



*CBM Annual Research Workshop 2021 - 26<sup>th</sup> November 2021*

A bird's eye view of the  
Computable General Equilibrium (CGE) model  
developed by  
the Central Bank of Malta and the University of Macerata

Francesca Severini, University of Macerata





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# The research project

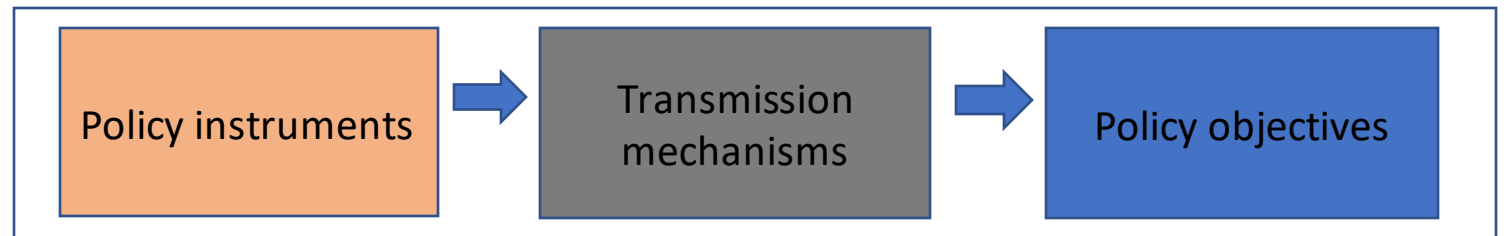
The Central Bank of Malta and the University of Macerata are cooperating on the construction of the *Computable General Equilibrium (CGE)* model based on the **Social Accounting Matrix (SAM)** for the *Maltese Economy*



# CGE models for policy impact analysis

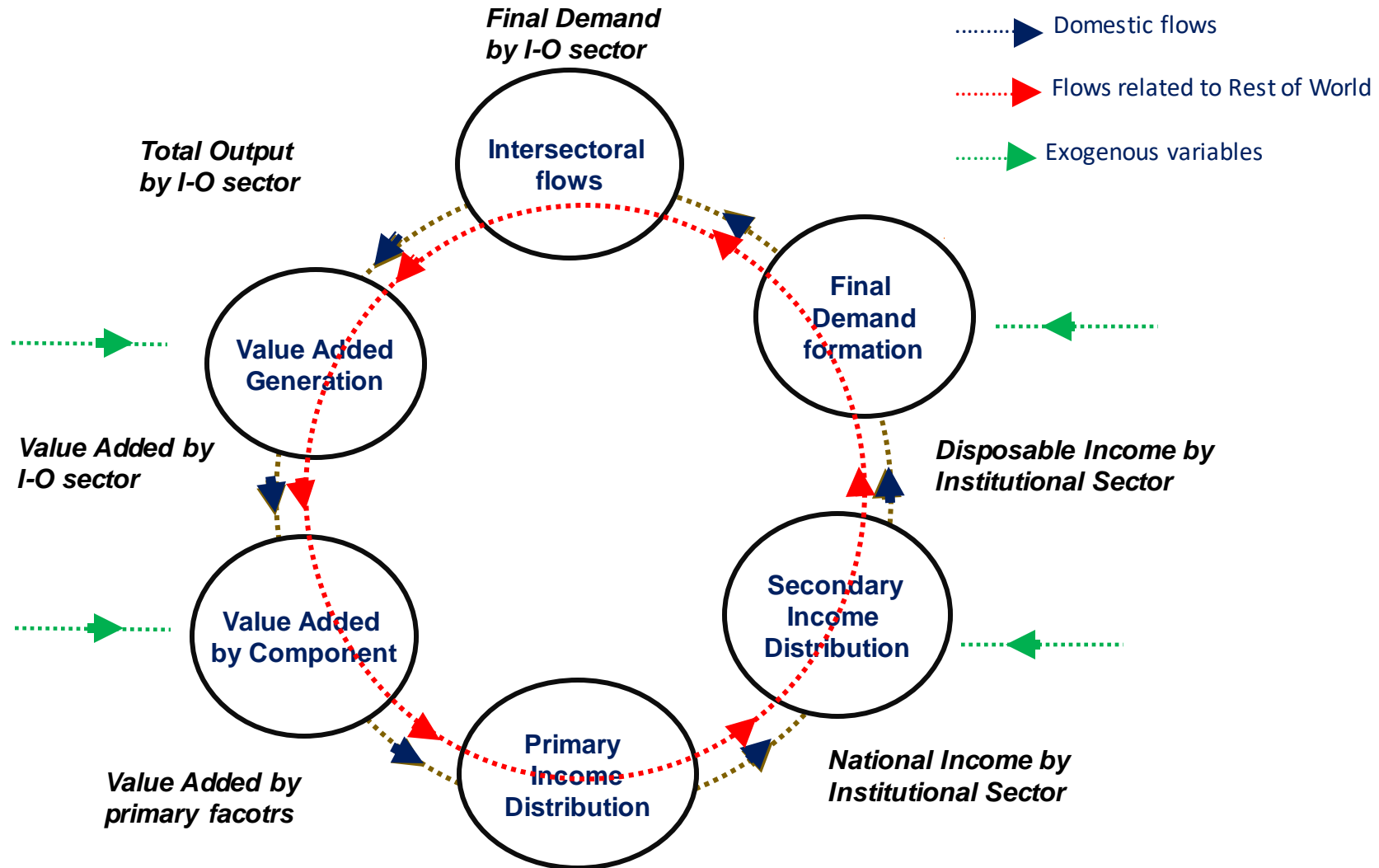
Impact Analysis of Economic Policies within the economic system faces several oppositions:

- Objectives VS Economic policy Instruments
- Instruments VS impacts of economic policy measures
- Impact of policies VS evaluation of effects
- Sub-sectoral VS sectoral
- Sectoral VS macro





# The income circular flow



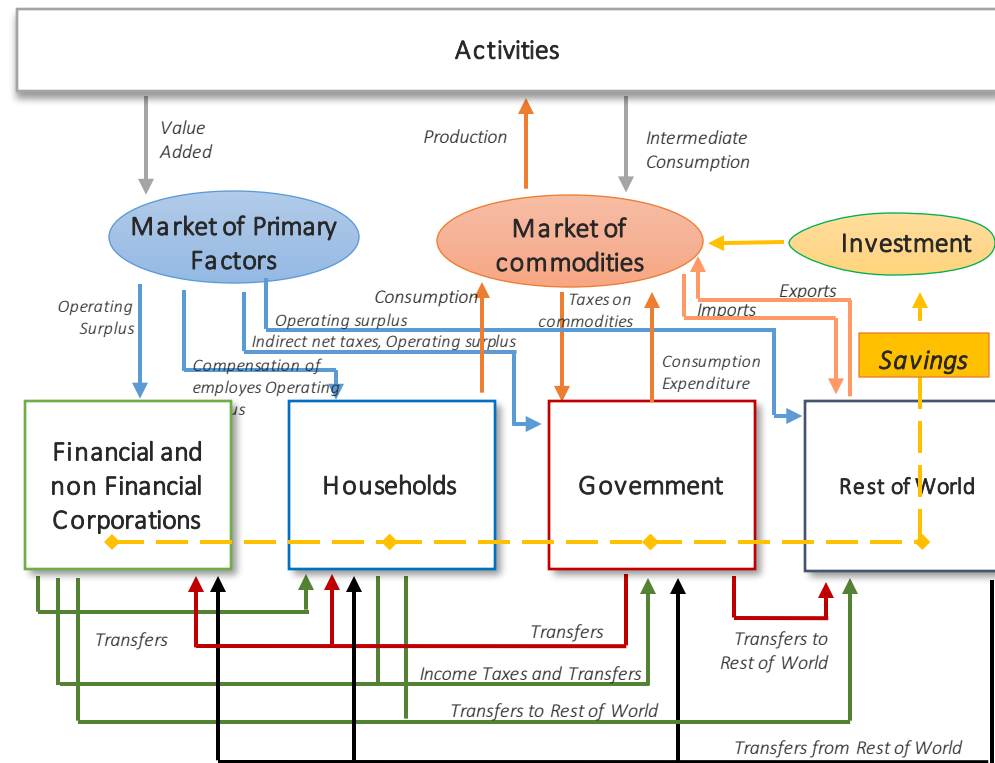


# CGE models for policy impact analysis

1. They provide a theoretical representation of the economic relations occurring in the economic system
2. Generality of relations' interdependency: all economic agents interact with each other and all markets are conditioned by the choices of all the operators.
3. Market rules and macroeconomic balances (competitiveness of markets, balance of payment, Government budget constraint, saving-investment closure etc.)
4. Quantitative consistency in operators' choices in the calibration process



# The CGE and the income circular flow





# Overview of CGE models (1)

The spirit of Computable General Equilibrium models is Walrasian:

- Including production, distribution and demand
- Determining equilibrium wages and prices (relative prices)
- Fixed supply of primary factors of production
- Market clearing of markets (prices and wages adjust to achieve supply-demand equilibrium in all goods and factors markets)
- In macro terms this implies *full employment* and neutrality of money

Arrow and Debreu (1954), Debreu (1959) demonstrated that the market system could be comprehensively analyzed under the neoclassical assumptions, allowing the application of GE approach to real economies.

Walras, L. (1874) *Éléments d'économie politique pure, ou théorie de la richesse sociale* (Elements of pure economics, or theory of social wealth.) Lausanne, L. Borbax ed.

Arrow, K and Debreu, G. (1954). Existence of a Competitive Equilibrium for a Competitive Economy. *Econometrica*, 22(3)

Debreu, G. (1959) *Theory of value: an axiomatic analysis of economic equilibrium*. New York, Wiley



# Overview of CGE models (2)

## Extension of CGE models to incorporate:

### Foreign trade:

- Imperfect substitutability between domestically produced and imported goods (Armington, 1969)
- New component of final demand (Exports)
- Introduction of a new actor “Rest of World”
- In macro terms this rises the question of how treating the trade balance (endogenous variables, exogenous variables – e.g. foreign saving and real exchange rate)

Armington, Paul S. (1969). "A Theory of Demand for Products Distinguished by Place of Production." IMF Staff Papers (16)

Devarajan, Shantayanan, Jeffrey D. Lewis, and Sherman Robinson (1990). Policy Lessons from Trade-Focused Two-Sector Models. *Journal of Policy Modeling*, 12, (4).

De Melo, Jaime, and Sherman Robinson (1989). Product Differentiation and the Treatment of Foreign Trade in Computable General Equilibrium Models of Small Economies. *Journal of International Economics*. 27(1-2).



# Overview of CGE models (3)

## Extension of CGE models to incorporate:

### Government:

- Implies the introduction of taxes on products, production processes, income
- Transfers to/from other Institutional sectors
- New component of final demand (Government consumption expenditure)
- In macro terms this rises the question of how treating the government deficit or surplus; how financing the deficit; tax rates etc.

Harberger, A, (1962) The incidence of corporate income tax. Journal of political economy. 70.

Showen, J.B. and Whalley J. (1972) A general equilibrium calculation of the effects of differential taxation on income from capital . Journal of public economics 1.

Showen, J.B. and Whalley J. (1974) A proof of the existence o a general equilibrium with ad valorem commodity taxes. Journal of economic theory 8.

Scarf, H.E. (1967). The approximation of fixed points of a continuous mapping. SIAM. Journal of applied mathematics. 15, 1328-43.



# Overview of CGE models (4)

## Extension of CGE models to incorporate:

### Additional markets:

- Financial instruments,
- Renewable and non-renewable energy,
- Emissions and Emissions certificates
- Primary factors: skills and gender

Ahmed I., Socci C., Severini F., Pretaroli R. and Al Mahdi H.K. (2019). Unconventional monetary policy and real estate sector: a Financial Dynamic Computable General Equilibrium model for Italy, in *Economic System Research*.

Ciaschini, M., Pretaroli, R., Severini, F., Socci, C. (2012). Environmental tax reform and double dividend evidence. *Research in Economics*, 66.

Bovenberg, A., Goulder, L. (1996). Optimal environmental taxation in the presence of other taxes: General equilibrium analysis. *American Economic Review*, 86.

Ciaschini, M., Pretaroli, R., Severini, F., Socci, C. (2014). Policies for electricity production from renewable sources: The Italian case. *Journal of Policy Modeling*.

Severini F., Felici F., Ferracuti N., Pretaroli R., Socci C. (2019). Gender policy and female employment: a CGE model for Italy. *Economic Systems Research*, (31)1.

Fontana, M., & Van Der Meulen Rodgers, Y. (2005). Gender Dimensions in the Analysis of Macro-Poverty Linkages. *Development Policy Review*, 23(3).



# Overview of CGE models (4)

## Extension of CGE models to incorporate:

### Economic systems peculiarities:

In the latest decades, countless applications of general equilibrium models have been carried out for policy impact analysis in different countries and the difference among them depends on:

- the purposes of the analysis,
- the theoretical assumption on the competitiveness of markets,
- their level of aggregation,
- the sources of statistical data utilized,
- the time span covered etc...

Dixon, P.B, Parmenter, B.R., Sutton, J. and Vincent ,D.P. (1982). *ORANI* A multisectoral model of Australian economy. New Holland.

Deardorf A.V. and tern R.M. (1986). *The Michigan model* of world production and trade: theory and applications. MIT press.

Socci, C., Felici, F., Pretaroli, R., Severini, F., Loiero, R. (2021), The Multisector Applied Computable General Equilibrium Model for Italian economy (*MACGEM-IT*), in Italian Economic Journal, 1.



# Overview of CGE models (5)

Two major families of CGEs can be identified (Willenbockel, 1994) :

1. CGEs rooted on the tradition of applied neoclassical welfare analysis:

Studies assuming that all the agents supplying and/or demanding factors and goods perform according to an optimizing behavior, there is homogeneity of degree zero in prices and incomes, and there exist an appropriate set of prices for goods and factors which clear all the markets.

2. CGE rooted in the tradition of quantitative development planning:

Studies that relax the strict Walrasian framework by introducing non-Walrasian elements such as nominal price rigidities, unbalanced government budgets in equilibrium, nominal exchange rates etc.

Willenbockel D. (1994) Applied general equilibrium modelling: Imperfect competition and European integration. Wiley.



# Overview of CGE models (6)

## *Less orthodox CGE models*

The so called “*macro-structuralists*” models (Taylor, 1990), follow more the tradition of Keynes, Kalecki and Kaldor rather than Walras, Arrow and Debreu, and emphasize how the causation links in a CGE run from the macro-economic equilibrating mechanisms to the micro-economic distributional implications.

Macro-closures substantially influence the outcomes of the models

Elements	Neo-classical	Keynesian	Johansen	Post- Keynesian (Kaldor-Pasinetti)
Output	Determined by factor endowments and technology	Determined by the effective demand	Determined by the effective demand	Determined by the effective demand (or by factor endowments if full employment is reached)
Investment	Endogenous Investment adapts to savings	Exogenous. Savings adjust to investments by means of changes in quantities and incomes (multiplier)	Exogenous. Savings adjust to investment by means of “compulsory” savings (taxes)	Exogenous. Income distribution adapts to adjust savings
Factors	Full employment	May be unemployed	Full employment	May be unemployed
Wages	Reflects MVP	May not reflect MVP	Reflects MVP	May not reflect MVP



# SAM-based CGE models for policy impact analysis

The SAM-based CGE modelling is considered a best practice in economic impact analysis

- It provides a comprehensive disaggregated macro framework of the economic system
- It allows assessing the direct, indirect and induced socio-economic impact of selected economic policies:
  - Industries/commodities
  - GHG Emissions and Energy
  - Income redistribution,
  - Value Added components

and economic policies differentiated by spatial, gender, age, level of education, etc.



# What is a Social Accounting Matrix

The SAM can be seen as an extension of the I-O table, which maintains the matrix structure and includes additional wealth data that can be transformed into highly useful information for the development of the national or regional economy.

It represents one of the relevant way to show the Social National Accounting system:

- in Matrix terms;
- incorporating extra details of special interest for the economic research (economic, social, geographical issues, ...);
- considering other Satellite Accounts (tourist, environmental, health accounts).

Miller and Blair, Input-Output Analysis, Cambridge Ed, 2015.

Pyatt, Some relationships between t-account, input-output tables and social accounting framework, in Economic System Research, (11): 365-387.

Pyatt, G., & Round, J. I. (1979). Accounting and fixed price multipliers in a social accounting matrix framework. The Economic Journal, 89(356).

King B.B (1994), What is a SAM? In Social Accounting Matrix a Basis for Planning (by Pyatt and Round), World Bank, Washington.

<https://www.iioa.org/>

Keuning, S. J., & de Ruiter, W. A. (1988). Guidelines to the construction of a social accounting matrix. Review of income and wealth, 34(1).



# The SAM

			Primary Factors					Institutional Sectors					Capital account	
			industries	Compensation of employees	Mixed income	Gross operating surplus	Firms	Government	Households	Rest of the World	Capital formation	Total		
		n.	1	2	3	4	5	6	7	8	9	10	11	12
	industries	1	Intermediate Consumption							Final consumption by Government	Final Consumption By Household		Exports	Gross fixed capital formation, Changes inventories,
Primary Factors	Compensation of Employees	2	Gross Value Added										Value Added om the Resto the World	
		3												
	Mixed income	4												
		5												
	Gross operating surplues	6												
Institutional Sectors	Firms	7		Gross National Income				current taxes on income, wealth etc; social contributions; social benefits; other current transfers						
	Government	8												
	Households	9												
		10		Value Added to Rest of World										
	Rest of the World	11	Imports											
Capital account	Capital formation	12						Savings						
	Total													



# Steps in deriving a standard CGE model

Formulation of a numerical model expressed as a system of equations and inequalities (linear and nonlinear) that can be solved through the use of different solution algorithms.

1. Specify dimensions of the model:
  - Activities/Commodities
  - Primary Factors
  - Institutional Sectors
  - Regions and Countries
2. Construct the Micro-Macro-Consistent data set
  - Input-output Tables
  - SAM
3. Chose the functional forms
  - Functional forms specify technologies (production functions) and preferences (utility functions)
  - Trade-off between flexibility and regularity. Usually CES functions allows a good level of flexibility (through nesting)



# Steps in deriving a standard CGE model

## 4. Calibration of the model

- Parameters are chosen such that functional forms and data are consistent (data represent a solution to the model).
- Therefore, the benchmark data determine: efficiency parameters, distribution parameters, Implicit tax rates, quotas, shares, average propensity to consumption and saving etc.

## 5. Micro-Macro closure rules for macro-system constraints

## 6. Replication of the benchmark

- Run model to see if it reproduces the input data (the benchmark)

## 7. Policy design and counter-factual experiments



# A standard Computable General Equilibrium Model

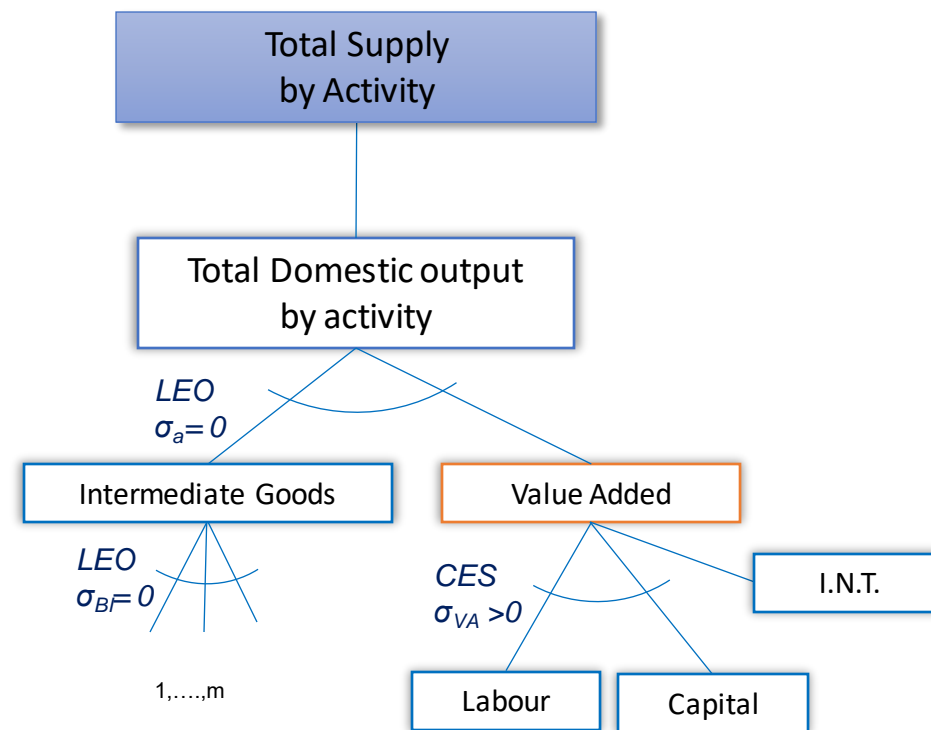
## Production technology

The value of output by commodity results from the combination (Nested production function) of intermediate goods, primary factors, taxes and imports (Armington, 1969).

## Primary factors markets

- Primary factors are perfectly mobile across sectors.
- Total endowments are exogenous.
- The factors demand derives from activities' process of profit maximisation.
- The price of primary factors fluctuates to balance the demand and the supply
- **Labour market can be not competitive:** wages are negotiated by Trade Unions and there is male and female unemployment

The nested production function by activity

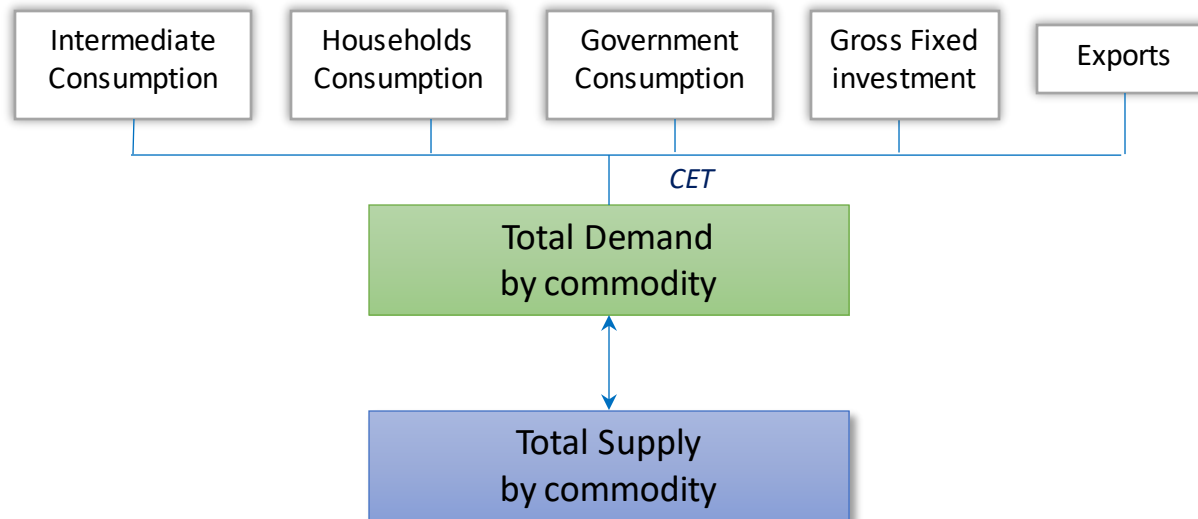




# A standard Computable General Equilibrium Model

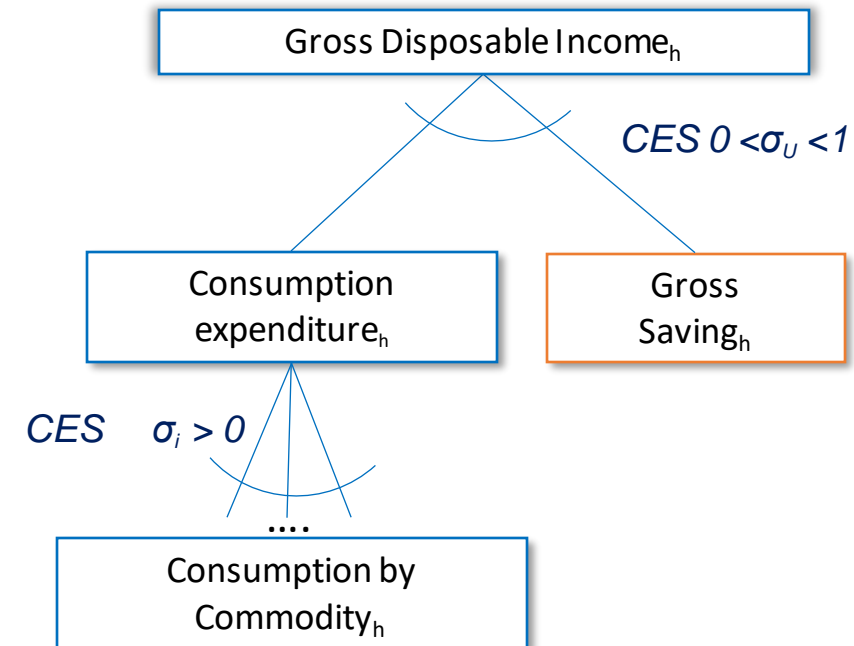
## Commodity markets

The value of output by commodity equals the sum of intermediate consumption and final demand



## Institutional Sectors behaviour

They maximize their utility function which depends on final consumption expenditure subject to the constraint represented by the disposable income net of savings (assumed as endogenous and alternative to Consumption expenditure).





# The SAM based CGE model for Malta

The SAM based CGE model for Malta can complement and support the range of models in use by the CBM for the policy impact analysis (*STREAM* and *MEDSEA*). It will help:

- **STREAM** – traditional macro-econometric model of the Maltese economy.
  - **MEDSEA** – a dynamic stochastic general equilibrium (DSGE) model of the Maltese economy as a small open economy in a monetary union.
- Characterizing and strengthening the results in disaggregated terms;
  - Analyzing the impacts of policies implying selective and precise interventions;
  - Expanding and integrating the information set when introducing the shocks and when evaluating their effects.



# Applications with the SAM based CGE models

- Environmental and fiscal policy
- Monetary Policy



# Regional double dividend from environmental tax reform: an application for the Italian economy.

Applications with  
SAM-based CGE  
models

- Environmental and  
fiscal policy

Ciaschini M., Pretaroli R., Severini F., Socci C.  
*Research in Economics*, Vol. 66, pp. 273–283

## Aim of the paper

Developing a disaggregated analysis to investigate the *Double Dividend* hypothesis from the introduction of an environmental tax to reduce the level of CO<sub>2</sub> emissions.

## Methodology

- Bi-regional SAM integrated with the Environmental data set concerning GHG emissions in physical terms (National Accounting Matrix with Environmental Accounts - NAMEA)
- Static Computable General Equilibrium Model

## Application

Introduction of environmental taxation on total output differentiated according to the polluting power of each commodity. Impact analysis of different tax revenue recycling schemes on economic and environmental variables.



Applications with  
SAM-based CGE  
models

- Environmental and  
fiscal policy

## Environmental policy proposal

1. Identification of the most polluting activities (those with CO<sub>2</sub> emissions above an environmental sustainability level)
2. Fiscal burden is differentiated according to CO<sub>2</sub> emissions by each commodity
3. NO-TAX area
4. Progressive and proportional structure of the environmental tax.
5. Tax revenue is completely recycled in the economy
  - To reduce Households Income Taxes
  - To reduce the Regional Tax on Economic Activities



Applications with  
SAM-based CGE  
models

- Environmental and  
fiscal policy

## The results: impact on CO<sub>2</sub> emissions (% change)

Regions	Simulation 1	Simulation 2
	revenue is used by the Central Government to reduce Households Income Tax	revenue is used by the Regional Government to reduce the Regional Tax on Economic Activities
South	-1.145	-1.150
North-Centre	-0.805	-0.805
<b>Total Italy</b>	<b>-0.898</b>	<b>-0.900</b>

**The first dividend is achieved in both two scenarios and for  
each region**



Applications with  
SAM-based CGE  
models

- Environmental and  
fiscal policy

## The results: Impact on primary factors' payments and unemployment (% change)

Primary Factors	South		North-Centre	
	s1	s2	s1	s2
Employed	0.043	0.025	-0.075	-0.040
Self Employed	-0.087	-0.069	-0.201	-0.156
Capital	-0.458	-0.437	-0.486	-0.439
<b>Unemployment rate %change</b>	<b>0.111</b>	<b>0.093</b>	<b>-0.059</b>	<b>-0.028</b>
Unemployment rate	17.75	17.68	4.60	4.56

Second “employment” dividend arises in both scenarios  
but only in North-Centre region



Applications with  
SAM-based CGE  
models

- Environmental and  
fiscal policy

## The results: Impact on private Real Disposable Income (% change)

Institutional sectors	South		North-Centre	
	s1	s2	s1	s2
Households	-0.009	-0.400	<b>0.149</b>	-0.306
Firms	-0.556	-0.527	-0.538	-0.495

A further benefit, the “*third dividend*”  
is observed on North-Centre households real disposable income  
when the policy maker uses the tax revenue to reduce income tax



- Monetary policy

## Unconventional monetary policy expansion: the economic impact through a dynamic CGE model

Socci C., Pretaroli R., Severini F., Ahmed I. and Ciaschini C.

*International Journal of Monetary Economics and Finance*, Vol. 11, No. 2, 2018

### Aim of the paper

Developing a disaggregated analysis to investigate the economic impact of monetary policy

### Methodology

- Financial SAM
- Financial Dynamic Computable General Equilibrium Model

### Application

Monetary policy scenarios inspired to the latest European Central Bank *unconventional* monetary policy decisions encompassed in the *Public Sector Purchasing Program* (ECB, 2015)



Applications with  
SAM-based CGE  
models

- Monetary policy

***Policy Scenario 1.***

- we assume that ECB purchases marketable debt instruments (bonds) issued by the Central Government directly from the Government, thus providing liquidity by the same amount.
- In the model we simulate a change in the composition of Institutional Sectors portfolio, so that the amount of bonds owned by Rest of the World increases likewise the currency owned by the Government.
- The volume of the policy is 10 billion Euro and is assumed to be permanent.

***Policy Scenario 2.***

- we assume that ECB purchases bonds issued by central Government on the secondary market, thus bonds owned by Households, Financial and non-Financial Corporation.
- In the model we change the composition of Institutional Sectors' portfolio accordingly and consider an increase of the same amount in liquidity for the system.
- The volume of the policy is still 10 billion Euro and is assumed to be permanent.



- Monetary policy

## Policy scenario 1: ECB purchases bond issued by National Government

Percentage change from benchmark path of main macroeconomic aggregates from 2017 to 2021

	2017	2018	2019	2020	2021
GDP	0.36	0.27	0.18	0.09	0.00
Consumption	0.37	0.37	0.38	0.38	0.39
Investments	1.25	0.55	-0.15	-0.87	-1.66
Exports	0.61	0.62	0.64	0.66	0.68
Imports	0.01	0.01	0.02	0.02	0.02
Inflation	0.12	0.18	0.23	0.26	0.27



## Policy scenario 2: ECB purchases bonds issued by Government from other Institutional Sectors

- Monetary policy

Percentage change from benchmark path of main macroeconomic aggregates from 2017 to 2021

	2017	2018	2019	2020	2021
GDP	0.57	0.44	0.30	0.15	0.00
Consumption	0.37	0.37	0.38	0.38	0.39
Investments	2.90	1.78	0.68	-0.45	-1.65
Exports	0.61	0.62	0.64	0.66	0.68
Imports	0.01	0.01	0.02	0.02	0.02
Inflation	0.24	0.38	0.47	0.53	0.56





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*Thank you*

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