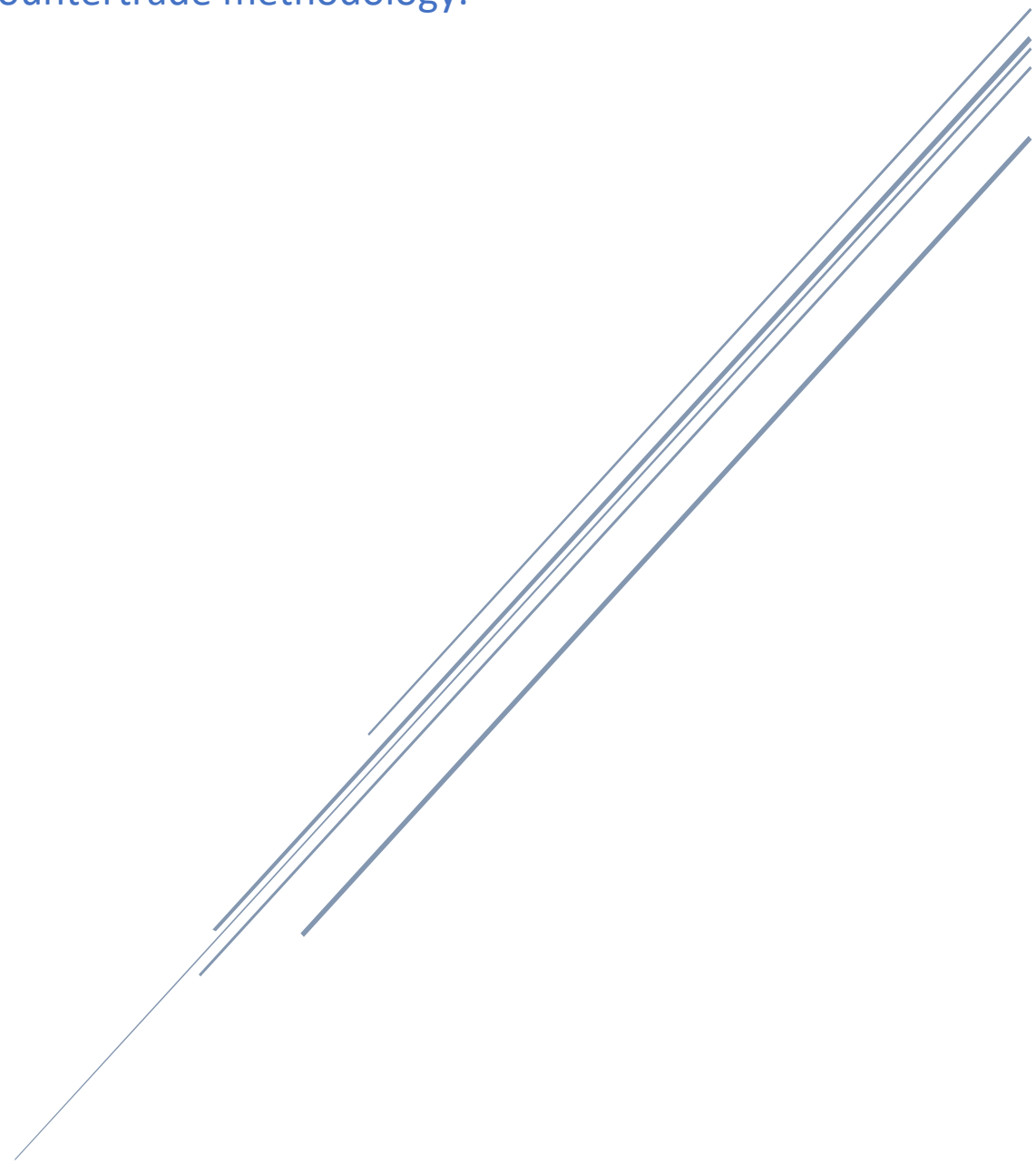
ARE COUNTERTRADE CREDITS AS FLEXIBLE AND EFFICIENT AS CASH?

A novel approach to reducing income inequality usingcountertrade methodology.



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I ODD+D PROTOCOL

The information below is a systematic description as proposed by Müller et al. (2013) of the agent-based model titled "Are Countertrade credits as flexible and efficient as cash? A novel approach to reducing income inequality using countertrade methodology." developed by Peter Malliaros.

A Purpose and Patterns

1 What is the purpose of the study?

This study explores a novel funding method that allows an increase in income payments to the lowest-paid workforce to reduce the level of income inequality in any economic system. There is strong evidence that the increase in income will affect the real economy by deacreasing the level of unemployment and poverty. Therefore, the purpose of the model is to test the hypothesis that the Countertrade Credits can reduce existing inequality in an economy by a statistically significant amount. It provides a systematic understanding of how the wealth of employees, is affected at a micro-level by restructuring the way they are paid. The model also monitors how the wealth of the overall economy is affected at a macro-level by the introduction of these changes.

2 For whom is the model designed?

This model is designed to be used by Scientists, Economists and Political decision-makers.

B Entities, state variables, and scales

3 What kinds of entities are in the model?

There are two types of employees, rich employees coloured blue and poor employees coloured red. There is one type of geographic environment with patches that produce a random amount of grain.

4 By what attributes (i.e. state variables and parameters) are these entities characterised?

Employee wealth is defined by the percentage of the accumulated income of individual employees compared to the employee with the highest amount of accumulated income. If they have income 50% or more as compared to the amount of the richest employee, then they are classified as rich (blue) otherwise they are classified as poor (red).

The Economic-System (chooser) – Allows users to choose between the "original model" that the ABM came with, the "Counterbalance" (CBE) model which provides a comparison between the status quo and the addition of the CBE to that economic system and the "Neoliberal-v-GovernmentRun" model which allows users to simulate any global economy using the following three sliders Tax-Collected-as-%-of-GDP, Welfare-Payment-to-Reds and Income-Growth-Volume (IGV).

In the "original model" setting, employees' income is set by the total amount of grain they can collect. In the "Neoliberal-v-GovernmentRun" setting, the amount of grain they collect is taxed

at a rate that is based on the country being simulated. There is also a percentage of welfare that is paid to the red employees, again based on the economy being simulated. In the "Counterbalance" setting, the red employees' income is set at a fixed minimum amount which is based on the CBE mean income which simulates payment in Countertrade Credits.

Countertrade Credits (CC's) is the name given by the author to a special type of in-kind transfer voucher that exhibits the characteristics outlined in *Are Countertrade credits as flexible and efficient as cash?A novel approach to reducing income inequality using countertrade methodology (*Malliaros & Pacheo, 2021).The concept behind Countertrade Credits has been adopted from the international model of "Countertrade" and the business model of "Contra-deals" where countries or businesses exchange their goods and services in-kind for the goods and services of another, where barter is only one of the options available in this system. (Halbach & Osterkamp, 1989).

5 What are the exogenous factors/drivers of the model?

Generally: Type of market being simulated, Labour market, Level of economic activity and income inequality.

Specifically: Tax rate, welfare payments and average weekly earnings

6 If applicable, how is space included in the model?

Agents move to any geographic point of the modelling world based on the location with the most amount of grain. To avoid all the agents converging on the same patch, their choice is limited to how far ahead they can see and this can be adjusted by the user.

7 What are the temporal and spatial resolutions and extents of the model?

Weekly time steps representing the weekly pay cycle with a simulation length of 500 ticks. The decision of which patch to gather grain from is made at each tick by each agent.

Agents are distributed randomly across the landscape at the start.

C Process overview and scheduling

8 What entity does what, and in what order?

<u>Setup-patches</u>

1. The modelled world is setup providing some of the patches the highest amount of grain possible. These **patches are the "best land"** and spread that grain around the window a little. Thereafter, they take a little back so that they remain the "best land". The amount of grain is then rounded to whole numbers and the initial grain level is set as the patch maximum.

```
ask patches
  [ set max-grain-here 0
```

```
    if (random-float 100.0) <= percent-best-land
      [ set max-grain-here max-grain
        set grain-here max-grain-here ] ]
  repeat 5
   [ ask patches with [max-grain-here != 0]
      [ set grain-here max-grain-here ]
    diffuse grain-here 0.25 ]
  repeat 10
   [ diffuse grain-here 0.25 ]
  ask patches
   [ set grain-here floor grain-here
    set max-grain-here grain-here  ]
```

2. Next, **patches are re-coloured** to indicate the amount of grain they hold.

```
 set pcolor scale-colour yellow grain-here 0 max-grain
```

3. After the grain has been harvested by employees, **the grow-grain procedure** asks the patch to top itself up to the maximum level that was set at the beginning.

```
;; patch procedure - if a patch does not have its maximum amount of grain, add
  ;; num-grain-grown to its grain amount
  if (grain-here < max-grain-here)
    [ set grain-here grain-here + income-growth-volume
      ;; if the new amount of grain on a patch is over its maximum
      ;; capacity set it to its maximum
      if (grain-here > max-grain-here)
        [ set grain-here max-grain-here ]
      recolor-patch ]
```

Setup-employees

1. Employees are set up with the default shape of a “person” and along with the number of employees in the simulation. Their size is set to 1.5 to make them easier to see and they are asked to stand in the centre of the patch they are on.

```
    ;; set up the initial values for the turtle variables
```

```
set-default-shape employees "person"
  create-employees num-people
   [ move-to one-of patches
   set size 1.5  ;; easier to see
    set-initial-employee-vars
    set age random life-expectancy ]
```

2. The **initial employee variables** are set next including their age which is set at 0, they are asked to face one of their neighbours, they are given a life expectancy, a set metabolism and a vision range that determines how many patches ahead they can see, all of which are set by users before commencing the simulation. They are also given a inocome based on the Average Weekly Earnings amount entered into the input box Country-AWE.

```
  set age 0
  face one-of neighbors4
  set life-expectancy life-expectancy-min +
                    random (life-expectancy-max - life-expectancy-min + 1)
  set metabolism 1 + random metabolism-max
  set income metabolism + random Country-AWE
  set wealth (wealth + 1)
  set vision 1 + random max-vision
```

3. **recolour-employees** - Employees are then coloured based on the amount of income they have. If they have 50% or more as an amount of the richest agent, then they are classified as rich (blue) otherwise they are classified as poor (red). This colouring system is used for all three settings, Original-Model, Counterbalance and Neoliberal-v-GovernmentRun models.

```
let max-income max [income] of employees
if ( Economic-System = "Original-Model" ) [ ask employees [ ifelse (income <= max-income / 2)
    [ set color red ]
  [ set color blue ] ] ]
  if ( Economic-System = "Counterbalance" ) [ ask employees [ ifelse income <= cbe-mean
    [ set color red ]
     [ set color blue ] ] ]
```

```
  if ( Economic-System = "Neoliberal-v-GovernmentRun" ) [ ask employees [ ifelse (income <= max-income / 2)

      [ set color red ]

   [ set color blue ] ] ]
```

4. **economic-system-selector** - In this section of code, users select the type of economy they want to simulate. They can choose from the original setting, the Neoliberal-v-GovernmentRun setting or the Counterbalance setting. The Neoliberal-v-GovernmentRun setting allows users to model any existing global economy by adjusting the tax and welfare settings as described in the info tab. They are then able to test how this economy would be affected with the introduction of the CBE, by changing the Economic System Selector chooser to the Counterbalance selection, without changing any other setting.

   In the original setting, employees' income is set by the total amount of grain they can collect. In the "Neoliberal-v-GovernmentRun", the amount they collect is taxed at a rate that is based on the country being simulated. There is also a percentage of welfare that is paid to employees based on the income they collect for that week (tick), again based on the economy being simulated. In the "Counterbalance" setting, the bottom 50 percentile employees income is set at a fixed minimum amount which is based on the CBE mean income while the top 50 percentile are taxed as per the country being simulated.

```
to economic-system-selector

  let max-income max [income] of employees

   if ( Economic-System = "Original-Model" ) [ ask employees [ ifelse (income <= max-income / 2)

    [set Tax-Collected  0 set welfare 0 ]

     [set Tax-Collected 0 ] ]]


  if ( Economic-System = "Counterbalance" ) [ ask employees with [color = red][ ifelse income <= cbe-mean

     [set income (cbe-mean ) set Tax-Collected 0  set welfare 0 ]

     [set income income set Tax-Collected 0 set welfare 0 ]]]


  if ( Economic-System = "Counterbalance" ) [ ask employees with [color = blue][ ifelse income <= cbe-mean

  [set income (cbe-mean ) set Tax-Collected 0  set welfare 0 ]

    [set income (income - Tax-Collected)set welfare 0 ]]]
```

```
;; when chosen, this component allows you to vary the overall tax rate and the welfare paid to emloyees based on their weekly income
 if ( Economic-System = "Neoliberal-v-GovernmentRun" ) [ ask employees [ ifelse (income <= max-income / 2)
   [set income ((income + Welfare) - Tax-Collected) ]
     [set income (income - Tax-Collected) set welfare 0 ] ] ]
End
```

5. **Go Procedure** – States the length of each simulation run and calculates the initial amount of income for the bottom 50 percentile of employees:

```
if ticks = 500 [ stop ]

if ticks = 0 [ set initial-bottom-50-inc bottom-50-inc ]
```

6. **turn-towards-grain** - In this step, employees are asked to look around and find the patch with the largest amount of grain within their field of vision and face that direction.

```
set heading 0
 let best-direction 0
 let best-amount grain-ahead
 set heading 90
 if (grain-ahead > best-amount)
  [ set best-direction 90
    set best-amount grain-ahead ]
 set heading 180
 if (grain-ahead > best-amount)
  [ set best-direction 180
    set best-amount grain-ahead ]
 set heading 270
 if (grain-ahead > best-amount)
  [ set best-direction 270
    set best-amount grain-ahead ]
 set heading best-direction
```

```
end
```

7. **report grain-ahead** - This code asks employees to check the distance from where they are standing to the patch that has been identified as having the largest amount of grain.

```
 let total 0
 let how-far 1
 repeat vision
  [ set total total + [grain-here] of patch-ahead how-far
   set how-far how-far + 1 ]
 report total
end
```

8. **harvest** – In this section employees are asked to harvest some grain on the patch and if there are multiple employees on this patch to split it equally amongst themselves.

```
 ask employees
  [ set income floor (income + (grain-here / (count employees-here) )) ]
 ask employees
  [ set grain-here 0
   recolor-patch ]
end
```

9. **to move-eat-age-die –** In this section, employees, move to their chosen location, they eat, they age by 1 week and they die if they either run out of energy or pass their designated lifespan. The amount of grain they eat is simulating their income less than what is spent on living expenses (metabolism). This is also where the taxation and welfare component is calculated.

```
 fd 1
 set Tax-Collected (income * Tax-Collected-as-%-of-GDP)
 set Welfare (income * Welfare-Payment-to-Reds)
 set wealth (( income - metabolism) + wealth )
 set age (age + 1)
 if (wealth < 0) or (age >= life-expectancy)
  [ set-initial-employee-vars ]
End
```

Update-lorenz-and-gini

1. This procedure recomputes the value of Gini-index-reserve and the points in Lorenz-points for the Lorenz and Gini-Index plots.

```
to update-lorenz-and-gini
  let sorted-income sort [income] of employees
  let total-income sum sorted-income
  let income-sum-so-far 0
  let index 0
  set gini-index-reserve 0
  set Lorenz-points []
```

2. Once the variables are set up, the procedure plots the Lorenz curve and the Gini index.

```
  repeat num-people [
   set income-sum-so-far (income-sum-so-far + item index sorted-income)
    set lorenz-points lput ((income-sum-so-far / total-income) * 100) lorenz-points
    set index (index + 1)
    set gini-index-reserve
      gini-index-reserve +
      (index / num-people) -
      (income-sum-so-far / total-income)
      ]
End
```

3. **Tick -** Advances the tick counter by one time-period

```
tick
```

D Theoretical and Empirical Background

9 ***Which general concepts, theories or hypotheses are underlying the model's design at the system level or the level(s) of the submodel(s) (apart from the decision model)? What are the link to the complexity and the purpose of the model?***

The model design follows mainstream neoclassical economic concepts and theories.

(a) Inspired by studies of:

Economic growth, inequality and poverty: Findings from a new data set (Adams, 2003).

Top incomes in the long run of history (Piketty et al., 2011).

The morale effects of pay inequality (Breza et al., 2018).

The right skills for the job? Rethinking training policies for workers (Almeida et al., 2012).

Guide to cash-for-work programming (MercyCorps, 2007).

BehaviorSpace in NetLogo (CSP-AIMS, 2015).

The small-sample bias of the Gini coefficient: results and implications for empirical research (Deltas, 2003).

Conditional cash transfers: reducing present and future poverty (Fiszbein et al, 2009).

NetLogo: A Modeling Tool (García Vázquez & Sancho Caparrini, 2016).

Exploring universal basic income: A guide to navigating concepts, evidence, and practices (Gentilini, 2019)

The other side of the coin (Gentilini, 2016).

Countertrade with developing countries: New opportunities for North-South trade?(Halbach & Osterkamp, 1989).

How automation and other forms of I.T. affect the middle class: Assessing the estimates (Jaimovich & Siu, 2019).

Targeting versus Universality: Is There a Middle Ground?. Social Protection and Jobs Policy Majoka & Palacios, 2019).

Are Countertrade credits as flexible and efficient as cash? A novel approach to reducing income inequality using countertrade methodology (Malliaros & Pacheco, 2021).

Boosting the benefits of cash transfer programs during the early years: A case study review of accompanying measures (Rawlings et al., 2020).

Altruism and beyond: An economic analysis of transfers and exchanges within families and groups (Stark,1999).

The price of inequality: How today's divided society endangers our future. (Stiglitz, 2012).

The spirit level: Why equality is better for everyone. Pickett & Wilkinson (2010).

(b) Suggested in studies of:

Boosting the Benefits of Cash Transfer Programs during the Early Years: A Case Study Review of Accompanying Measures (Rawlings et al., 2020).

Conditional cash transfers: reducing present and future poverty (Fiszbein et al, 2009).

Countertrade with developing countries: New opportunities for North-South trade? (Halbach & Osterkamp, 1989).

Exploring universal basic income: A guide to navigating concepts, evidence, and practices (Gentilini et al., 2019).

Guide to Cash-for-Work Programming (MercyCorps, 2007).

How automation and other forms of IT affect the middle class: Assessing the estimates (Jaimovich & Siu, 2019, pp. 20-22).

Targeting versus Universality: Is There a Middle Ground? (Majoka & Palacios, 2019).

The right skills for the job? Rethinking training policies for workers (Almeida et al., 2012).

The Other Side of the Coin (Gentilini, 2016).

Altruism and beyond: An economic analysis of transfers and exchanges within families and groups (Stark,1999).

10 On what assumptions is/are the agents' decision model(s) based?

Based on established microeconomic theories:

Homo economicus (inequality calculation)

11 Why is a/are certain decision model(s) chosen?

Established economic models and theories are followed to ensure scientific reliability of the model along with the availability of national statistical information which allows independent data collection.

12 If the model / a submodel (e.g. the decision model) is based on empirical data, where does the data come from?

Most of the parameter values are set based on information downloaded from the OECD database for Australia, the US, UK, Switzerland and Germany along with the Average Weekly Earnings for the country being modelled. The model uses a novel method of calculating the Average Weekly Earnings (AWE) for employees thereafter, which requires that the total amount of income of the bottom 50% of employees be set at the start as part of the calibration process. This is done by capturing the total amount of income available to the bottom 50% of agents at ticks = 0 (initial-bottom-50-inc). After that, the AWE is calculated as follows: sum top 50% agent income + initial-bottom-50-inc / number of agents.

Other parameter values such as the number of employees, max vision, metabolism max, life expectancy min and max and per cent best land, are chosen at random during the calibration process of the model whilst directly observing the behaviour of the modelled dynamics.

13 At which level of aggregation where the data available?

National level

E Individual Decision Making

14 What are the subjects and objects of decision making? On which level of aggregation is decision making modelled? Are multiple levels of decision making included?

Objects of decisions:
Income generated, amount of income of the top earner compared to everyone else, the value of countertrade credit (level of income inequality)

The level of inequality is calculated at the end of each weekly cycle during the simulation. Income and welfare less tax and energy used (metabolism) determine the outcome.

15 What is the basic rationality behind agents' decision-making in the model? Do agents pursue an explicit objective or have other success criteria?

Agent decision making follows the rational choice theory. Success criteria are based on agents maximizing their income and overall wealth.

16 How do agents make their decisions.

All agent decisions are based on income maximisation.

17 Do the agents adapt their behaviour to changing endogenous and exogenous state variables? And if yes, how?

Adaptation is based on endogenous variables:

- Locating the maximum amount of grain within the field of vision (determines where the agent will go to gather grain and earn an income)
- Metabolism will determine whether the agent survives the move based on the amount of energy it has left, the distance it travels

Exogenous variables:

- Rich and Poor (this variable determines whether an agent is eligible to receive welfare in the Neoliberal-v-GovernmentRun selection or eligible for countertrade-credits in the Counterbalance setting).
- The number of agents that randomly choose a specific location to harvest grain (this will determine the amount of grain (income) each agent will receive).
- Tax collected (this variable determines the amount of taxation that is deducted from income)
- Welfare (this setting determines the amount an agent will receive in income support if eligible)

18 Do social norms or cultural values play a role in the decision-making process?

Yes, norms and value outcomes are determined by which economy is being modelled, which then determine the level of taxation and the level of welfare provided.

19 Do spatial aspects play a role in the decision process?

Yes. The income of agents varies depending on which patch of ground they move to along with the number of other agents that have chosen to move to the same location.

20 Do temporal aspects play a role in the decision process?

Yes. While the level of income is earned at each time-period (week) and is a discreet amount, any income not consumed as energy is cumulative and adds to the wealth of each agent. This means, that there is less likelihood of agents running out of wealth and dying. However, if this were to occur, they would die, and a new agent would be born (hatched).

21 To which extent and how is uncertainty included in the agents' decision rules?

N/A

F Learning

22 Is individual learning included in the decision process? How do individuals change their decision rules over time as consequence of their experience?

N/A

23 Is collective learning implemented in the model?

N/A

G Individual Sensing

24 What endogenous and exogenous state variables are individuals assumed to sense and consider in their decisions? Is the sensing process erroneous?

(a) ***Endogenous state variables*****:**

- Ability to locate the most profitable job (income source – the amount of grain)
- Minimising expenditure and maximizing savings/wealth

(b) ***Exogenous variables*****:**

- Natural resource supply
- Competition for income sources
- Government support mechanisms
- Government taxation
- Level of economic growth

25 What state variables of which other individuals can an individual perceive? Is the sensing process erroneous?

Agents can sense when there is another agent located in the same space. The sensing process is sound as it is used by the agents to determine the portion of the income they can keep.

26 What is the spatial scale of sensing?

The spatial scale of sensing includes where the highest grain yield is located along with how far from that location they are situated.

27 Are the mechanisms by which agents obtain information modelled explicitly, or are individuals simply assumed to know these variables?

Income calculations occur at the microeconomic level and are modelled explicitly as part of the weekly business process. Global information is available to agents directly and they are expected to be aware of them (the patch with the largest amount of grain, the distance of this grain from where they are standing and the number of agents standing in the same space as they are).

28 Are costs for cognition and costs for gathering information included in the model?

The cost for cognition occurs because agents must share the amount of income equally among the total number of agents standing in the same location as they are. The cost for gathering information is included in that agent vision is limited therefore, the asymmetric information results in agents moving to what they perceive to be the most profitable location. This cost is compounded as mentioned because agents are not aware of how many other agents are going to choose the location they have chosen until they get there.

H Individual Prediction

29 Which data uses the agent to predict future conditions?

N/A

30 What internal models are agents assumed to use to estimate future conditions or consequences of their decisions?

N/A

31 Might agents are erroneous in the prediction process, and how is it implemented?

N/A

I Interaction

32 Are interactions among agents and entities assumed as direct or indirect?

Agents interact directly with each other when dividing the amount of income each will receive at the end of each time cycle (week).

33 On what do the interactions depend?

Geographic location

34 If the interactions involve communication, how are such communications represented?

The communication is represented through the division of the income (grain) equally among agents.

35 If a coordination network exists, how does it affect the agent behaviour? Is the structure of the network imposed or emergent?

N/A

J Collectives

36 Do the individuals form or belong to aggregations that affect, and are affected by, the individuals? Are these aggregations imposed by the modeller or do they emerge during the simulation?

The level of income that an agent achieves each week, determines whether they are classified as rich or poor. This then determines whether they are entitled to government assistance or countertrade credits and whether their income is taxed or not.

37 How are collectives represented?

Collectives are represented by changing their colour to either blue for rich or red for poor.

K Heterogeneity

38 Are the agents heterogeneous? If yes, which state variables and/or processes differ between the agents?

Agents are heterogenous initially as they are provided with a random amount of initial income/wealth and placed in a random location as their starting point.

39 Are the agents heterogeneous in their decision-making? If yes, which decision models or decision objects differ between the agents?

Each agent makes decisions heterogeneously with regards to where the most profitable patch is located to maximise their income. They then act on that decision, move to the location, and harvest the available grain.

L Stochasticity

40 What processes (including initialization) are modelled by assuming they are random or partly Random.

At initialization, all state variables are randomly set, from the income of each agent, the location they are situated along with where the most profitable patch of grain is located in relation to each agent. All these variables determine the level of income equality or inequality that each agent experiences and the consequences thereafter. This means that once an agent has received their initial income/wealth, they will be classified as either rich or poor and they will then be processed by the governmental system accordingly. They will either receive welfare or countertrade credits or they will pay tax on the income they have received. If they have enough income they will continue to thrive and if not, they will die and be replaced with a new agent.

M Observation

41 What data are collected from the ABM for testing, understanding, and analysing it, and how and when are they collected?

Testing via parameter sweep:
After model validation was complete confirming that it was able to mimic the real-world phenomenon under study, it was then tested via parameter sweeping (CSP-AIMS 2015). First, the analysis was manual at random which aimed at identifying parameters that are observably relevant for significantly modifying the behaviour of the ABM. To answer the research question, the focus relied on parameters related to the Gini Index. To analyse the wealth and inflationary impact of the proposed model, income levels, as well as the inflationary change, was reviewed for both systems to determine the economic and inequality impacts of the CBE. Further, a methodological approach was used utilising NetLogo's simulation tool 'BehaviorSpace' to test these specific parameters (García Vázquez &Sancho Caparrini 2016). This approach allowed the automated performance of a vast number of experiments. The values

selected for testing was done to allow for a minimum and maximum range, as well as a more sensitive range around the initially calibrated value. The results were then analysed using the statistical computing environment "Stata".

42 What key results, outputs or characteristics of the model are emerging from the individuals? (Emergence)

The agent-based perspective uncovered insights into how inequality develops in both systems guided by simple economic rules on a macro and micro level which is dynamically influenced by the complexity of the environment. The hypothesis related to income inequality and overall wealth has been tested regarding their sensitivity to the initial condition. The computational simulations served as a virtual lab for demonstrating how an increase in taxation or welfare can affect the outcome of inequality along with the impact of introducing the CBE. This has highlighted the importance of the variables tested along with the role of the CBE as the key determinants of shifted economic realities leading to the outcome of reduced income inequality.

N Implementation Details

43 How has the model been implemented?

Computer system:
NetLogo

Programming language:
Logo

Simulation platform:
BehaviorSpace

Simulation runtime:
500 ticks

Development time:
November 29th, 2020 until March 1st, 2021

44 Is the model accessible and if so where?

The model will be accessible on the OpenABM library: https://www.comses.net/

O Initialisation

45 What is the initial state of the model world, i.e. at time t=0 of a simulation run?

Variable: **Country-AWE**
Description: describes the amount entered as the average weekly earnings (AWE) for the country/economy being modelled
Initial value: dependent on the country and year being modelled
Unit: currency USD

Variable: **percent-best-land**
Description: sets some of the patches with the highest amount of grain possible
Initial value: user set between 0 and 25
Unit: percent

Variable: **max-grain**
Description: creates patches with a random level of grain and sets their maximum grain level
Initial value: initial value is the value set in input Country-AWE
Unit: currency USD

Variable: **max-grain-here**
Description: the maximum amount of grain this patch can hold
Initial value: random between > 0 and < 100
Unit: ratio

Variable: **income-growth-volume**
Description: describes the level of growth in the modelled world calibrated to the country being modelled
Initial value: user set between 0 and 30, dependent on the country being modelled
Unit: ratio

Variable: **num-people**
Description: describes the total number of employees representing the modelled economy
Initial value: random between > 2 and 1000
Unit: employee

Variable: **move-to**
Description: moves employees on to a random patch centre
Initial value: random
Unit: employee

Variable: **set size**
Description: enlarges the size of employees to make them easier to see
Initial value: 1.5
Unit: number

Variable: **setup-employees**
Description: sets default shape of employees as ‘person’
Initial value: turtle
Unit: person

Variable: **life-expectancy-min**
Description: sets employee minimum life expectancy
Initial value: user set between 1 and 100
Unit: number

Variable: **life-expectancy-max**
Description: sets employee maximum life expectancy
Initial value: user set between 1 and 100
Unit: number

Variable: **life-expectancy**
Description: sets employee life expectancy
Initial value: random between life-expectancy-max less life-expectancy-min
Unit: number

Variable: **face one-of neighbors4**
Description: employees randomly turn and point towards another employee
Initial value: random between the four cardinal points North, South, East and West
Unit: direction

Variable: **metabolism max**
Description: sets the maximum range of energy that employees burn each time they move and is used to calculate the actual employee metabolism
Initial value: user set between 1 and 25
Unit: ratio

Variable: **vision**
Description: sets how many patches forward an employee can see
Initial value: random between 1 plus a random level of the max-vision slider setting
Unit: number

Variable: **max vision**
Description: sets the maximum number of patches forward an employee can see
Initial value: user set between 1 and 25
Unit: number

Variable: **initial-bottom-50-inc**
Description: determines the total amount of income received by the bottom 50% of the population being modelled
Initial value: 0
Unit: currency USD

Variable: **recolour employees**
Description: recolours employees based on the amount of income they earn
Initial value: red or blue
Unit: colour

Variable: **economic-system**
Description: determines the type of economy the employees find themselves participating in
Initial value: Original economy, Neoliberal-v-GovernmentRun economy and Counterbalance economy
Unit: Type of economy

Variable: **Tax-Collected-as-%-of-GDP**
Description: the amount of income tax collected from employees
Initial value: user set between 0 and 99
Unit: percentage

Variable: **Tax-Collected**
Description: the amount of income tax collected from employees
Initial value: 0
Unit: currency USD

Variable: **Welfare-Payment-to-Reds**
Description: the amount of welfare paid to employees
Initial value: user set between 0 and 99
Unit: percentage

Variable: **Welfare**
Description: the amount of welfare paid to employees
Initial value: 0
Unit: currency USD

Variable: **move-eat-age-die**
Description: describes the process by which employees find a job, earn an income, age, reproduce and die
Initial value: 0
Unit: ratio

Variable: **harvest**
Description: describes the process by which employees earn an income
Initial value: 0
Unit: ratio

Values of the following variables are path-dependent, meaning that they aggregate only after originating from other variables. This means they are heterogeneous for every single employee and patch:

Variable: **grow-grain**
Description: describes the process of patches growing more grain
Initial value: 0
Unit: ratio

Variable: **grain-here**
Description: describes the current amount of grain on this patch
Initial value: random between > 0 and < 100
Unit: ratio

Variable: **recolor-patch**
Description: recolours patches to indicate the level of grain on a patch
Initial value: random scale-colour yellow
Unit: scale-colour yellow

Variable: **age**
Description: describes how old an employee is
Initial value: random between life-expectancy-max less life-expectancy-min
Unit: number

Variable: **metabolism**
Description: sets the amount of energy that employees burn each time they move
Initial value: random between 1 plus metabolism-max setting
Unit: ratio

Variable: **income**
Description: sets the amount of income (grain) an employee has harvested at
Initial value: random between employee metabolism plus a random number between 1 and 50
Unit: currency USD

Variable: **wealth**
Description: sets the amount of wealth (grain) each employee has accumulated
Initial value: 1
Unit: currency USD

Variable: **Lorenz-points**
Description: used to rank employees based on their level of income as a percentage, from the highest earner to the lowest
Initial value: the ranges on both axes are from 0% to 100%. Unit: percentage

Variable: **Gini-index-reserve**
Description: determines the numerical measurement of the inequity in the distribution of income and is derived from the Lorenz curve
Initial value: between 0 and 1
Unit: ratio

46 Is initialization always the same, or is it allowed to vary among simulations?

The initialization varies with each new run based on the economy that is being modelled and analysed.

47 Are the initial values chosen arbitrarily or based on data?

The initial values are based on real-world data obtained from OECD database for each country being modelled. This data includes:

- Annual GDP
- Total Tax
- Annual Welfare Payments
- Percentage of Tax to GDP
- Percentage of Welfare to Tax
- Annual Gini Index
- Average Weekly Earnings

Although the above data has been used to set initial settings the Gini index is calculated for each setting based on agent interaction and is one of the methods being used to determine the usefulness of the data being produced. Another is the level of total income produced as compared to the actual country GDP.

Components of the novel counter-trade credit model were inspired in part by Countertrade with developing countries: New opportunities for North-South trade? (Halbach & Osterkamp, 1989) and The Other Side of the Coin (Gentilini, 2016).

- Values that have been assigned at random:
- Level of initial income
- The initial geographical location of agents
- Movement of agents

- Level of weekly income
- Level and speed of wealth accumulation

Exceptions are variables which are dependent on their counterpart:

- Lorenz Curve
- Gini Coefficient

P Input Data

48 Does the model use input from external sources such as data files or other models to represent processes that change over time?

No.

Q Submodels

49 What, in detail, are the submodels that represent the processes listed in 'Process overview and scheduling?

- Setup: sets up the modelled world
- Setup-patches: sets up patches
- Setup-employees: sets up employees
- set size 1.5: sets the size of employees
- set-initial-employee-vars: sets up employee variables
- set age random life-expectancy: sets up employee age limit
- set metabolism 1 + random metabolism-max: sets employee metabolism
- set income metabolism + random Country-AWE: sets employee income
- set vision 1 + random max-vision: sets up employee vision
- set Tax-Collected (income * Tax-Collected-as-%-of-GDP): sets up the level of income tax
- set Welfare (Tax-Collected * Welfare-Payment-to-Reds): sets up the level of welfare payment
- recolour-employees: sets up the class employees belong to
- economic-system-selector: determines what type of economy the employees are working in. This then determines the level of income, taxation and welfare that they are exposed to, which then determines individual financial wellbeing and level of inequality experienced.
- Go: describes the process of one simulation run
- Harvest: describes the process by which employees earn an income
- to move-eat-age-die: describes the process of employees living their lives, which includes finding a job, earning an income, consuming, aging and dying.
- Update-Lorenz-and-Gini: describes the process of calculating the Lorenz curve and the Gini coefficient used to measure the level of inequality that the simulated economy is producing.

50 What are the model parameters, their dimensions and reference values?

Variable: **Country-AWE**
Description: describes the amount entered as the average weekly earnings (AWE) for the country/economy being modelled
Initial value: dependent on the country and year being modelled
Unit: currency USD

Variable: **percent-best-land**
Description: sets some of the patches with the highest amount of grain possible
Initial value: user set between 0 and 25
Unit: per cent

Variable: **max-grain**
Description: creates patches with a random level of grain and sets their maximum grain level
Initial value: initial value is the value set in input Country-AWE
Unit: currency USD

Variable: **max-grain-here**
Description: the maximum amount of grain this patch can hold
Initial value: random between > 0 and < 100
Unit: ratio

Variable: **income-growth-volume**
Description: describes the level of growth in the modelled world calibrated to the country being modelled
Initial value: user set between 0 and 30, dependent on the country being modelled
Unit: ratio

Variable: **num-people**
Description: describes the total number of employees representing the modelled economy
Initial value: random between > 2 and 1000
Unit: employee

Variable: **move-to**
Description: moves employees on to a random patch centre
Initial value: random
Unit: employee

Variable: **set size**
Description: enlarges the size of employees to make them easier to see
Initial value: 1.5
Unit: number

Variable: **setup-employees**
Description: sets default shape of employees as ‘person’
Initial value: turtle
Unit: person

Variable: **life-expectancy-min**
Description: sets employee minimum life expectancy
Initial value: user set between 1 and 100
Unit: number

Variable: **life-expectancy-max**
Description: sets employee maximum life expectancy
Initial value: user set between 1 and 100
Unit: number

Variable: **life-expectancy**
Description: sets employee life expectancy
Initial value: random between life-expectancy-max less life-expectancy-min
Unit: number

Variable: **face one-of neighbors4**
Description: employees randomly turn and point towards another employee
Initial value: random between the four cardinal points North, South, East and West
Unit: direction

Variable: **metabolism max**
Description: sets the maximum range of energy that employees burn each time they move and is used to calculate the actual employee metabolism
Initial value: user set between 1 and 25
Unit: ratio

Variable: **vision**
Description: sets how many patches forward an employee can see
Initial value: random between 1 plus a random level of the max-vision slider setting
Unit: number

Variable: **max vision**
Description: sets the maximum number of patches forward an employee can see
Initial value: user set between 1 and 25
Unit: number

Variable: **initial-bottom-50-inc**
Description: determines the total amount of income received by the bottom 50% of the population being modelled
Initial value: 0
Unit: currency USD

Variable: **recolour employees**
Description: recolours employees based on the amount of income they earn
Initial value: red or blue
Unit: colour

Variable: **economic-system**
Description: determines the type of economy the employees find themselves participating in
Initial value: Original economy, Neoliberal-v-GovernmentRun economy and Counterbalance economy
Unit: Type of economy

Variable: **Tax-Collected-as-%-of-GDP**
Description: the amount of income tax collected from employees
Initial value: user set between 0 and 99
Unit: percentage

Variable: **Tax-Collected**
Description: the amount of income tax collected from employees
Initial value: 0
Unit: currency USD

Variable: **Welfare-Payment-to-Reds**
Description: the amount of welfare paid to employees
Initial value: user set between 0 and 99
Unit: percentage

Variable: **Welfare**
Description: the amount of welfare paid to employees
Initial value: 0
Unit: currency USD

Variable: **move-eat-age-die**
Description: describes the process by which employees find a job, earn an income, age, reproduce and die
Initial value: 0
Unit: ratio

Variable: **harvest**
Description: describes the process by which employees earn an income
Initial value: 0
Unit: ratio

51 How were submodels designed or chosen, and how were they parameterised and then tested?

(a) Parameterisation:

The timely order of the submodels initially follows an intuitive order of setting up the economy, level of production, and employees first. Further, the production location of the employees is determined. Looking next at employee-specific set-up, individuals are equipped with a seed income and wealth amount. These two randomised initial values in combination with defined global parameters result in the aggregation of all other path-dependent submodels. This includes the level of economic growth, income level potential, tax rate, welfare payments, equity level and socioeconomic status as a key determinant of health. The parameterisation of employment, wages, and inequality calculations follow microeconomic examples (Deltas 2003). During calibration, values of different parameters were adjusted based on the country being modelled aiming at the behaviour of the model to replicate the level of inequality in an economy and the ability for that economy to positively adjust their level of inequality.

(b) Testing and validation:

To validate the created model, the values of the initial setting were controlled whilst testing a minimum and maximum range of values for a selected number of variables. The selection was guided by the reasoning to obtain results that mimic economic dynamics as they can be observed in the real-world which is useful for verifying the functionality of the model.

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