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IMPACTS OF CO_2 TAX

ON

ITALIAN ECONOMY

A COMPUTABLE GENERAL EQUILIBRIUM APPROACH (CGE)

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"When I began the study of economics some forty one years ago, I was struck by the incongruity between the models that I was taught and the world that I had seen growing up"

Nobel Prize Winning Economist Joseph Stiglitz

ABSTRACT

Anthropogenic CO_2 emission is one of the chief greenhouse gases that coming from the burning of fossil fuels by households and firms imposing a cost and negative impact on present and future generations in the form of climate change and global warming. There are many ways and instruments to reduce fossil fuel emissions. Making pollution expensive by imposing tax would be one way to motivate consumers and producers to continuously substitute fuels with high carbon content by alternative with low carbon content.

This paper uses a top-down static Computable General Equilibrium (CGE) model for a small open economy to analyze the effects of carbon tax policy on Italian macroeconomic variables. Standard assumptions of CGE models are employed. By considering various direct and indirect effects, CGE models are appropriate for analysis policies like CO_2 reduction, which generate significant direct and indirect impacts. Our approach at this study is to apply CO_2 tax instrument as a result of burning input fossil fuel into production function.

The empirical basis for the model is a Social Accounting Matrix (SAM) that consists of several production sectors which employ primary factors as well as intermediate inputs to produce goods (output) for the domestic and foreign market. Domestic demand includes intermediate demand and final demand. The domestic goods are used as intermediate inputs in production processes or consumed by final users like households, government, and investment sector.

There are 57 production sectors in GTAP[1] database version 7, 2004 which are aggregated into five production sectors, one household, government, and the rest of the world. WIOD [2]environmental accounts are used which consist of information on energy consumption that has broken down into a number of energy carriers. The model is formulated using GAMS[3] and solved with the PATH[4] algorithm.

Results show that reducing CO_2 emissions through carbon tax instrument would have small negative effect on GDP and consumer welfare i.e. consumer's real income. Under a carbon-tax-compensation by redistribution back to the household, welfare loss is lower and economy is less adversely affected by higher prices. We use different values on key exogenous elasticity

[1]Global Trade Analysis Project

[2] World Input output Database

[3] General Algebraic Model System

[4] PATH is Large scale MCP solver from University of Wisconsin at Madison

parameters to ensure the robustness and the reliability of the model. Sensitivity analysis results illustrate that our model is robust and reliable with respect to most parameters' value.

The Kyoto protocol has fixed the base year (1990) CO_2 emissions for Italy to 436 million s. In order to meet Kyoto target, Italian sectors should reduce CO_2 emission around 1.2 millions in each following year. Our simulation results show that by imposing tax between 5 and 10 dollar per tCO_2 (18.35 and 36.7 dollar per carbon) Italy could meet the Kyoto target by 2012 and this rate should rise through time gradually to meet second commitment (CP2) target as well. However, as reported by European Environment Agency (2014), Italy' GHG is not fully on track towards its burden-sharing target and need to purchase additional international credits before the end of the true-up period.

Key words: Carbon tax, Italy, Computable General Equilibrium (CGE), Social accounting matrix (SAM), Input output multipliers, GAMS

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Confucius said: "During your parents' lifetime, do not journey afar. If a journey has to be made", you must have convincing reasons. I owe to my parents who have given me encouragement for PhD journey.

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Publications

- Calculation of Emission Multipliers in Italy, Spain and Germany (1995–2009). An Environmental Input Output Analysis. Warsaw School of Economics Press ISBN 978-83-7378-940-1

- A 2004 Social Accounting Matrix (SAM) analysis for Italy

- Impacts of carbon tax on Italian economy: A CGE approach

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Chapter 1

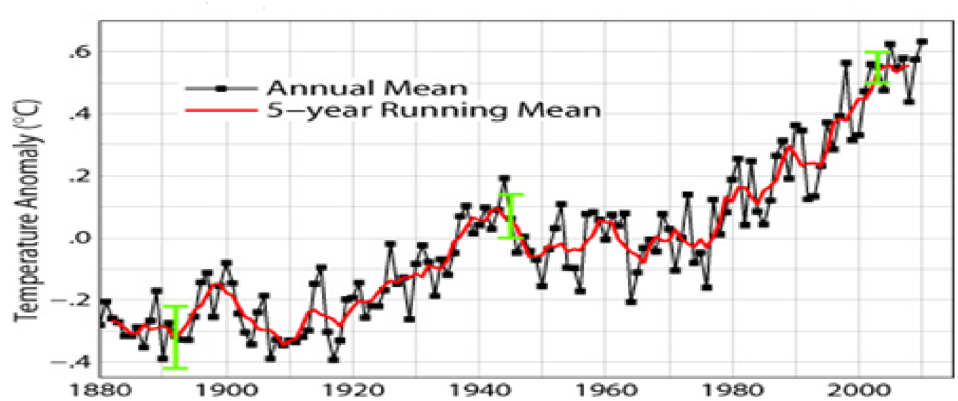
1.1 INTRODUCTION

"We have forgotten how to be good guests, how to walk lightly on the earth as its other creatures do."

Barbara Ward, Only One Earth, 1972.

In this century, our home planet is in crisis, because for many years, humankind had an imperfect responsiveness of its relationship with the natural environment. Nowadays, we are vigilant those natural resources are limited and that our actions affect the ecosystem. Currently, our earth and its guest are faced with a problem of global warming and climate change. Figure 1-1 shows the history of global mean temperature versus time. Scientist anticipate by the year 2100 our planet's temperature will be increased by 3 to 4 Celsius degrees, if current energy consumption continue, consequently we face with melting ice caps and sea level rise between 30 and 110 cm, even a rapid stabilization CO2 at 450 ppm[1] will generate temperature change approximately 2° C (IPCC Synthesis report); thus people who lives in coastal and equatorial areas as well as vulnerable places such as Netherlands, Bangladesh and Egypt are at risk with flood, storm surge. This event can drown out several islands as well.

Figure 1-1 Global mean temperature



Source: Hanssen j, et al. (2010)

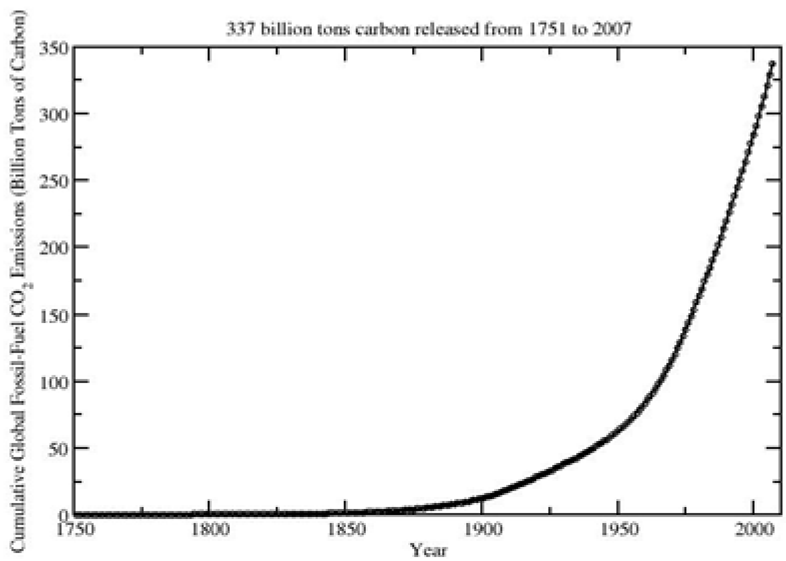
[1] About 80 % of atmospheric concentration has been caused by fossil energy (Mulder, 1995)

Energy especially fossil fuels plays an important role in overall GDP growth and still a crucial input for producing goods and services both in developing and developed countries. As a result economic growth and energy consumption persist to be closely interrelated.

When fossil fuels such as coal, gas and oil are burned they react with oxygen and produce carbon dioxide (CO2). Carbon dioxide is one of the numerous heat-trapping greenhouse gases (about 77% of the volume of GHGs) emitted into atmosphere (with a longer lifetime in atmosphere) through anthropogenic activities in indifferent ways, mostly by the combustion of fossil fuels and deforestation. Carbon dioxide (CO2) is added in various steps during the production of goods especially in pollutant industrial sectors like: pulp, cement, glass, and so on. Most of this gas is produced by the combustion of fossil fuels in energy intensive sectors and creates climate changes and global warming. These gases are main cause of current global challenge commonly referred to climate change furthermore negatively affect human life.

Historical trends in Carbon dioxide (CO2) emissions figure1-2 show that worldwide emissions of CO2 have raised steeply since the start of the industrial revolution. According to CDIAC [1](2010) approximately 337 billion metric tons have been released to the atmosphere since 1751 and about 50% of this gas has emitted since mid-1970s.

Figure 1-2 The Growth of global CO2 emissions

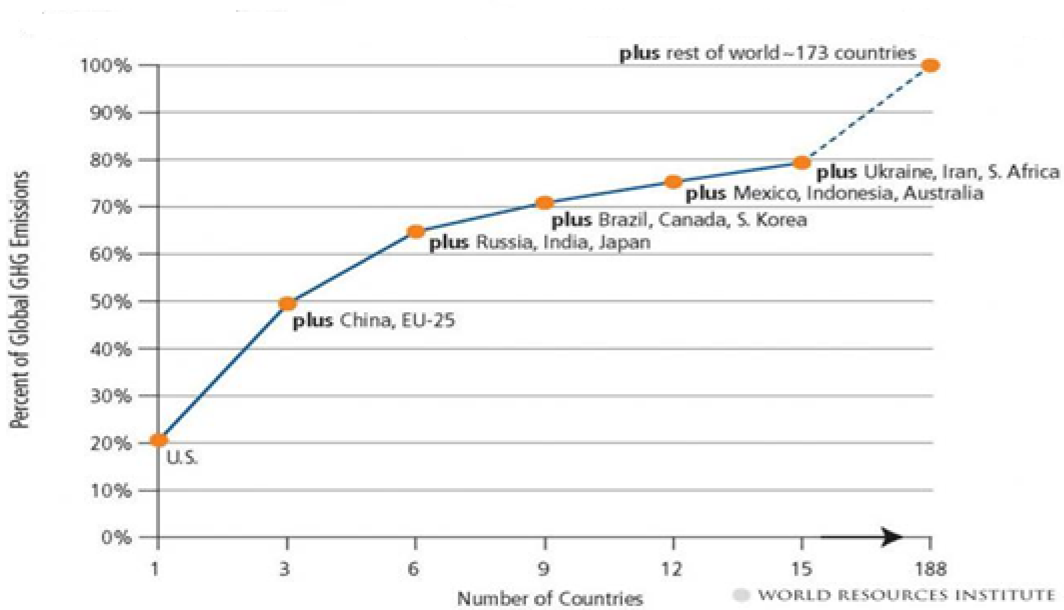


Source: CDIAC (2010)

[1] Carbon Dioxide Information Center

Figure 1-3 shows the emissions from major emitting countries contribute to the world total. It goes without saying that, just a few countries are responsible for 80% of the world's greenhouse gas emissions accordingly developed countries tend to produce more emissions than developing countries. However, it is anticipated that between 2020 and 2030, carbon dioxide emissions from energy consumption at developing countries will exceed those of developed countries due to dealing with poverty and other social challenge at their economic growth process. Developing countries can justify this issue and can say to developed countries that "you created problem, you fix it"[1]. This position from them is completely understandable but finally who will take responsibility for climate change issue? So it is better to be rational and forget about who caused the problem, this phenomenon is a global problem and all countries- whether developed or developing- require global cooperative actions.

Figure 1-3 Emissions from the major emitting countries



Different policy instruments have been established to protect natural environment, human life as well as reduce the dependency on energy, most notably on fossil fuels.

One possible instrument to reduction of greenhouse gas emissions especially carbon dioxide is the taxation of CO_2 emissions. It is clear that pricing carbon will significantly impact on industries and end users in form of higher marginal cost and commodity price respectively.

[1] US constitute less than 5 % of global population but use about 24 % of world's energy. US resident use energy much greater than Chinese and Indian. They emit 6 times more GHG than the Chinese and 18 times more than the typical Indian.

Carbon tax would lead to decrease of the demand thereof, lastly leading to a reduction of the CO_2 emission level.

1.2 Objectives and research questions

The purpose of this research is to explore the effects of imposing carbon tax policy on Italian economy by simulating different scenarios. We will focus on CO_2 emissions from the fossil fuel energy users, so the main questions addressed in this research are:

- Q1: What are the impacts of carbon tax on Italian macroeconomic variables? We consider the impacts on variables such as: industry-by-industry output level, households and governmental consumption, social welfare, and foreign trade.
- Q2: What range of carbon tax is required to achieve Italian Kyoto target?

We will provide a quantitative answer to each of these broad set of questions in the Italian context. Some more particular objectives are:

- Provide a literature review of previous research on the carbon tax
- Collect and compile Italy SAM from GTAP database and convert into standard form for construction of CGE models
- Prepare computer programs for numerical simulations in GAMS
- Conducting policy simulations with the models and interpret the simulation results

1.3 Methodology

A static top down computable general equilibrium (CGE) model of the Italy economy is constructed for this research. Carbon tax is implemented on the intermediate demand for fossil fuels .The model consists of five industries, one representative household, government, two factor inputs, and a trade system.

1.4 Outline of the Thesis

A brief outline of the procedure used to write this research is shown in figure 1-4. This dissertation is organized into four more chapters following this introduction. First we shall start by giving a review of energy and environment facts in Italy then go to review environmental tax reform (ETR) in Europe as well as introduce two common reductions of

CO_2 emissions instruments from fossil fuels: tradable permits and carbon tax. In chapter three the general structure of computable general equilibrium (CGE) as well as some microeconomic theory which play dominant role in CGE modeling are discussed then the chapter goes on to focus on algebra and functional forms of CGE model that representing behavior of different individual agents and mathematical statement of model. Chapter 4 will review conceptual framework and general structure of social accounting matrix that we used in building model. In the following we calculate key macroeconomic indicators in SAM database as well as explain how input output and SAM multipliers are calculated and analyzed. We describe how Rasmussen backward and forward linkages are calculated in order to identify the most important sector in Italy's economy

Finally, Chapter 5 will expose the different simulation policy scenario to assess the impact of carbon tax on Italy's macroeconomic variables and will provide a clear answer to the research questions.

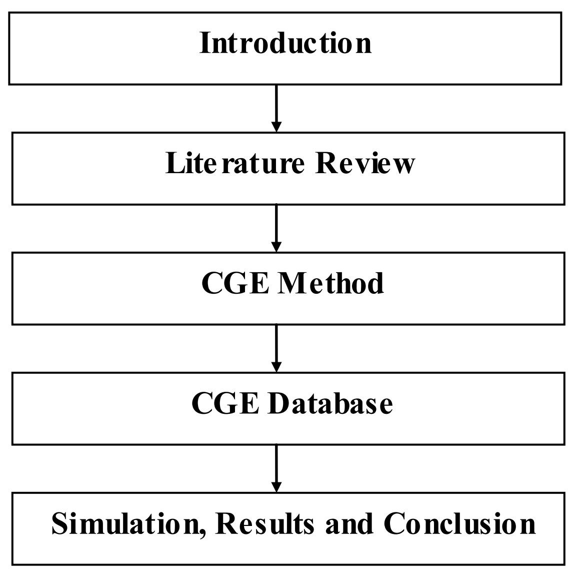


Figure 1-4 Thesis Outline

Chapter 2

"The art of taxation consists in so plucking the goose as to obtain the largest amount of feathers with the least possible amount of hissing"

Jean -Baptiste Colbert

2.1 Energy and Environment facts in Italy and Europe

Italy is the tenth largest economy in the world in terms of GDP measured at purchasing power parity (PPP) as well as largest energy consumers among European countries (IEA, 2010). According to Energy Charter (2009) the traditional fossil fuels – oil, natural gas and coal - account for 87.5% total primary energy supply (TPES). More than 85% of this energy source is imported.

Oil and gas are still the dominant resource of providing 78.5 % of total energy. The amount and Percent share of TPSE in 2007 were: Oil 82 MTOE (42.5%), gas 70 MTOE (36%), Coal 17.5 MTOE (9%), electricity and renewable energy (12.5%).

Table2.1 shows the main energy trends in Italy from 2002 to 2007.

Table 2-1 Main energy trend in ITALY

Parameter	2007	2002/2007 Growth Rate
GDP (Euro million 2000)	1.284.868	+5.5%
TPES (MTOE)	194.45	+3.4%
Primary Energy Intensity (TOE/Euro million 2000)	151.4	-1.9%
Electricity Intensity (TOE/Euro million 2000)	20.70	+3.5%

SOURCE: ISTAT

Also below graphs shows GDP and Energy trends in Italy from 1995 to 2009.

Energy intensity is proxy for efficiency of a nation's economy. It is calculated as units of energy per unit of GDP, in other words quantity of energy required to produce one unit of output (GDP); thus less energy intensity means consuming less energy to obtain the same products and services.

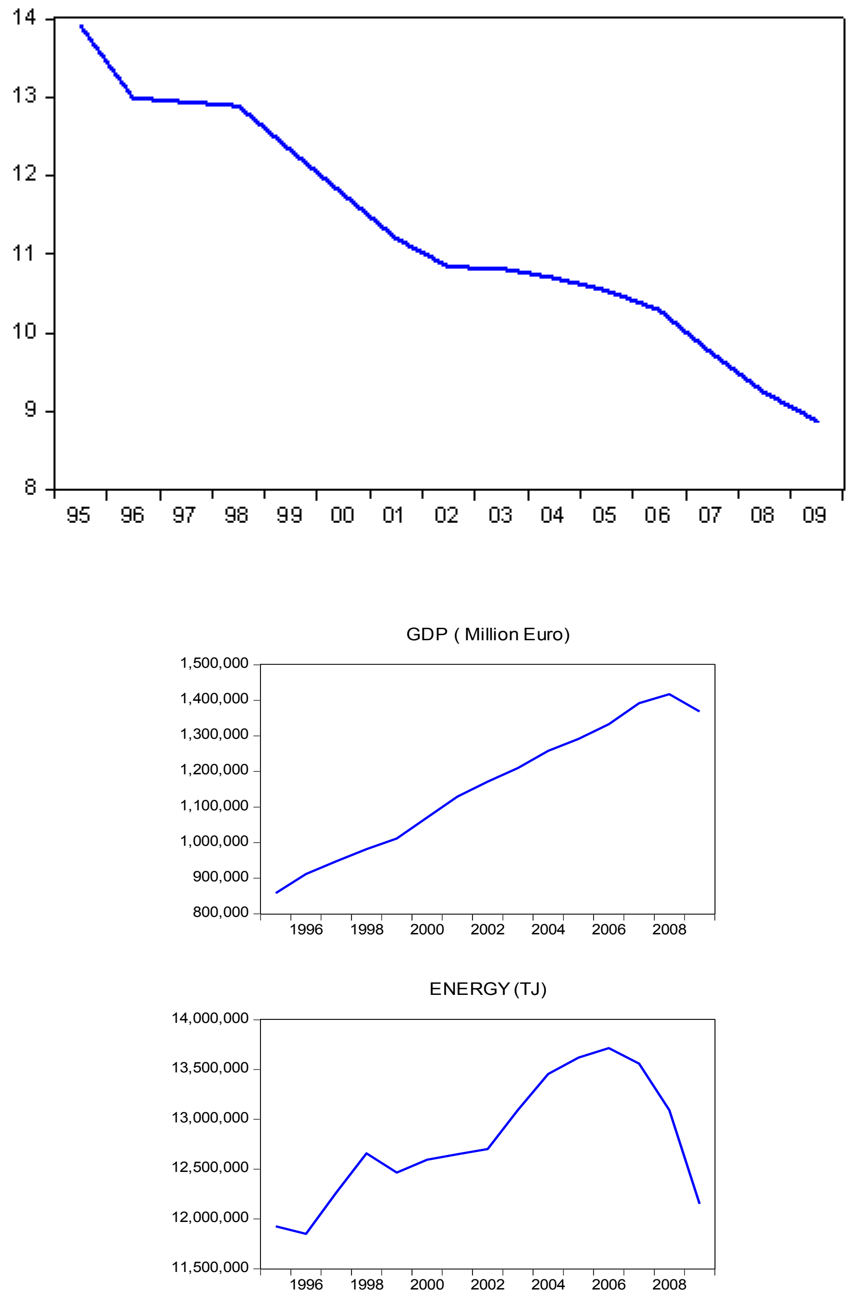
Mathematically:

$$EI = \frac{E}{GDP}$$

2.1)

This indicator can be computed both physically and financially. When output is measured in Physical units like liter or s, energy consumption or energy input is expressed in energetic units, for example MJ / tone. On the other hand, when output is measured in monetary units, this indicator is calculated by energy consumed divided by dollar value of output like: TJ / GDP in €. Figure 2-1 shows the trend of the energy intensity in Italy from 1995 to 2009.

Figure 2-1 Energy Intensity (TJ / Million Euro)

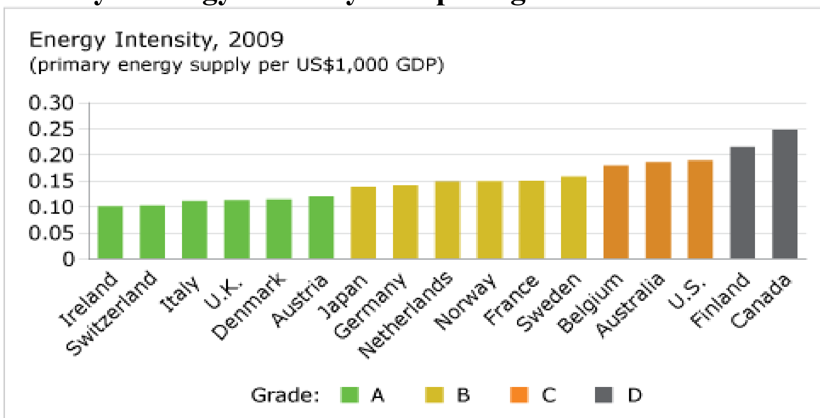


Source: WIOD and author calculations

Another kind of indicator is energy efficiency which is often used interchangeably with energy intensity, but the different between them is significant. Simply energy efficiency is the inverse of the energy intensity. It should be noted that, for analyzing trends in energy efficiency over time a common indicator that used widely is energy intensity. For example declining of energy intensity in specific period reports improvement in energy efficiency.

As we can see from the below graph, in 2009, Italy ranks in the third place out of 17 peer countries and earns “A” grade.

Figure 2-2 Italy’s energy Intensity comparing with selective countires ,2009



REPORT CARD

Energy Intensity

	1970s	1980s	1990s	2000s
Australia	B	C	C	C
Austria	A	A	A	A
Belgium	C	B	C	C
Canada	D	D	D	D
Denmark	B	A	A	A
Finland	C	C	D	D
France	B	B	B	B
Germany	C	C	B	B
Ireland	B	B	A	A
Italy	A	A	A	A
Japan	B	A	A	A
Netherlands	B	B	B	B
Norway	B	B	B	B
Sweden	C	C	C	B
Switzerland	A	A	A	A
U.K.	B	B	B	A
U.S.	D	D	C	C

Source: The Conference Board of Canada.

Moreover, figure 2-2 Illustrates that Italy was leading in the Europe and got top quartile of energy intensity in the period 1970s to 2000s; now this index is 15% lower than EU average Reducing energy intensity was principally strategic goals with highest priority of Italian policy maker in order to reducing dependence of energy imports. The following table indicates the priority of Italy's policy objectives.

Table 2-2 Italy's priority policy objectives

Policy Objective	Priority
Reduce total final consumption / GDP	1
Reduce dependency on energy imports	2
Diversification of fuels	3
Reduction of $\mathbf{CO_2}$	5
Increase utilization of indigenous primary energy sources	4

Source: Regular Review of Energy Efficiency Policies

At the industrial level energy intensity is defined as energy consumption in physical units (Ei) by Sector (i) divided by value added (Yi). In mathematics form:

$$\mathbf{EI} = \frac{\mathbf{Ei}}{\mathbf{Yi}} \qquad \textbf{2.2)}$$

In spite of reduction in final energy consumption in Italian industrial sector from 33.6% in 1990 to 28.7 % in 2008 but more than one quarter of total energy still has been consumed by industry sector (Buzzigoli and Viviani, 2012). Table2-3 shows the energy intensity (koe/ 1000 Euro) in Italian industries and National Energy Balance (BEN) classification.

Table 2-3 Energy intensity in industry and in BEN sub-sectors

	1990	1995	2000	2005	2008
Industry	147.9	143.6	146.5	149.2	134.8
Mining	85.0	93.2	86.6	82.3	85.2
Basic metals	1455.6	1015.1	1065.4	1233.3	1166.9
Machinery	42.4	50.5	57.1	58.6	53.3
Food	114.3	137.6	158.3	176.2	153.5
Textile	77.1	87.1	100.2	102.9	75.2
Non metallic minerals	655.7	629.8	759.1	746.0	731.9
Chemicals	517.1	484.5	384.6	385.3	343.1
Paper	151.3	184.7	193.6	217.8	202.5
Other manufacturing	151.2	59.6	65.1	75.1	69.2
Construction	1.8	3.5	2.9	3.4	3.3

Source:Buzzigoli and Viviani (2012)

2.2 Energy and Environment facts in Italy and Europe

Climate change, ecosystem degradation, deforestation, the impact of variety pollution on human health is the most current concern in environmental sustainability subject. Because of this as well as other reasons, there is a worldwide consensus to finding solutions to alleviate global warming.

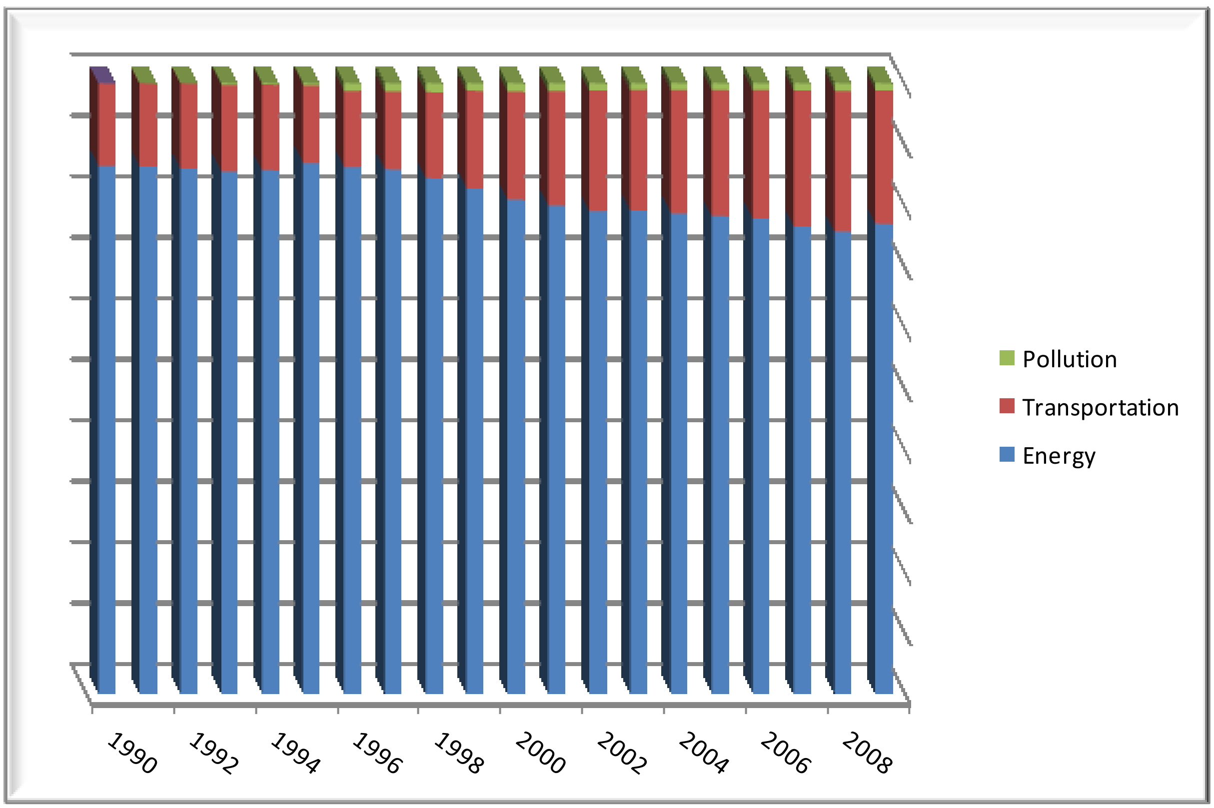
Green (environmental) taxation policy instrument has been widely discussed in the last two decades. The objective of this tax is used to enhance environmental protection and control any kinds of pollution as well as collecting revenues simultaneously. Environmental taxation can defined as "compulsory payments levied on tax bases deemed to be of particular environmental relevance "(OECD, 2001). It can be categorized into i) energy taxes ii) taxes on pollution and resources and iii) energy taxes. Table2-4 presents detailed classification of those taxes in Italy according to the European Commission's categories.

Table 2-4 Environmental taxes by European Commission classification

Energy	Excise duty on mineral oils In-bond surcharge on mineral oils In-bond surcharge on liquefied petroleum gases Excise duty on liquefied petroleum gases Excise duty on methane Local surcharge on electricity duty Excise duty on electricity Tax on coal consumption
Transport	Motor vehicle duty paid by households Motor vehicle duty paid by enterprises Public motor vehicle register tax (PRA) Provincial tax on motor vehicles' insurance
Pollution	SO2 and NOx pollution tax Contribution on sales of phytosanitary products and pesticides Regional special tax on landfill dumping Provincial tax for environmental protection Regional tax on aircraft noise

Figure 2-3 shows environmental tax revenues in Italy in 1990 until 2008 in three main categories. Throughout (over) this period, the revenue from taxes related to energy was about 82% of total environmental taxes. Energy tax revenues have raised from 19.3 billion to 31.7 billion euro in 2009, or about 2.6 GDP percent. Oil demand is increasingly concentrated in the transportation sector in Italy (IEA, 2010), for this reason government decided to increase tax rate in transportation sector thus revenue from transportation fuel taxes increased approximately from 3000 million to 9000 million euro between 1990 and 2009 (ISTAT,2010). Resource and pollution taxes represented small shares about 1% of the total in Italy.

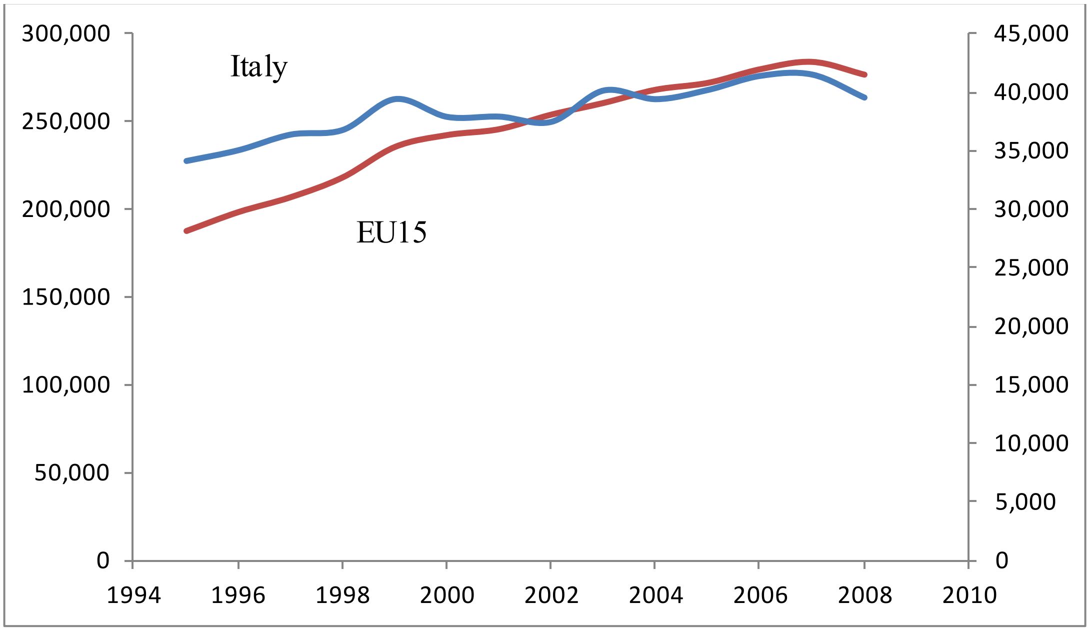
Figure 2-3 Environmental tax revenues in Italy 1990-2009



Source: ISTAT

Figure2-4 shows that the total revenue from environmental taxes in EU15 and Italy between 1995to 2008. As can be seen in the below figure environmental tax revenue in EU and Italy increased this period except 2008 due to economic crisis.

Figure 2-4 Total Environmental tax Revenue in Italy and EU15



Source: ISTAT

The reduction of greenhouse gas emissions (GHG) has been undertaken in European countries during the 1990s, in recognition of serious environmental challenges. Some countries like Finland, Sweden, and Denmark pledged soon to curb CO2 emissions by up to 20 % by introducing unilateral carbon tax.

In Italy, Japan and New Zealand, carbon energy taxation emerged in political agenda in governmental section by applying environmental tax reform (ETR) which is vital to assist sustainable macroeconomic, environment protection also crucial to low carbon growth in European Union. In broad sense," ETR includes the establishment of environmental tax, the reformation of fiscal policies related with environment and natural resource, as well as the elimination of inappropriate subsidy and charge policies are adverse to environment" (Cahzhong, et al.2012). ETR plays not only a significant role in environmental protection but also promoting economic agents behavior toward low carbon economy.

2.3 ETR and Double Dividend Approach

As part of greening of taxation systems, the Europe 2020 strategy emphasizes the potential of ETR, to shift tax burden from conventional taxes such as labor to environmentally damaging activities such as resource use or pollution; simply as Delors[1] recommendation 'goods' to 'bad'. Clearly, one factor that has negative effect on employment is high taxes; by replacing some part of the tax with green tax in ETR approach it can lead to reduction in unemployment and boost employments in market.

In 1990s and 2000s some Scandinavian countries implemented ETR with broadly positive results. The consequence of ETR idea which is shift taxation –from labor to pollution-, lead to opportunities to improve not only employment but also tackle negative economic impacts.

The study set up by Manersa and Sancho (2005) as well as Faehn et al. (2009) using a CGE model examines double dividend policy action in Spain. They concluded that, by imposing energy tax not only toxic gas emissions are reduced but also unemployment rate would improve.

Generally speaking environmental tax revenue can provide two kinds of benefits that known as double dividend. First and most importantly is an improvement in environment and the second is improving economic efficiency through offsetting the extra cost of production.

One way to evaluate achievement of the ETR objectives is comparing the trend labor taxation to GDP ratio with the environmental taxation to GDP (EEA, 2005).

Table 2-5 summarizes analysis of tax on labor versus environmental taxes in Finland, Denmark, Sweden, Germany, The Netherlands, UK and Italy between 1990 and 2010.

Despite of fundamental motivations for implementing ETR in EU member states are similar; the approach of the respective tax shift program in terms of economic sector affected and recycling

Mechanism varies. The most common policy tool of ETR in EU members is carbon tax or energy consumption tax but UK for example introduced special tax like landfill taxation whereas Denmark and Dutch have increased existing tax on waste disposal.

In the late 1990s, Italy's environmental tax was the highest level entire EU with a 3.5 percent out of GDP. But this edge subsequently scaled down and in 2010 environmental taxes accounted 2.6 as a percent of GDP, just equaled the EU average.

In contrast, tax in Italian fiscal system increased from 18.1% to 22 % in the period 1995-2010 as a percentage of GDP. This tax accounted for 52% of total collected revenues in 2010

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[1] Eighth President of the European Commission

whereas consumption taxes in the same period were 10.2% and 10.6% with respect to GDP and below the European Union average.

Table 2-5 Labor Tax versus Environmental Tax in member State

	1990	1995	2000	2005	2010
Finland					
Labor tax as % GDP	24.8	26.1	23.7	23.3	22.6
Env. Tax as % of GDP	2.2	2.9	3.1	3.0	2.78
Denmark					
Labor tax as % GDP	24.1	28	26.6	24.8	24.5
Env. Tax as % of GDP	3.6	4.4	5.2	5.8	3.99
Sweden					
Labor tax as % GDP	35.8	31	32.3	31.2	25.7
Env. Tax as % of GDP	3.4	2.8	2.8	2.8	2.74
Germany					
Labor tax as % GDP	20.9	24.9	24.3	22.3	21.5
Env. Tax as % of GDP	2.0	2.4	2.4	2.5	2.19
Netherlands					
Labor tax as % GDP	25.8	22.1	20.3	17.7	21.4
Env. Tax as % of GDP	3.1	3.5	3.9	4	4.01
UK					
Labor tax as % GDP	14.3	14	14.3	14.4	14.2
Env. Tax as % of GDP	2.7	2.9	3.1	2.5	2.61
Italy					
Labor tax as % GDP	NA	18.1	20.1	20.3	22
Env. Tax as % of GDP	NA	3.5	3.1	2.7	2.62

Source: ISTAT

But let us be realistic. Ecotax are complex mechanism because it should be balance not only between social and economic effect but also should consider political and public acceptance like income distribution or international competitiveness as well.

Manersa (2009) stated that, double divided in actual situation will not necessarily map with theoretical situation and it is highly influenced by model structure, behavioral rules of agents, government policies and many other parameters.

2.4 Tradable permits

Tradable pollution (or emission) permits are a cost-efficient, market-driven approach to controlling pollution caused by negative externalities. Tradable emission permits allow the central authority to decide how much tones of a toxic gas may be released into atmosphere over a specified interval of time by allocating licenses to individual firms to pollute at a certain level. The main type of allowance emissions trading is known as "cap and trade". Governmental body sets an absolute pollution limit or cap on the amount of a pollutant that may be emitted.

By putting a price and giving financial value on emission permit companies as a seller and buyer can trade these permits on the stock market. If company “A” achieves a reductions goal which has been set by law or agreement, can benefit by sell permits to company “B” that pollute higher than standard permit allow. The ability to sell permits incentives company “A” to invest in pollution abatement.

By far the first large multi-country and multi-sector emissions trading scheme for CO2 allowance in the world is The European Union Emissions Trading System (EU ETS) which launched in 2005 to combat climate change, and works on the ‘cap and trade’ principle. The system furnishes for interconnection with emission-reduction credit programs (ECR) in other countries such as the Kyoto Protocol’s Clean Development Mechanism (CDM) and joint implementation (JI).

The CDM and JI mechanism are two project- based defined in article 12 and 6 of Kyoto protocol respectively. The CDM mechanism allows private companies with emission reduction to fund an emission removal project in developing countries and earn tradable certified emission reduction (CER) units. Similarly, JI is a mechanism that allows for Annex I Parties to undertake and invest in emission reduction projects in any other Annex I Parties to generate Emission Reduction Units (ERU). Compared to tradable permits, the tax system is much easier to handle.

Although, cap and trade instrument gives government a macro control of pollutant volume but administrative, monitoring and enforcement cost may be high. This instrument is criticized by ethicists for that the polluters are undue right to continue to burn fossil fuels, destroy forests and pollute communities (Lee, 2012).

2.5 Carbon Tax

Air pollution is most dangerous threats to our health and environment. Air pollution has been a problem throughout history. Even in ancient Rome Empire a Roman philosopher for instance, Seneca, complained about air pollution in Rome in 61 CE, he wrote:

> *"As soon as I had escaped the heavy air of Rome and the stench of its smoky chimneys, which when stirred poured forth whatever pestilent vapours and soot they held enclosed, I felt a change in my disposition."*

But since industrial revolution, the air quality became worse mainly as a result of burning fossil fuels. This matter will increase not only the occurrence of respiratory disease like asthma and other serious human health problem but also erode our environment.

Carbon dioxide (CO_2) is one of the chief greenhouse gases and responsible for driving climate change. In theory, the mitigation of CO_2 emissions can be achieved through different instruments. A carbon tax is a form of explicit carbon pricing and a type of Pigovian tax levied on the carbon content of fuels. Carbon tax often expressed as a value per CO_2 equivalent (per tCO_2e). [1]It is one of the most efficient instruments available to curb of carbon dioxide emissions by providing a motivation for producers and consumers to substitute carbon- poor for carbon-rich flues that could be a feasible alternative. While such carbon taxes can raise significant amounts of revenue, it could also have negative effects and unintended consequences on macroeconomic variables such as economic growth rate, income distribution, competitiveness of a country's exports (Cuervo, J. and V. Gandhi, 1998), as well as adverse impacts on the distribution of welfare (Creedy,J and Sleeman,C,2005).

In order to stabilize energy consumption and decrease CO_2 emissions, Finland and Netherlands in 1990, Norway and Sweden in 1991 were adopted carbon tax. Later other European countries such as Ireland (2010), Switzerland (2008) and Slovenia (1997) were implemented carbon tax which is levied on motor and heating oil. The average price of a carbon is relatively different from country to country .The highest tax rate in 2010 is related to Sweden by 103 € per of CO_2 and lowest is related to eastern European countries like: Estonia

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[1] **One ton of carbon (tc) equals 44/12 = 3.67 tons of carbon dioxide (t CO_2)**

(2010), Latvia (2008) and Poland (2010) by 2, 0.2 and 0.1 euro per ton of CO_2 respectively. The Table 2-6 provides an overview of CO_2 tax in different countries.

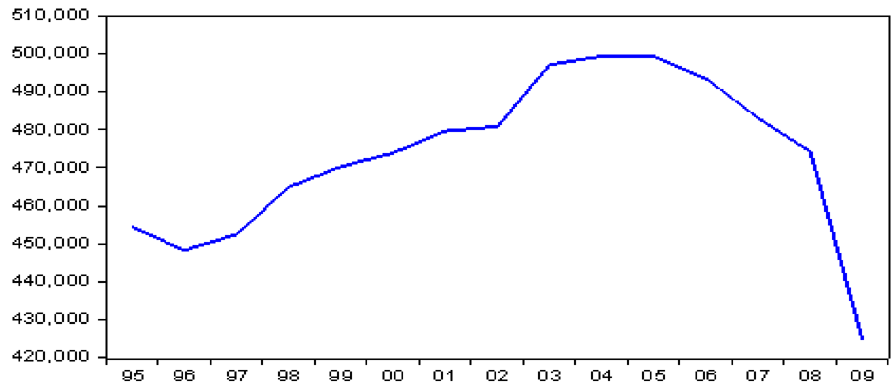
Table 2-6 Carbon dioxide taxation in different countires

Country	CO2 Tax
Australia	$24.151 per tCO2e (2013)
British Columbia	CAD30 per tCO2e (2012)
Denmark	USD31 per tCO2e (2014)
Finland	EUR35 per tCO2e (2013)
France	EUR7 per tCO2e (2014)
Iceland	USD10 per tCO2e (2014)
Ireland	EUR 20 per tCO2e (2013)
Japan	USD2 per tCO2e (2014)
Mexico	Mex $ 10 -50 per tCO2e 2014 Depending on fuel type
Norway	USD 4-69 per tCO2e (2014) Depending on fuel type
South Africa	R120/tCO2 (Proposed tax rate for 2016)
Sweden	USD168 per tCO2e (2014)
Switzerland	USD 68 per tCO2e 2014
United Kingdom	USD15.75 per tCO2e (2014)

Source: World Bank

In 2009, the total Italian CO_2 emission was 424.765 kilo tone that industry sector and households were responsible for 78% and 22 % respectively. Graph below shows the trend of CO_2 in Italy from 1995 to 2009.

Figure 2-5 CO2 (1000 Tone)

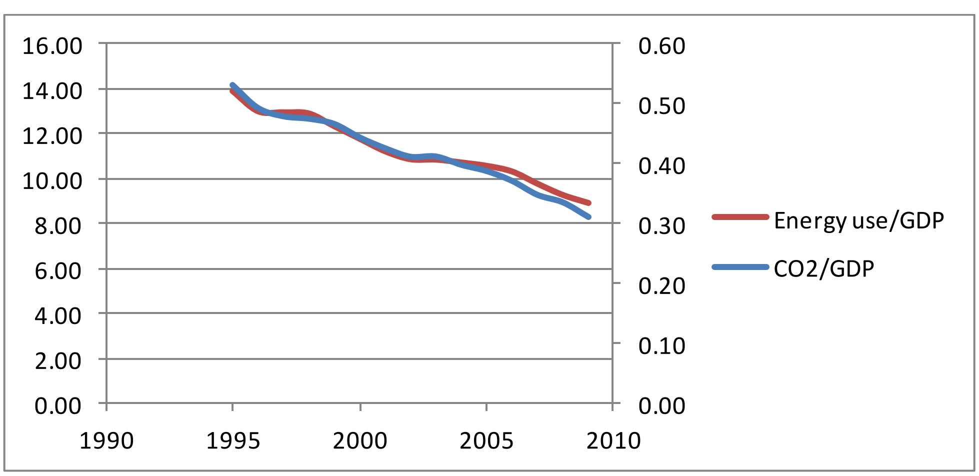


Source: WIOD and author calculation

Over the first ten years since 1995, the CO2 emissions steadily increased and start to decrease from 2006. According to Kyoto protocol, EU member state should cut of 20% in GHG emissions with respect to 1990 levels by 2020. Kyoto target for Italy is set at 485.1 metric tons of carbon dioxide equivalent for the first commitment period. According to official data (APAT, 2007) in 2005, GHG emissions were 12.1% over 1990 levels. As reported by European Environment Agency (2014), *"Italy is not still fully on track towards its burden-sharing target under EU law thus Italy should purchase about 28 million Kyoto units to commit its target"*.

Graph below represents improvement in energy efficiency in the period 1995-2009. But still some industrial sectors like cement, chemicals as well as steel are inefficient and not being balanced out by good performances like transport and households sectors.

Figure 2-6 Energy intensity and CO2 intensity 1995-2009



Source: WIOD and author calculations

A great deal of energy resources in Italy is imported and expected to grow up in future thus in order to reducing the dependence on fuel imported from non-EU countries, also reducing CO2 emissions a revolution in the energy sectors is mandatory. An essential element of this revolution must be energy efficiency. According to National Agency for New Technology, Energy and Environment (ENEA) by 2016 the total energy savings target is set at 126.327 GWh (454.777 TJ) and contribution of transportation sector, industry sector, tertiary sector and residential sector are 18%, 17%, 20% and 45% respectively. This target is about 4% of energy consumption in 2009. We will show it would be possible to reach to the target by imposing about 100 $ carbon tax per tone for each industry based on energy consumption in 2004.

In order to meet requirements of policy makers for energy monitoring, Italy government has established regulation and policy to cut toxic gas emissions of at least 20% below 1990 levels by 2020 and shift final energy consumption to the renewable energy sources.

At top level ministry of economic development is responsible for national energy efficiency policy and establishing regulation and limits is handled by ministries of the environment. Numerous economic instrument and policies have been designed and implemented to promote improvement energy efficiency as well as saving by Italian governments since 2001 like White certificates, the fiscal incentives by the budget the laws 2007 and 2008 and so on.

But still there are some barriers to implement energy efficiency policy in Italy. Financial obstacle, lack of knowledge at financial institutions about energy efficiency and inexact subsidy distribution at different level are the main barriers to implement energy efficiency policy.

2.5.1 Carbon emissions calculation

The dominant source of emissions arise from industrial and residential activities by combustion of fossil flues and just a few percent release as fugitive emissions, or escape without combustion. Fugitive emissions are intentional or unintentional leak and flare of gas resulting from oil and gas extraction operations. But it requires attention fugitive emissions for some countries like Nigeria that produce or transport huge amount of fossil fuels, is significant portion of emissions.

CO2 is created when fuels are burned in combustion processes. The quality of CO2 emission factor mainly depends on the average carbon content of the fossil fuels which is actually fairly constant across countries and years as well as total amount of fuels combusted, in technical words combustion efficiency. Oxidization factor or combustion rate vary across industries ranging from 0.8 to 0.99.Unit carbon content in different units for some common fossil fuels is indicated in table 2-6 .Further information about other fuels carbon content can be found at appendix No.

Table 2-7 Carbon Emission Factors in Different Units

Fuel type	T C/TJ	T C/SCE[a]	T C/TOE[b]	T C/T[c]
Raw Coal	25.8	0.75613608	1.0801944	0.5394264
Crude Oil	20.2	0.59201352	0.8457336	0.8446832
Natural gas	15.3	0.44840628	0.6405804	n/a

Note: a. SCE is an acronym of Standard Coal Equivalent which refers to the amount of energy released by burning one metric ton of coal. It is widely used in Chinese energy statistics.
1 SCE=29.3076* 10^{-3}TJ
b. TOE is an acronym of ton Oil Equivalent which refers to the amount of energy released by burning one metric ton of oil. It is accepted by many nations to record their energy statistics.
1 TOE=41.868*10^{-3}TJ. *1* SCE is about *0.7* TOE.
c. T denotes one metric ton. We use net calorific values for raw coal *0.020908* TJ per ton and for crude oil *0.041816* TJ. Per ton. Natural gas is often measured in volume and thereby we don't report the carbon content in physical mass.

Source: IPCC Guideline

The conversion factors shown below are approximate and were taken from U.S energy information administration (eia) source.

Table 2-8 Energy Equivalent Conversions

	Milion Btu (British thermal units)	Giga (10^9) Joules	TOE (Metric Tons of Oil Equivalent)	TCE (Metric Tons of Coal Equivalent)
Milion Btu (British thermal units)	1.00000	0.94782	39.68320	27.77824
Giga (10^9) Joules	1.05506	1.00000	41.86800	29.30760
TOE (Metric tons of Oil Equivalent)	0.02520	0.02388	1.00000	0.70000
TCE (Metric tons of Coal Equivalent)	0.03600	0.03412	1.42857	1.00000

Source; EIA

In order to calculate CO2 emissions, WIOD environmental accounts are used which consist of information on energy consumption that has broken down into a number of energy carriers.

List of energy commodities included in the WIOD database can be found in appendix…..In this research we used WIOD fossil flues energy data in Terajoule for Italian economy by 2004. Table below shows the energy carrier definition and classification. Other types of energy commodities like renewable are listed on appendix no …

Table 2-9 List of energy commodities included in the WIOD database

WIOD Code	IEA Code	FLOW
COAL		
HCOAL	ANTCOAL + BITCOAL + COKCOAL + PATFUEL + SUBCOAL	Hard coal and derivatives
BCOAL	BKB + CAOLTAR + LIGNITE + PEAT	Lignite and derivatives
COKE	GASCOKE + OVENCOKE	Coke
CRUDE & FEEDSTOCKS		
CRUDE	CRUDEOIL + NGL + REFFEEDS + ADDITIVE + NONCRUDE	Crude oil, NGL and feedstocks
PETROLEUM PRODUCTS		
DIESEL	GASDIES(1)	Diesel oil for road transport
GASOLINE	MOTORGAS	Motor gasoline
JETFUEL	AVGAS + JETGAS + JETKERO	Jet fuel (kerosene and gasoline)
LFO	GASDIES(2)	Light Fuel oil
HFO	RESFUEL	Heavy fuel oil
NAPHTA	NAPHTA	Naphtha
OTHPETRO	BITUMEN + ETHANE + LPG + LUBRIC + ONONSPEC + OTHKERO + PARWAX + PETCOKE + REFINGAS + WHITESP	Other petroleum products
GASES		
NATGAS	NATGAS	Natural gas
OTHGAS	BLFURGS + COKEOVGS + GASWKSGS + MANGAS + OXYSTGS	Derived gas

Source: WIOD

According to the WIOD database, Italy consumed about 13.455.217 Terajoul energy in 2004, Where industrial sector used approximately 83% of total energy and rests of the energy were consumed by household sectors.

Table 2-10 Gross energy use by sector and energy commodity (Terajoules) by 2004

	Coal	Crude	Petrol	Gas	Others	Total
Agriculture	3642	0	127140	19451	33955	184188
Manufacturing	218497	4160763	966779	776689	702431	6825158
Utility& Construction	445628	16370	631129	991199	659592	2743919
Transportation & Communication	93	0	843551	34339	38480	916464
Services	914	0	150704	220035	240192	611845
Subtotal	668,775	4,177,134	2,719,303	2,041,713	1,674,650	**11,281,575**
Household	2,540	0	1,120,308	750,767	300,028	**2,173,643**
Total						**13,455,217**

Source: WIOD energy database, Constructed by author

Table 2-11 Emission relevant energy use by sector and energy commodity

Energy use (TJ)	Coal	Oil and Petroleum	Gases	Renewable and Waste	Electricity and Heat	Losses[1]	CO2	CO2 percentage
Agriculture	3,642	126,922	19,451	6,063	27,892	0	10,837	2.2%
Manufacturing	68,844	700,740	735,381	13,148	682,834	0	101,085	20.4%
Utility & Construction	442,908	530,527	991,199	82,280	482,632	94,680	143,574+30249[2]	29.0%+6%
Transportation & Communication	0	827,591	133,128	5,167	137,546	0	68,5181	13.8%
Services	0	150,704	121,247	6,667	129,292	0	18,621	3.8%
Household	319	1,120,308	750,767	52,013	248,015	0	122,309	24.7%
CO2	49,332	255,141	153,769	6,702	0	30,249	495,194	

Source: WIOD energy database, Constructed by author

It should be noted that, according to the WIOD "the emission relevant energy use, derived from the gross energy use but excluding the non-energy use (e.g. asphalt for road building)

[1] Losses due to conversion and transmission

[2] CO2 from energy losses

and the input for transformation (e.g. crude oil transformed into refined products) of energy commodities, is the direct link between energy use and energy-related emissions. Others are consisted of non fossil fuels energy sources like: nuclear, wind, solar and so on".

The energy data reported in table 2-10 can be used to calculate the amount of CO2 emissions as a result of industrial and household activities.

The following method is used to calculate CO2 emissions from the combustion of each type of fuel (IPCC guideline 2006):

$$\text{CO2 emissons (1000Tonne)} =$$
$$\{Energy\ Use\ (TJ)\} \times \{Carboncontent\ (TC/TJ)\} \times 10^{-3} \times \{\text{fraction of carbon oxidized}\} \times$$
$$\{\text{ratio of molecular weight CO2 (44) to molecular weight of CO (12)}\}$$

Total carbon emissions of each sector are calculated for each fossil fuel and incorporated as computer code into GAMS program. For comparability with other studies, we measure CO2 in tones.

But how we can engage pollutions externalities into the economy models? Xepapadeas (2005) and Koesler (2010) illustrated three principal methods to incorporate pollution externalities in an economic model. In the first view the amount of emissions are determined by consumer hence household is responsible for pollution generation.

Alternatively, emissions can be linked to the production process, which means producers determine how much emissions will be released into atmosphere as by-product of production. Finally, emissions may emerge as result of choosing primary inputs type by producer.

But in reality, as Munksgaard , Pedersen (2001) as well as Gupta and Bhandari(1999) pointed out ,determining responsible sector either producers or consumers for pollution and specifically carbon dioxide is not a binary decision.

It might be useful to bring your attention about the difference between energy tax and carbon tax. An energy tax is excise tax, which is imposed ;on both fossil fuels and non fossil fuels and is expressed as a fixed absolute amount of energy units, for example Euro per Kwh, BTU or Terajoule. On the other hand carbon tax is an excise tax that levied on fossil fuels based on their carbon content. Both instruments by increasing the cost of fuel provide an incentive to reduce emissions of CO2.

The question then arises, how does economist and policy maker choose between carbon tax and energy tax as instruments of controlling CO2 emissions?

According to Jorgenson and Wilcoxen (1993) and Cline (1992), CO2 tax instrument is more cost effective than energy tax when eco-policy maker want to achieve a lower level of CO2 emissions

Our approach at this study is to apply CO2 tax instrument as a result of burning input fossil fuel into production process source hence our strategy to reduce CO2 in Italy is production based. Also it should be noted that we will leave out other toxic gases like CH4, N2O, CO, Sox, NMVOC and NH3 which emerge in processing phase.

2.6 Review of previous studies

This section of chapter aims to review previous researches on the impacts of environmental tax on economic. Several national and international numerical studies have already examined to analyze the dimension and the effects of climate protection on economic variables. Most of these studies focus on analyzing the impacts of CO2 and energy tax. The strategies and mitigation target as well as methodology are differing from study to study; consequently it would be difficult to compare results. Thus we will restrict our review to CGE modeling on carbon tax policies.

Although, there is no general agreement in the literature about the impact of environmental taxes on the micro and macro economic variables, but according to the majority of scholars economic growth would be influenced negatively by levying green tax especially CO2 tax. In the following some of this research will be discussed.

Probably, the main obstacle to implementing unilateral carbon taxes would likely reduce the competitive position that producers have in world markets (Harrison and Kriström 1997), but it should be noted that carbon intensity of each sector is core of the determination of its competitiveness (Wang et al,2010).

In short term some of the macro and micro economic variables would be influenced negatively as a result environmental tax but in a long term levying CO2 tax will increase government revenue in order to offset negative impacts in economy by capital accumulation and productivity improvement (Mingxi, Z. 2011).

The study of Anshory (2008) addressed that unlike majority of research from developed countries, imposing carbon tax in Indonesia “would not necessarily be regressive” and there is not “a conflict between environmental and equity objectives”.

The research made by Bucher (2009) uses a dynamic CGE to examine impacts post-Kyoto climate policy on Switzerland's economy. He conclude that in order to cut CO_2 emissions by 20% until 2020 compared to 1990,the emission tax should be increase up to 120 Swiss Franc per ton. And this policy would lead to significant losses both in industry and household welfare but it is manageable.

Schneider and Stephan (2007) conducted a static CGE model for the Switzerland's economy. Their model also examined CO_2 taxation for a 20 % reduction target for CO_2 emissions by 2020 compared to the1990 level. They realized that for reaching reduction target, CO_2 tax should be levied between 100 and 400 Swiss Franc per.

Wissema and Delink (2006) by applying a CGE model noted that in order to reduce 25.8 percent CO_2 based on energy target for Ireland compared to 1998 level; it should be levied 10-15 euro tax per for CO_2 emission. This objective is attainable by fuel switching but with high sensitivity degree of substitution for producers. They conclude that GDP decrease less than one percent and welfare would fall by small percentage and due to changes in relative prices; pattern of energy demand would be change significantly from high emission carbon factor to lower carbon intensity. Finally imposing carbon tax is more efficient than an equivalent uniform energy tax.

Zhou et al. (2011) simulated the impacts of carbon tax policy on reduction of CO_2 and economics growth in China by applying a dynamic CGE model. They noted that for cutting CO_2 emissions by 4.52, 8.59 and 12.26 percent, the government should impose 30, 60 and 90 RMB per ton CO_2 tax rate also China economy will face with decline in GDP by 0.11, 0.25 and 0.39 percent, respectively in 2020 with energy efficiency improvement. They proposed double dividend approach in order to offset negative impacts on sectors and households.

Lu, Z., et al. (2012) research focused on efficacy of a carbon tax in order to reduce carbon emissions as well as the following effects on China's economy. They applied a static CGE model and found that imposing CO_2 tax will lead to reduction of consumption, total demand, total supply, export and increase import but will cut CO_2 emissions significantly. For example a policy that set a price of 100 RMB CO_2 emissions per would decrease CO_2 emissions by 10.98% while the GDP will drop only by 0.613%.

Bruvoll and Larsen (2002) in their paper used applied general equilibrium simulation to investigate the specific effect of carbon taxes in Norwegian's economy. They stated that Norway has the highest carbon taxes in the world (51 US dollar in 1999) nevertheless surprisingly carbon pricing instrument has had only 2.3 percent reduction in emissions. They found that, this moderate impact is related to the exemption of the CO2 tax for most of the fossil fuel intensive industries due to competitiveness concern.

Mingxi(2011) designed a CGE model for studies of impacts of CO2 emissions on China's economy in short and long term. He note that in short run levying a carbon tax by 5 and 10 US dollar per of carbon will lead to decline in GDP by 0.51% , 0.82% as well as will reduce emissions of carbon dioxide by 6.8% ,12.4% respectively.

Siriwardana, M., et al. (2011) examined framework for conducting research with respect to assessing CO2 tax effects of Australia's economy. They build a CGE model in order to simulate impact of a carbon tax of 23 $ a tone on macroeconomic variables. The analysis reveals that CO2 emission may decline about 12 %, real GDP may decrease by 0.68 percent and consumer prices as well as electricity price increase by 0.75, 26 percent respectively. They concluded that reduction of CO2 via a carbon tax is feasible without any serious negative impacts on Australian economy.

Labandeira et al. (2004) analyzed the effects of a double dividend CO2 tax of 12.3 euro per in Spain economy by applying a CGE and econometrics model. Their results show that, this tax rate would reduce by 7.7 % CO2 in relative terms as well as real GDP decreased by 0.7 %. It is found that real labor income increase by 0.2% and social welfare tends to improve.

Wei and Glomsord (2002) applied a CGE model to analyze the impacts of levying CO2 tax in China's economy and result shows that carbon tax will decline China's economy but it can reduce emissions of carbon dioxide (CO2).

The study of Jafar et al. (2008) analyzed the effect of carbon dioxide tax on Malaysian economy by a static CGE model. The simulation results indicate that levying carbon tax will lead to reduce carbon dioxide without losing the investment and government revenue but with negative effect on GDP and trade.

Chapter 3

CGE modeling is an "art" and well as a "Science"

Wright R. E.

3.1 Foundation of the CGE model

Objective

In this chapter, we include a summary of literature review related to computable general equilibrium (CGE). It is also commonly referred to as applied general equilibrium (AGE).In section 3.6 an overview and details on the model are provided.

3.1.1 Introduction

For simulating alternative economic policy scenario, quantitative simulations play a decisive role in applied economic analysis. Different policy measures have different results on a complex socio-economic system thus various models have been built and applied to address a variety of policy issues.

In order to assessing the policy effects on the economy among different agents within an economic system, computable general equilibrium (CGE) models play an important role in applied economic research and the most appropriate approach to environmental policy analysis(Xie 1995; Zhang & Folmer 1998; Zhang & Nentjes 1998).

Computable general equilibrium models are originated from microeconomics agents and follow the Walrasian competitive economy; accordingly general equilibrium models are often called Walrasian models. In order to proof of equilibrium existence in the general equilibrium theory, K.Arrow and G.Debreu (1959) applied Brouwer's fixed point theorem and constructed a precise logical model of the interaction of consumers and producers based on Walras structure; whereas Walras did not give any proof of the existence of the solution for this system[1]. They established a key link between a market equilibrium and welfare.

Because of Arrow-Debreu' model was so abstract, general and tough also doesn't include any numerical analysis, CGE models are designed to convert their model from general form into

[1] I remembered the famous sentence from P.Firma for his conjecture:

"I have discovered a truly marvelous proof of this, which this margin is too narrow to contain" realistic of actual economies, in other words CGE model is an algebraic representation of the abstract Arrow-Debreu model. CGE models are capable to quantify the effects of shock as well as outcome of various" what if "scenario on an economy. This is why they are called "Computable" because they should produce numerical results that are applicable to particular situations.

The pioneering CGE model was empirically-based multisector, price endogenous model to analyze the effects on resource allocation of Norwegian trade policy that formulated by Johansen. (1960).

Harberger (1959, 1962), investigated tax incidence analysis using CGE method numerically in a two sector Walrasian economy. It must be noted that, with rapid improvement in computer technology for solving systems of nonlinear equations, Scarf (1960s) developed computer algorithm for the numerical determination of a Walras system. Whalley did him doctoral dissertation under Scarf and continued to be involved with him. He and Shoven (1972, 1974) used Scarf's algorithm and examined multicounty model which have mainly focused on tax and trade policies on resource allocation.

A model of the Australian economy ORANI was constructed by Dixon, Parmenter, Suttorn and Vincent (1982).since then; many CGE models has been developed; for example Dervis et al (1982) in World Bank applied other solution algorithm differ than Scarf's algorithm from Brouwer's fixed point theorem to Newton-Raphson method with Jacobian algorithm.

3.1.2 Framework of CGE models

In this section the general structure of a static CGE model is presented. The main characteristic of static CGE models is that data for modeling are for a single year. The models are called "general" refers to the model that encompasses complete system of interdependent and interlinkage components simultaneously among them; including production, consumption, taxes and etc. The fundamental conceptual starting point to depict the interrelationship in a CGE model is the circular flow of income and spending in national economy, shown in figure3-1

This figure illustrates schematically a very basic version of economy and relationship with environment where the main actors in the diagram is modeled according to the certain behavior assumptions; that is households own factors of production (capital and labor) and supply them to business firms in exchange for income and firms in turn, pay them wages, rent, profit and interest. Household using part of the income received from sales factors to spend goods and services, pay taxes to the government, and put aside saving. In some CGE models, there is also a government, which collects taxes and uses its tax revenue to buy goods and services, transfers wealth by collecting taxes and providing services or giving subsidies to households and firms (Paltsev et al., 2005; Sue Wing, 2004). Output of each industry can also be exported as an additional source of domestic goods, and imported goods can be purchased from other countries in meeting some of the domestic demand.

The figure shows clearly that:"everything depends on everything else" and this is the essential difference between general equilibrium analysis and partial equilibrium analysis.

Partial equilibrium focuses on the one part of economy and particular industry or few markets. In other words partial equilibrium theory, therefore, asks economists to limit the scope of their analysis and placing a magnifying glass over one part of economy. In other words ignoring what goes on in other markets and may, even, assume that p=mc .But what about trade-off and interdependent relationship with rest of the economy, when these linkages are particularly important? While, general equilibrium economics takes a perspective in numerous markets in an

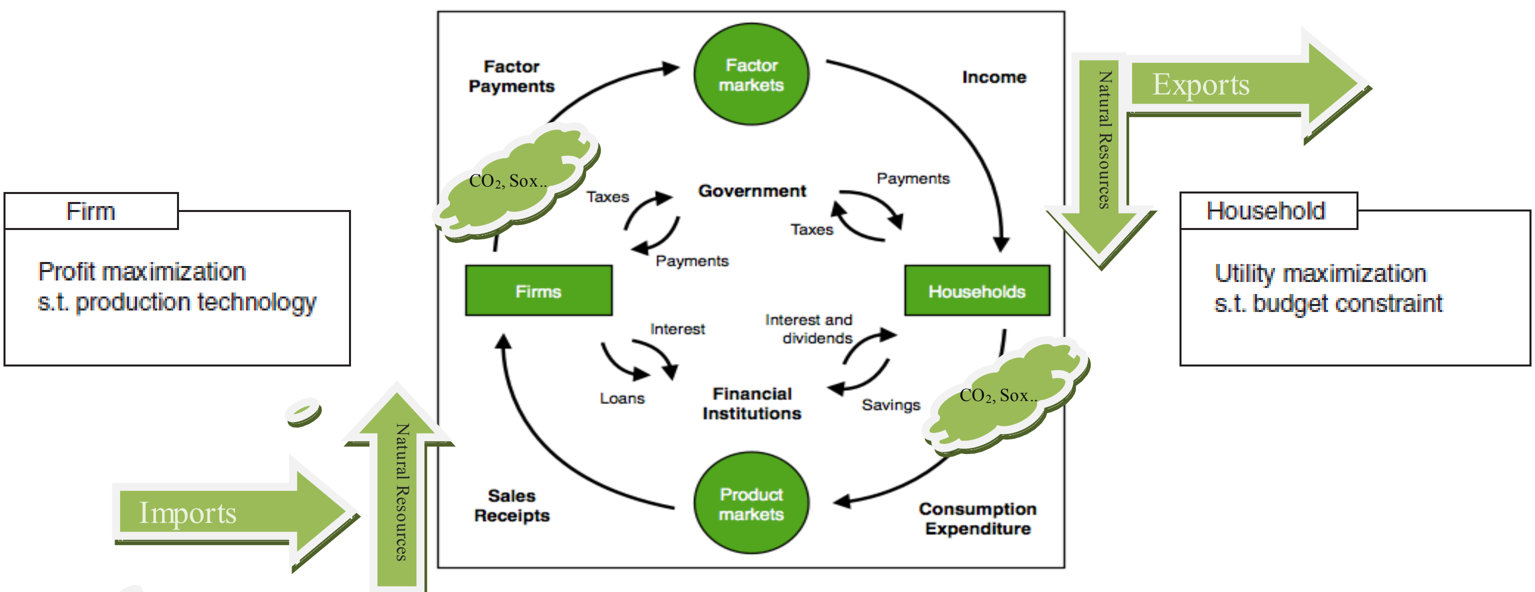


Figure 3-1 Circular flow in a CGE model

Economy to account for all possible direct and indirect effects of a change; Economist has two different answers in partial and general analysis if spillover effects in economy are large.

3.1.3 Advantages and disadvantages of CGE models

Each models has its own benefits and also drawbacks, here is some of the advantages and shortcoming of CGE model.

1-One of the major advantages of CGE models in comparison to the other quantitative methods is the relatively small data requirements considering the model size. The core of a CGE model is macroeconomic data such as Social Accounting Matrix (SAM), input output tables (I/O) as well as national accounts for one year (Pyatt and Round, 1979; Hanson and Robinson, 1988) thus developing countries widely employ CGE approach rather than standard econometrics, because of lack of availability of sufficient statistical data.

2-Another major advantage of CGE model is, taking into account all flows in the economy and captures a much wider and broad range of economic impacts as well as policy reform at global, multi-regional and Multi-sectoral level.

3-Other advantages of CGE models are formulated based on solid microeconomics foundation and incorporate many aspects of economic theory. Most of them use neo-classical behavioral concepts (optimization & choice) such as utility maximization and cost minimization to characterize the workings of the economy.

4-CGE models also have the potential advantage of being highly customizable. A model builder can construct any type of functional form for example C.E.S, Leontief or Cobb-Douglass and etc. then choose which variable should be including in the model, in brief CGE models are flexible in specifications.

5-CGE models are solved based on numerical methods not analytically. There are many important non-linear equations for which it is not possible to find an analytic solution.

And finally welfare analysis is benefit from using CGE model, if it is broken down into its different components. This will allow identification of the sources of welfare changes.

What are the disadvantages of CGE models relative to more standard modeling approaches? Computable general equilibrium models may be criticized from several perspectives. Here is some of its shortcoming:

1-CGE models are complex and require skill to maintain them. They can be difficult to use, especially for non-expert readers." Without detailed programming knowledge, the CGE approach is doomed to remain a "black box "for non-modelers" (Rutherford et al).

2-CGE models are expensive, time consuming and sometime to build a model takes some month.
3-When violations of assumptions lead to serious biases like imperfect competition vs. monopoly markets
4- CGE models are not in a strict sense forecasting models

3.1.4 Application of CGE models

Over the past half-century, computable general equilibrium (CGE) models have been used in economic analysis. Here lists of economic research topics are presented briefly as follows:

- The effects on general macroeconomics variables for example, tax reform on income distribution and welfare.
- Impact of international trade policy like: WTO,ASEAN
- Environmental policy on economy and vice versa: like climate changes shock, pollution Pigovian taxation, CO_2 emissions permit approach or economy liberalization and growth.
- Labor policies: such as impact of remittances on economy variable or labor force inflow impacts.

3.1.5 Key steps for constructing CGE model

The key issues in CGE model development has been shown in figure 3-2. At first, the policy issue should be carefully determined to decide on the appropriate model design as well as the required data. Then modeler should specify the dimension of the model which includes number of goods and factors, consumers and countries as well as active markets (Markusen and Rutherford, 2004).

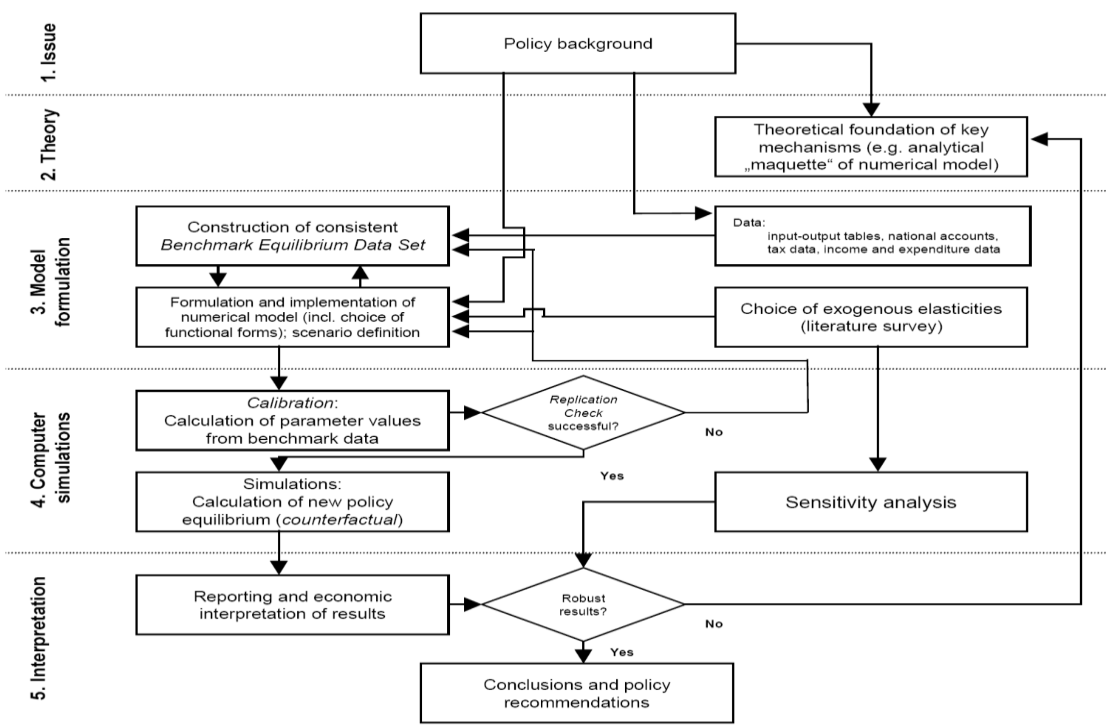
At the next step, the best economic theory should be applied to explain the result of numerical policy simulation, scenario analysis as well as alternative policy. To fulfill this step modeler should choose correct functional forms of production function, transformation and utility function. The next step is constructing social accounting matrix (SAM). Dimensionality which mentioned earlier must be identified as well, that is the level of disaggregation such as the number of products sectors and production factors from I/O accounts should be considered. This step also involves checking consistency of data by calibration process which is selecting

Parameter values in order to replicate benchmark data or base year. In simple words the model can reproduce the data set as an equilibrium. Data should satisfy zero profits and market clearing conditions for all activities and markets respectively. Those parameters also exogenous elasticities are taken from literature surveys. The next step is exogenous variable or single parameters should be changed in simulation phase under different scenarios to compute new equilibrium (new policy equilibrium).

Finally, counterfactual and the benchmark equilibrium should be compared; this comparison provides useful information about economic variables changing and muse be interpreted based on economic theory.

The key point that any modeler and policy maker need to take into account is, before any concrete policy recommendation the robustness of the simulation results must be tested by systematic sensitivity analysis. The modeler can use different values on key exogenous elasticites to assure about credibility and the reliability of the model.

Figure 3-2 Key issues in CGE model (Steps towards a policy experiment with CGE models)

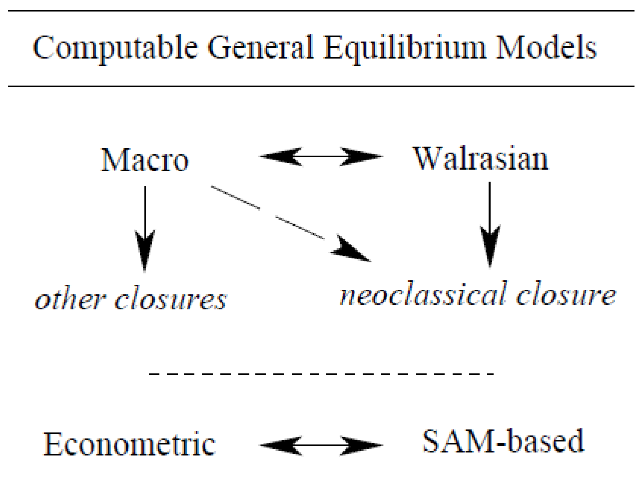


Source: Böhringer and Rutherford (2003)

3.1.6 CGE model Classification

In this section we introduce the CGE classification and look at the different approaches in CGE models. Thiessen(1998) classified CGE models in three different groups based on their purpose, historical development and parameters calculation techniques, but still there is discussion in CGE classification between economists. The three classifications are shown in the figure3-3

Figure 3-3 Computable General Equilibrium Classification



Source: Thiessen (1998)

The first kind of CGE model is macro CGE that evolved from input output tables in 1930 and after long pause developed in 1970s by Johansen. This type of CGE modeling frequently applied to assessing the policy effects on developing countries. Walrasian CGE models are the second kind of classification that developed by Scarf and his algorithm to compute numerically Walras general equilibrium system. It should be noted that, in the second type of classification, there is theoretical differences based on closure rules which is the decision about which variable are exogenous and which are endogenous (Burfisher,2011). The concept of closure first was introduced by Amartya Sen- Nobel laureate- in 1963 (Gisbson, 2008). In mathematical terms model cannot be solved when the number of equations is one less than number of unknown. In other words in the CGE model, the number of equations and endogenous variable should be equal so we must add an equation to make model solvable. Sen classified closure based on economic theories and schools" as listed below:

- Neoclassical closure
- Neo Keynesian closure
- Johansen closure
- Kaleckian Closure
- The loanable fund closure
- Pigou closure

But regardless of Sen's classification, generally in any CGE model there are three main macro closures that are: government balance, saving and investment balance and finally the trade balance.

The third type of CGE models is based on parameter calculation techniques which are categorized into calibration techniques and econometrics estimation. Calibration involves determining the numerical values of unknown parameters of functions compatible in some known equilibrium observed in SAM (Annabi, N., et al. 2006, Hosoe, N., et al. 2010).

Every technique has its own advantages and disadvantages however, Thiessen (1998) stated that calibration technique is better applied in short run and econometrics estimation would be more appropriate technique in long run.

3.1.7 Top down vs. Bottom-up models

Two different approaches are used to assess the policy effects on economy in CGE models: top down and bottom up model.

Bottom-up models emphasize on technological options, engineering information and data by disaggregating the energy sector to simulate interaction energy transformation technologies with demand for energy services.

Alternatively, top- down models are very aggregated national-wide models and focus on different market and economy wide feedbacks which allow better assessment of the change in relative prices of the supply-demand interactions and incomes across the markets. Top-down models often sacrificing the technological options which maybe relevant to the energy policy (Böhringer and Rutheford, 2008; McFarland et al., 2002).

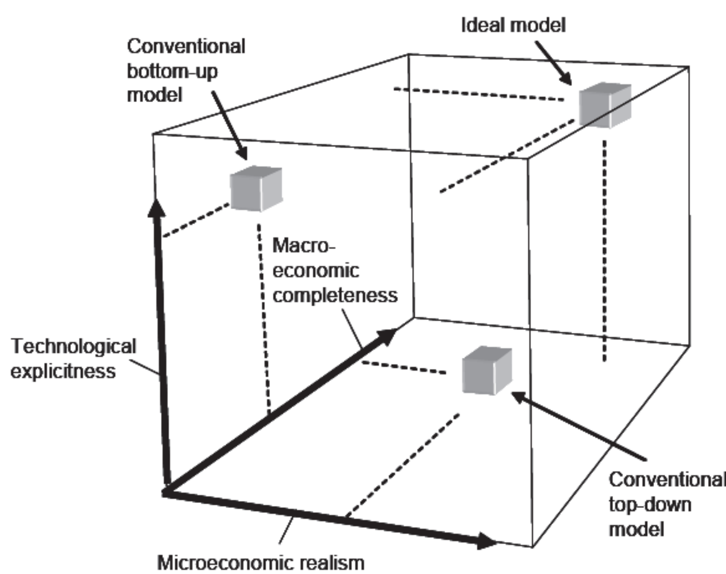
In top- down analysis carbon emission are modeled for assessing the macroeconomic impacts of CO_2 emission that released from the combustion of fossil fuels on prices, commodity, factor substitution in production function and households income.

The bottom-up models are applied to examine CO_2 emissions reduction through a various low cost abatement technology and fuel switching possibilities but ignore the market and social welfare interaction.

It should be however that, the results from the bottom-up model are quite different from the macro-level top-down model (Cao, J., et al. 2008). Due to specific strengths and weaknesses as well as gap between those model mentioned above, Hybrid models emerged to compensate for the limitations of top down and bottom up models by combining the detailed technological explicitness with economic comprehensiveness.

Figure 3-4 compares top down and bottom up models respect to their character. (Hourcade *et al.*, 2006).

Figure 3-4 Top Down, Bottom up and Hybrid model



Hybrid models can be defined as those top down and bottom up models that transform their position and move toward "ideal" location in the back, right, and top corner of the cube (Hourcade et al.2006).

3.2 Some of microeconomics theory in CGE modeling

In this section, we briefly review some microeconomic theory which play dominant role in CGE modeling by following.

3.2.1 Envelope theorem

In envelope theorem we face with the constrained optimization. We will have an objective function g, n choice variables x1, x2,…. , xn, and one parameter a ,also $\underline{h}$ is constraint which is function of xi and parameter a.

The problem then becomes:

$$\text{Max or Min } g(x_{1,}x_2, \dots \dots \dots., x_n, a) \tag{3.1}$$

$$\text{S.t} \quad h(x_{1,}x_2, \dots \dots \dots., x_n, a) = 0 \tag{3.2}$$

The Lagrangian for this problem is:

$$\boldsymbol{L = g(x_{1,}x_2, \dots \dots \dots., x_n, a) - \lambda h(x_{1,}x_2, \dots \dots \dots., x_n, a)} \tag{3.3}$$

The first order conditions are:

$$\boldsymbol{\frac{\partial L}{\partial x_i} = 0 \rightarrow \frac{\partial g(x_{1,}x_2, \dots\dots\dots, x_n, a)}{\partial x_i} = \lambda \frac{\partial h(x_{1,}x_2, \dots\dots\dots, x_n, a)}{\partial x_i} \quad i = 1, 2, \dots, n} \tag{3.4}$$

$$h(x_{1,}x_2, \dots \dots \dots., x_n, a) = 0 \tag{3.5}$$

Solving this (n+1) system of equations gives us:

$$x_1^* = x_1(a), x_2^* = x_2(a), \dots \dots \dots \dots \dots \dots.., x_n^* = x_n(a) \tag{3.6}$$

Substituting the solutions into the objective function, we get:

$$g^* = (x_1(a), x_2(a), \dots \dots \dots \dots, x_n(a), a) = M(a) \tag{3.7}$$

Where M (a) is the indirect objective function or maximum value function (VF).

How does M (a) change as *a* changes? The envelope theorem tells us how M (a) changes as the parameter (a) changes. First, we differentiate M with respect to a:

$$\frac{dM(a)}{da} = \frac{\partial g}{\partial x_1}\frac{dx_1}{da} + \frac{\partial g}{\partial x_2}\frac{dx_2}{da}, \dots \dots \dots \dots + \frac{\partial g}{\partial x_n}\frac{dx_n}{da} + \frac{dg}{da} \tag{3.8}$$

According to the F.O.C :

$$\frac{\partial g(x_{1,}x_2, \dots \dots \dots., x_n, a)}{\partial x_i} = \lambda \frac{\partial h(x_{1,}x_2, \dots \dots \dots., x_n, a)}{\partial x_i}$$

(3.9)

We have:

$$\frac{dM(a)}{da} = \lambda(\frac{\partial h}{\partial x_1}\frac{dx_1}{da} + \frac{\partial h}{\partial x_2}\frac{dx_2}{da}, \dots\dots\dots\dots + \frac{\partial h}{\partial x_n}\frac{dx_n}{da}) + \frac{dg}{da}$$

(3.10)

If we differentiate h (constraint) with respect to a:

$$h(x_1(a), x_2(a), \dots\dots\dots\dots, x_n(a), a) = \frac{\partial h}{\partial x_1}\frac{dx_1}{da} + \frac{\partial h}{\partial x_2}\frac{dx_2}{da}, \dots\dots\dots\dots + \frac{\partial h}{\partial x_n}\frac{dx_n}{da} + \frac{dh}{da} = 0$$

(3.11)

$$\frac{dM(a)}{da} = \lambda\left(-\frac{dh}{da}\right) + \frac{dg}{da} = \frac{dL}{da}$$

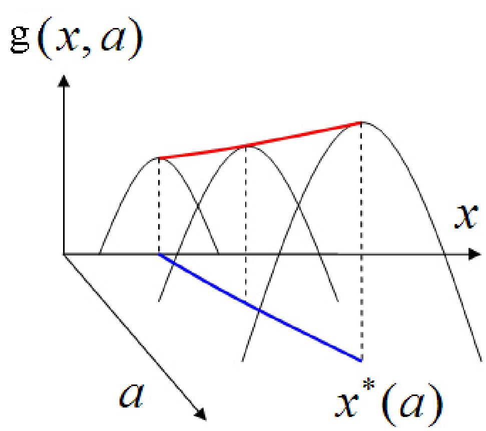
(3.12)

Which we often write:

$$\frac{dM(a)}{da} = \frac{\partial L}{\partial a}|x = x^* \qquad |: holding\ x\ fixed$$

(3.13)

Figure 3-5 Visual explanation of the Envelope theorem for Parabola function



This relation expresses that if we take derivative of the value function respect to parameter (a) is exactly equal to take partial derivative of the Lagrangian function in the optimum value.

3.2.2 Profit function and Hotelling lemma

By definition profit function is:

$$\pi(p, w) = \max\ (pf(x) - w.x)$$

(3.14)

Where p is output price and w is input price.If we know the profit function, without first having to specify production functions then according to the Hotelling's Lemma, it is easy to find the net supply function. Hotelling's lemma is a result in microeconomics and is widely used in many areas of economics research especially in the firm theory. Hotelling (1932) stated that if we know the profit function it is easy to find the net supply function, just by taking differentiate the profit function respect to the price.

Hotlling lemma can be stated:

$$\frac{\partial\pi(p, w)}{\partial p} = y(p, w)$$

(3.15)

Similarly, differentiating the profit function with respect to price of a particular input give us input facto quantity.

$$\frac{\partial\pi(p, w)}{\partial w} = -x(p, w)$$

(3.16)

3.2.3 Expenditure minimization and Shephard lemma

Differentiating the profit and utility
functions with respect to input and output prices provides compensated demand and supply coefficients (Shephard's lemma), as
shown in the market clearance conditions.

Shephard's lemma is one the result of envelope theory. Shephard (1953) states that, the derivative of the expenditure function with respect to the price of good j is equal to the Hicksian (compensated) demand for good j.

Let us consider the dual problem to the utility maximization problem. We can find a solution to the expenditure minimization problem subject to attaining a given level of utility, by finding a minimum to the following Lagrangian function:

$$Min \sum_{j=1}^{n} P_j x_j$$

$$s.t.: u(x_1, \dots\dots\dots x_{n) - \bar{u} = 0}$$

(3.17)

$$L(x,\lambda;p) = \sum_{j=1}^{n} p_j x_j + \lambda(\bar{u} - u(x_1, \dots \dots \dots x_n))$$

(3.18)

$e(p_1, \dots p_n, \bar{u})$ illustrates the minimized value of the expenditure function. The envelope theorem states that:

$$\frac{\partial e(p,\bar{u})}{\partial p_j} = \frac{L(x^*,\lambda;p)}{\partial p_j}$$

(3.19)

And therefore we obtain at the point x* which solves the minimization problem.

$$\frac{\partial e(p,\bar{u})}{\partial p_j} = \frac{\partial}{\partial p_j} \langle \sum_{j=1}^{n} p_j x_j^* + \lambda(\bar{u} - u(x_1^*, \dots \dots x_n^*)) \rangle = x_j^* - \lambda 0 = x_j^* \equiv h_j(p,\bar{u})$$

(3.20)

This is called the Hicksian (or compensated) demand for good j. We denote it by $h_j(p_1, \dots \dots p_n, \bar{u})$ to indicate that it is a function of prices and utility. It should be point noted that Hicksdian demand function is differs from the Marshallian (or uncompensated) demand$x_j(p_1, \dots \dots p_n, \bar{y})$ for good j which is a function of prices and income. The above result is known as Shephard's Lemma.

3.3 Algebra of a AGE model : N Sectors, N commodities

Historically the roots of competitive market economies study from a general equilibrium perspective traced back to the Leon Walras, French mathematical economist (Mas-Collel *et al.* 1995).

Schumpeter (1954) stated that the Walrasian general equilibrium model has been considered as "the only work by an economist that will stand comparison with the achievements of theoretical physics".

Walrasian general equilibrium model explains each economic agents are price taker and all agent is individually defining his supply or demand behavior by optimizing his own utility and profit; in addition price mechanism freely adjust to equilibrium in order to clean market. This means that the total value of excess demands is zero.

Lange (1942) Polish economist proposes to call this identity Walras' Law in order to distinguish from Say's Law, also "because Walras was the first to recognize its fundamental importance in the formulation of the mathematical theory of prices."

For better understanding of Walras law, imagine an economy in which there are *n* commodities and for a given price vector p, there is a set of supply vectors y_j for each supplier j and set of demand vectors x_i for each consumer i.

Supply vectors could be shown as:

$(s_1)\{y_1^1, y_1^2, \dots\dots\dots y_1^n\}$

$(s_2)\{y_2^1, y_2^2, \dots\dots\dots y_2^n\}$

…

$(s_l)\{y_l^1, y_1^2, \dots\dots\dots y_1^n\}$ Where: $y_i^j \in \mathbb{R}^n$ for $i \in \langle 1,2, \dots l\rangle$ $and\ j \in \{1,2, \dots n\}$

(3.21)

And demand vectors for consumer 1, 2….S where $x_i^j \in \mathbb{R}^n$ for $i \in \langle 1,2, \dots r\rangle$ $and\ j \in \{1,2, \dots n\}$ Can be written symbolically:

$(d_1)\{x_1^1, x_1^2, \dots\dots\dots x_1^n\}$

$(d_2)\{x_2^1, x_2^2, \dots\dots\dots x_2^n\}$

…

$(d_s)\{x_r^1, x_r^2, \dots\dots\dots x_r^n\}$

(3.22)

And:

$$S^t(\boldsymbol{p}) = \langle \textstyle\sum_{i=1}^{l} y_i^t : t = 1, n\rangle - \ the\ supply\ set\ for\ commodity\ t\ given\ prices\ p$$

$$D^t(\boldsymbol{p}) = \langle \sum_{i=1}^{l} x_i^t : t = 1, r\rangle - \ the\ demand\ set\ for\ commodity\ t\ given\ prices\ p$$

The excess demand ED can be defined as:

$$ED^i : \mathbb{R}_+^n \to \mathbb{R}^n, ED^i(\boldsymbol{p}) = D^i(\boldsymbol{p}) - S^i(\boldsymbol{p})$$

A Walrasian perfect competitive equilibrium price vector $P^* \in \mathbb{R}^n$ is a price vector such that $ED^i(\boldsymbol{P}^*) = 0$ for all i.

It says that there exists a price vector at which combinations of supply and demand vectors add up to zero. In other words, at P^* -perfect competition equilibrium price- market is cleared.

This is the main goal of any CGE model to determine a vector of prices for both consumer and producer to balance the quantity supplied and the quantity demanded, such that the economy will eventually be cleared of all surpluses and shortages.

The proof of existence of the equilibrium in Walrasin system is formalized by Arrow-Debreu. They broke down the economy as a set of agents, divided into suppliers and demanders who maximize profits or utility which interacting across interconnected markets. In order to solve numerically the model they applied Brower-Kakutani theorem.

3.4 Actors and their behavior

This section outlines the standard economic calculus that dictates how firms choose which Inputs to use in producing goods, and how consumers choose which goods to consume.

3.4.1 General Form of Mathematical Relations in Computable General Equilibrium Models

Most Computable General Equilibrium (CGE) models are based on a system of equations that include the supply and demand functions. The system's mathematical relations and functions are derived from the household and producer optimization problem. This section tries to describe some of calibration aspects of CGE models. Production and utility functions are usually formulated as Constant Elasticity of Substitution (CES). This functional form is a typical form in the applied models of general equilibrium. Of course, the nested form of this function is implemented in practice. This section explains step by step how to extract essential functions for a general equilibrium model.

3.4.1.1 Utility Function with CES

Let us consider a utility function with CES for a sample household. This function can be shown in terms of consumption (demand) of different products and services as follows:

$$U(\mathbf{X}) = \left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad \textbf{(3.27)}$$

where X is a vector of products and services. Each product or service is shown by x_i. There are 2 products in the household's expenditure portfolio. This relation contains n+1 parameters consisting of n share parameters $(\alpha_i > 0)$ and one parameter associated with the substitution of products and services shown as δ.

Households optimize their utility by considering their budget constraint. In other words, a household's goods and services expenditure portfolio equals, at most, to its revenue. Let us state the household's problem as follows:

$$\max U(\mathbf{X})$$
$$s.t. \quad \sum_{i=1}^{n} p_i x_i = M$$

(3.28)

where M is the household's revenue and p_i is the price of product or service i. The optimized consumption level of products and services is determined based on the household's optimization problem.

3.4.1.2 First Order Conditions of Optimization

Different factors affect a household's demands for different products and services. In the current optimization problem, household demand will be determined based on household revenue, price of product, price of substituted goods or services, and substitutability of goods. The function of the household's demand for goods and services can be calculated by solving its optimization problem. The Lagrange function can be written as:

$$L = \left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} - \lambda \left(\sum_{i=1}^{n} p_i x_i - M \right)$$

(3.29)

As a first step in defining demand functions, we need to determine the first order conditions of optimization. In the current optimization problem, the conditions for a given good j are:

$$\frac{\partial L}{\partial x_j} = \left(\frac{\sigma}{\sigma-1} \right) \left(\frac{\sigma-1}{\sigma} \alpha_j^{\frac{1}{\sigma}} x_j^{\frac{\sigma-1}{\sigma}-1} \right) \left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}-1} - \lambda p_j = 0$$
$$\Rightarrow \left(\alpha_j^{\frac{1}{\sigma}} x_j^{\frac{\sigma-1}{\sigma}-1} \right) \left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}-1} = \lambda p_j$$

(3.30)

3.4.1.3 Extracting Marshallian Demand Function

Technically, the demand is calculated as follows. First, a good's demand is calculated based on another good's demand as well as the relative prices. Then, the good demand is derived in terms of price, revenue, the price of similar goods, elasticity of substitution and share parameter factors using a mathematical relation corresponding to the budget constraint.

By applying similar calculations, the first order conditions for the household's utility optimization of a given good j can be stated as follows:

$$\left(\alpha_{j'}^{\frac{1}{\sigma}} x_{j'}^{\frac{\sigma-1}{\sigma}-1}\right)\left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}-1} = \lambda p_{j'}$$

(3.31)

By applying the computed first order conditions on j and j′ we have:

$$\frac{\left(\alpha_{j}^{\frac{1}{\sigma}} x_{j}^{\frac{\sigma-1}{\sigma}-1}\right)\left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}-1}}{\left(\alpha_{j'}^{\frac{1}{\sigma}} x_{j'}^{\frac{\sigma-1}{\sigma}-1}\right)\left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}-1}} = \frac{\lambda p_j}{\lambda p_{j'}}$$

(3.32)

And further calculation produces the following relation:

$$\frac{\alpha_j^{\frac{1}{\sigma}}}{\alpha_{j'}^{\frac{1}{\sigma}}}\left(\frac{x_j}{x_{j'}}\right)^{\frac{-1}{\sigma}} = \frac{p_j}{p_{j'}}$$

(3.33)

Now, the demand function of a good can be stated based on relative prices as well as another good's demand. In other words, after simplification we have:

$$\left(\frac{\alpha_{j'}}{\alpha_j}\frac{x_j}{x_{j'}}\right)^{\frac{-1}{\sigma}} = \frac{p_j}{p_{j'}}$$

(3.34)

$$\Rightarrow \frac{\alpha_{j'}}{\alpha_j}\frac{x_j}{x_{j'}} = \left(\frac{p_j}{p_{j'}}\right)^{-\sigma}$$

$$\Rightarrow x_{j'} = \left(\frac{p_{j'}}{p_j}\right)^{-\sigma}\frac{\alpha_{j'}}{\alpha_j}x_j$$

(3.35)

Since the demand function of a given good can be stated in terms of another good's demand and relative prices, the demand function of the given good i can be written as:

$$x_i = \left(\frac{p_j}{p_i}\right)^{\sigma}\frac{\alpha_i}{\alpha_j}x_j$$

(3.36)

Now, the Marshallian demand function can be computed using the mathematical relations of the budget constraint. By replacing the value of x_i in the left side of the budget constraint we have:

$$\sum_{i=1}^{n} p_i x_i = \sum_{i=1}^{n} p_i\left(\frac{p_j}{p_i}\right)^{\sigma}\frac{\alpha_i}{\alpha_j}x_j$$

$$\Rightarrow \sum_{i=1}^{n} p_i x_i = \frac{p_j^{\sigma}}{\alpha_j}x_j\sum_{i=1}^{n}\alpha_i p_i^{1-\sigma}$$

(3.37)

Since the left side of the latter term should be equal to the household's revenue, the relation can be reformulated as:

$$M = \frac{p_j^{\sigma}}{\alpha_j}x_j\sum_{i=1}^{n}\alpha_i p_i^{1-\sigma}$$

(3.38)

If we define the price index of the expenditure portfolio as:

$$\left(\sum_{i=1}^{n}\alpha_i p_i^{1-\sigma}\right)^{\frac{1}{1-\sigma}} = p_u$$

(3.39)

then we can explain the household's demand for good j as a function of revenue and prices. As it can be seen, a good demand is inversely related to its price and directly related to revenue and price of other goods.

$$x_j = \frac{\alpha_j M}{p_j^{\sigma}} p_u^{\sigma-1}$$

(3.40)

In other words, households' demand is derived as a function of income, good's price, price ratio and elasticity of substitution. It should be take into account that the effect of other goods' price may be low or high depending on the elasticity of substitution.

$$x_j = \frac{\alpha_j M}{p_u}\left(\frac{p_u}{p_j}\right)^{\sigma}$$

(3.41)

This form of the demand function is usually used in CGE models. In nested forms, however, the price index is separately calculated via the CES function and is considered in the demand function.

3.4.1.4 Calculating Indirect Utility Function

The indirect utility function shows utility level in terms of revenue and prices. By replacing Marshallian demand function in the indirect utility function, we can indirectly state the utility function in terms of price and revenue.

In GE models, the utility function is stated in two forms. In the first form, the utility function is introduced in terms of the price of expenditure portfolio index while in the second form it is stated in detail and in terms of different goods' prices separately.

$$U(\mathbf{X}) = \left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, x_i = \frac{\alpha_i M}{p_i^{\sigma}} p_u^{\sigma-1}$$

$$\Rightarrow v = \left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} \left[\frac{\alpha_i M}{p_i^{\sigma}} p_u^{\sigma-1}\right]^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

(3.42)

Indirect utility function can be shown in terms of income and the price of expenditure portfolio index. After some calculations we have:

$$v = \left(M^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \left(\left[p_u^{\sigma-1} \right]^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \left(\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}+\frac{\sigma-1}{\sigma}} \left[p_i^{-\sigma} \right]^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

$$\Rightarrow v(M,\mathbf{P}) = M\left(p_u^{\sigma-1}\right) \left[\left(\sum_{i=1}^{n} \alpha_i p_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \right]^{-\sigma} = M\left(p_u^{\sigma-1}\right)\left[p_u^{-\sigma}\right]$$

(3.43)

After simplification, we have:

$$v(M,\mathbf{P}) = \frac{M}{p_u}$$

(3.44)

This form of utility function is generally used in CGE models. In these models, the households' welfare decreases as the price index of the expenditure portfolio increases. In contrast, welfare increases as revenue level increases.

The indirect utility function can be stated in detail in terms of the price of different goods and services, elasticity of substitution, revenue, and share of every good in the expenditure portfolio. In other words, the indirect utility function can also be states as follows:

$$v(M,\mathbf{P}) = \frac{M}{\left(\sum_{i=1}^{n} \alpha_i p_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}}}$$

(3.45)

In cases where the prices of some goods and services increase and those of other goods and services decrease, welfare change is not clear. In other words, numerical calculations are required to determine whether welfare decreases or increases and whether welfare is lost or gained.

3.4.1.5 Production Function with CES

The functions associated with enterprises' goods supply and enterprises' input demand are extracted via the optimization of enterprises. Suppose that the production function is in the form of constant elasticity of the substitution function. Therefore, we can write:

$$q = \left(\sum_{i=1}^{n} \delta_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

(3.46)

The constraint of enterprises is production cost. Suppose that production inputs are supplied with price w. Then, the optimization problem of enterprises can be stated as:

$$\min \sum_{i=1}^{n} w_i x_i$$

$$s.t. \quad q = \left(\sum_{i=1}^{n} \delta_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

(3.47)

3.4.1.6 The first order condition of optimization of enterprises

The demand of enterprises for different goods, services, labor and capital depends on different factors. In the current optimization problem, the demand will be determined in terms of production level, inputs' price, substituted inputs' price and substitutability of goods. By solving the corporation optimization problem, the function of enterprises demand for goods can be computed.

The Lagrange function can be written as:

$$L = \sum_{i=1}^{n} w_i x_i + \lambda \left\{ q - \left(\sum_{i=1}^{n} \delta_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \right\}$$

(3.48)

It is necessary to compute the first order conditions for every input.

$$\frac{\partial L}{\partial x_j} = w_j - \lambda\left(\delta_j^{\frac{1}{\sigma}} x_j^{\frac{\sigma-1}{\sigma}-1}\right)\left(\sum_{i=1}^{n} \delta_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}-1} = 0$$

$$\Rightarrow \lambda\left(\delta_j^{\frac{1}{\sigma}} x_j^{\frac{\sigma-1}{\sigma}-1}\right)\left(\sum_{i=1}^{n} \delta_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}-1} = w_j$$

(3.49)

In other words, we have two arbitrary inputs:

$$\lambda\left(\delta_j^{\frac{1}{\sigma}} x_j^{\frac{-1}{\sigma}}\right)\left(\sum_{i=1}^{n} \delta_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}-1} = w_j$$

$$\lambda\left(\delta_{j'}^{\frac{1}{\sigma}} x_{j'}^{\frac{-1}{\sigma}}\right)\left(\sum_{i=1}^{n} \delta_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}-1} = w_{j'}$$

(3.50)

Now, we can state any input's demand in terms of another input's demand, relative prices and elasticity of substitution:

$$\frac{\left(\delta_j^{\frac{1}{\sigma}} x_j^{\frac{-1}{\sigma}}\right)}{\left(\delta_{j'}^{\frac{1}{\sigma}} x_{j'}^{\frac{-1}{\sigma}}\right)} = \frac{w_j}{w_{j'}}$$

(3.51)

After simplification, we have:

$$\Rightarrow x_j = \left(\frac{w_{j'}}{w_j}\right)^{\sigma} \frac{\delta_j}{\delta_{j'}} x_{j'}$$

(3.52)

In other words, for a given input i, the demand can be stated in terms of another input's demand, substitutability and relative prices.

$$x_i = \left(\frac{w_j}{w_i}\right)^{\sigma} \frac{\delta_i}{\delta_j} x_j$$

(3.53)

In order to compute the demand function in terms of prices and production level, we would need to use the production function. By replacing the computed demand function in the production function formula, we will have:

$$q = \left(\sum_{i=1}^{n} \delta_i^{\frac{1}{\sigma}} \left[\left(\frac{w_j}{w_i} \right)^{\sigma} \frac{\delta_i}{\delta_j} x_j \right]^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

(3.54)

After simplification:

$$q = w_j^{\sigma} \frac{1}{\delta_j} x_j \left(\sum_{i=1}^{n} \delta_i w_i^{1-\sigma} \right)^{\frac{\sigma}{\sigma-1}}$$

(3.55)

If, after some calculations, the input demand is rewritten in terms of inputs' price and production level, we will have:

$$x_j = \delta_j . q . w_j^{-\sigma} \left(\sum_{i=1}^{n} \delta_i w_i^{1-\sigma} \right)^{\frac{-\sigma}{\sigma-1}}$$

(3.56)

This demand function shows that demand for every input is inversely related to its price and a directly related to production level, share in production cost and price of other inputs. If we define the unit cost functions as:

$$c = \left(\sum_{i=1}^{n} \delta_i w_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

(3.57)

then the input demand function can be stated in terms of production cost and product price indices as:

$$x_j = \delta_j . q . \left(\frac{c}{w_j} \right)^{\sigma}$$

(3.58)

GE models generally use a similar function to show the demand of enterprises for production inputs.

The cost production of enterprises can be calculated using the demand function of different inputs. One only needs to replace the computed sentence in the enterprises cost function:

$$C = \sum_{i=1}^{n} x_i w_i, \quad x_i = \delta_i . q . \left(\frac{c}{w_i} \right)^{\sigma}$$

(3.59)

After replacing, the cost function of the manufacturer enterprise is derived in terms of inputs' price, activity level, substitutability and share in production cost:

$$C = \sum_{i=1}^{n} \delta_i . q . \left(\frac{c}{w_i} \right)^{\sigma} w_i$$

(3.60)

After simplification we have:

$$C = qc^{\sigma} \sum_{i=1}^{n} \delta_i w_i^{1-\sigma}$$

(3.61)

The cost function can be stated in terms of production level and unit cost index. The cost function in terms of the mentioned variables is:

$$C = qc$$

(3.62)

Also, the cost function can be stated in terms of production level and the price index of each input. In this way, the cost function is derived as:

$$C = q \left(\sum_{i=1}^{n} \delta_i w_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

(3.63)

3.4.2 Calibration of CGE Models

CGE models contain the interactions of all markets and activities. There are different variables in production, utility as well as demand functions. Price, good demand, production and so on are important variables used in the models. In the applied studies of CGE, it is necessary to develop the price and quantity statistics and information associated with production and supply and demand of all goods and services. But this is impossible due to several reasons:

1-The first problem is that the price of a good varies over a year. Therefore, one needs to have access to detailed information in order to calculate price index and quantity

2-The second problem is that markets and goods are not homogenous. The difference in the quality of goods and services makes it a complex process to calculate price and quantity indices.

3-The third problem is that recording and compiling such a huge volume of data is a time and cost consuming process, far outweighing its benefits.

The question is: considering the problems, what is the fundamental data or information based on which CGE models can act? To explain how price and quantity indices are calculated in CGE model, it is necessary to explain the calibration and Harberger techniques used in the models.

3.4.2.1 Harberger Technique

The parameters of the functions employed in CGE models indicate technology or preferences. Calibration is a process by which the values of a model's parameters are selected. This selection should be done in a manner that the obtained values agree with the actual data. The social accounting matrix or micro-data adoptive matrix is an appropriate data structure for CGE models. These matrices collectively present the demand, supply and production data for all goods and services of different goods categories.

Social Accounting Matrix (SAM) states the values of production, demand and supply of goods and services but it lacks accurate data about price and quantity. Harberger technique is used to calculate price and quantity indices based on SAM. This technique briefly assumes that the indices of goods and services price, labor wage and capital return are equal to one. In this way, quantity indices can be easily calculated. By applying the Harberger technique, production, utility and demand functions can be stated as calibrated coefficients.

3.4.2.2 Calibrated Coefficients Form

In the applied studies of CGE models, the production, utility and demand and supplies are used in the form of calibrated coefficients. The coefficients contain various data including:

1- Demand of producer sector for factors of production in the base year
2- Price index of factors of production in the base year
3- Costs in the base year
4- Amount of manufactured products in the base year
5- Elasticity of substitution[1] and;
6- Share coefficients in the base year

For example, the utility function in the form of the calibrated coefficients is stated as:

$$U(\mathbf{X}) = \left(\sum_{i=1}^{n} \theta_i^{\frac{1}{\sigma}} \left(\frac{x_i}{\bar{x}_i} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

(3.64)

where θ is share coefficient and $\bar{x}_i$ is good demand in the base year. Since the value of x_i is equal to the demand value in the base year, utility index of the base year would be equal to unity. Share coefficients show the share of each good in the household expenditure portfolio. In the calibrated coefficients form, the share parameters are calculated from the following relation:

$$\theta_i = \frac{\bar{p}_i \bar{x}_i}{\sum_{i=1}^{n} \bar{p}_i \bar{x}_i}$$

(3.65)

Where: $\bar{p}_i$ shows the price index of goods in the base year. Similarly, if $\bar{M}_i$ is the household's revenue in the base year, the calibrated coefficients form of the indirect utility function will be:

$$v(M, \mathbf{P}) = \frac{M / \bar{M}}{\left(\sum_{i=1}^{n} \theta_i \left(\frac{p_i}{\bar{p}_i} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}}$$

(3.66)

[1] In the calibrated coefficients form, the elasticity of substitutions is exogenous.

However, the unit expenditure function (the price index of households' expenditure portfolio) is:

$$p_u = \left(\sum_{i=1}^{n} \theta_i \left(\frac{p_i}{\bar{p}_i} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

(3.67)

Again, since p_i is equal to the price index in the base year, the price index of households' expenditure portfolio in the base year equals unity.

For the manufacturer, the calibrated coefficients form of the production function will be:

$$q = \bar{q} \left(\sum_{i=1}^{n} \theta_i^{\frac{1}{\sigma}} \left(\frac{x_i}{\bar{x}_i} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

(3.68)

$\bar{q}$ is the activity level index in the base year. However, the calibrated coefficients form of the production inputs demand function can be written as:

$$x_j = \frac{\bar{x}_j}{\bar{q}} q. \left(\frac{c}{w_j} \frac{\bar{w}_j}{\bar{c}} \right)^{\sigma}$$

(3.69)

where $\bar{w}$ and $\bar{c}$ are the price index of inputs in the base year and the unit cost index in the base year respectively. Finally, the unit cost index of the manufacturer will be:

$$c = \bar{c} \left(\sum_{i=1}^{n} \theta_i \left(\frac{w_i}{\bar{w}_i} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

(3.70)

These calibrated forms are the fundamentals of complex mathematical relations in the applied CGE models. The next section explains some of the relations used for CGE model in this study.

3.5 Model Assumptions

CGE model is a proper calculative framework for analyzing costs and benefits of economic policies or shocks. The vast majority of studies are about tax and subsidies, tariff and economic, and energy policies. However, there are various studies also for analyzing population changes and labor aging, migration, occupation and work market changes, oil shocks, and foreign exchange changes by using CGE models.

Every economic model consists of assumptions and variables, and their relations. CGE models have been founded on different assumptions. Our current CGE model also considers different assumptions. The main assumptions of this model are:

- Market clearing condition is satisfied in economic markets. In other words, supply and demand have the same value in every market. It is assumed that there is a perfect competition in all markets. This means that all activities are prictaker.
- The zero-profit condition (perfect competition) is satisfied in all production activities. In other words, the revenue of activities is equal to their costs.
- The revenue balance condition is satisfied in households and institutes. In other words, in every economic agent, the sum of financial and non-financial resources is equal to the sum of financial and non-financial consumptions. This condition shows the balance sheet equilibrium of economic agents.
- It is assumed that producers minimize costs and households maximize utility. In every market, the demand-supply function is derived from this optimization assumption.
- It is assumed that production and utility functions are NCES functions.

It is important to note that the perfect competition assumption of this model does not necessarily mean that all economic active markets are competitive. A CGE model considers all goods and services collectively. For example, the agriculture sector is considered collectively (as a whole) and it is assumed that the activities are collectively price-taker and competitive. A sub market of the agriculture sector may not satisfy the perfect competition condition, but as we consider the industry as a whole, this condition may be considered as an acceptable and valid assumption. In fact, the supply and demand model of the whole economy, which is dealt with by macro economy, has been considered as a multi-sectional model.

In a GE model, demands and services demand are extracted based on the utility optimization theory and cost optimization in micro economy. If c is the minimum production cost, we have:

$$C = C(p_1, ..., p_n, Q) \tag{3.71}$$

where p and Q are price indexes of input cost and production level respectively. This function has three important features:

- Cost function is a homogeneous function of degree one in terms of prices. In other words, if all prices rise by K, the production cost will rise by k, too.
- Cost function is a homogeneous function of degree one in terms of production. In other words, if production level rises by k, the production cost will rise by k, too.
- Inputs' demand function, X, is stated as follows and it is a homogeneous function of degree one in terms of prices. In other words, if all prices rise by k, the inputs demand will not change.

$$X_i = \frac{\partial C}{\partial p_i} = C_i(p_1, ..., p_n, Q) \tag{3.72}$$

3.6 Mathematical Relations of Static CGE Model

In this study, the static CGE model is a single-period one. This model considers open economy and in addition to the households' and corporations' behavior, simulates the import and export behavior of goods and services as well. All markets can be classified into three categories: goods and services, labor, and capital markets. The perfect competition assumption governs all markets. In other words, prices serve as an exogenous factor for every agent and are predefined factors. It should be noted that price serves as an indigenous factor throughout the model and is determined based on demand-supply interactions.

Households create utility by consuming different goods and services. On the other hand, the households are the owners of work and economic capital. Therefore, they earn via work and capital supply. They determine their consumption level so that maximum utility can be generated and at the same time, their expenditure will not exceed their revenue.

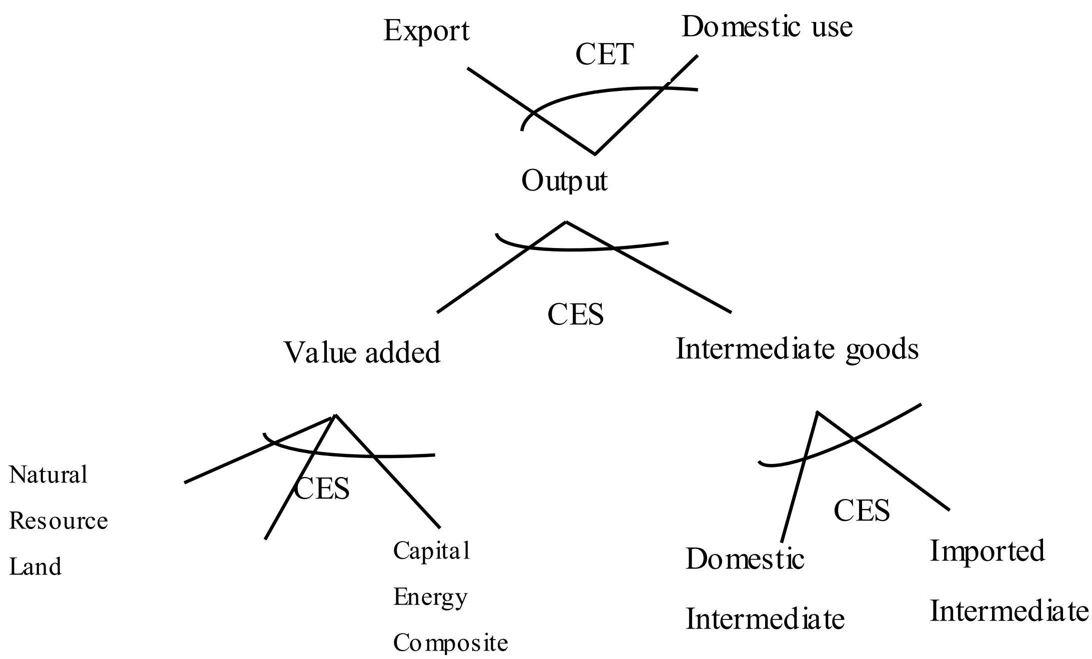
Enterprises, however, supply goods and services using production inputs. The supply level of goods and services and the demand level of inputs are determined in a manner that the production is practiced with the minimum possible cost. The revenue of activities is distributed between production inputs, and the zero profit condition governs all production activities.

In this study, the CGE model was developed within a Mixed Complementary Problem (MCP). Since the unit cost function is a very important factor for enterprises, an attempt was made to study all components of this function. In this model, the indigenous variables are divided in two classes: Activity level or AL variables and price index or p variables. Other variables including demand-supply level in different markets are computed based on the mentioned variables. The model's parameters, however, are stated by the elasticity of substitution in different layers as well as technical coefficients (share parameters). In future relations, the elasticity of substitution will be shown as γ, σ, ν and β and technical coefficients as θ, ω, φ and ψ.

3.6.1 Nested Structure of Production Cost in Different Activities

In order to determine the sectional effects of economic policies, it is necessary to study markets separately. The inputs used in every production section are divided to three classes. In other words, the products of any section are produced using intermediate (INT), labor (L) and capital (K) inputs. The nested structure of which is shown in figure 3.6.

Figure 3-6 : Nesting struture of Production in CGE model



Zero profit condition is hold for all activities. The general form of unit revenue structure as well as unit cost of every economic activity can be shown by the combination of CES in the first layer and the combination of CET in the products layer:

$$Z_s \left[(1+Ctax_s)\left(\omega_{KL,s} PVA_s^{1-\sigma_{klm,s}} + \omega_{\text{int},s} PINT_s^{1-\sigma_{klm,s}}\right)^{\frac{1}{1-\sigma_{klm,s}}} - PO_g \right] = 0,$$

$$Z_s \geq 0, \underbrace{(1+Ctax_s)\left(\omega_{KL,s} PVA_s^{1-\sigma_{klm,s}} + \omega_{\text{int},s} PINT_s^{1-\sigma_{klm,s}}\right)^{\frac{1}{1-\sigma_{klm,s}}}}_{\text{CES unit cost function}} \geq \underbrace{PO_g}_{\text{unit revenue function}}$$

(3.73)

Where subscript *s* stands for sectors; PVAs and PINTs are price index of value added layer and price index of the intermediate materials layer, Ctax is sector carbon tax and σ shows the elasticity substitution between intermediate (INT), and value added. As it is observed, the MCP problem consists of two inequalities and one equation and it is similar to the Karush-Kuhn-Tucker (KKT) problem.

The inputs are separated to different categories as the layers have different elasticity of substitution. Therefore, the CES consisting of capital and in the added value layer with a given elasticity of substitution can be shown as follows:

$$PVA_s = \left\{ \theta_{k,s} pf_k^{\,1-\sigma_{kl,s}} + \theta_{l,s} pf_l^{\,1-\sigma_{kl,s}} \right\}^{\frac{1}{1-\sigma_{kl,s}}}$$

(3.74)

In goods layer (g) it is assumed that goods are mixed within a CES function based on an elasticity of substitution:

$$PINT_S = \left(\sum_g \theta_{g,s} PD_g (1+TX_S)^{1-\sigma_{\text{int},s}} \right)^{\frac{1}{1-\sigma_s}}$$

(3.75)

Where: TX_S is the ad-valorem tax of the intermediate good received from the manufacturer. This is notable that the cost expended by an activity for goods (PDG) is a composition of domestic and import prices of products. However, domestic products (PO) and imported products (PM) are imperfect substitutes for each other. In the following relation, TX_M is the import tariff.

$$PS_g = \left\{ \varphi_{dg} PO_g^{\,1-\beta_g} + \varphi_{mg} P_{Mg} (1+TX_M)^{1-\beta_g} \right\}^{\frac{1}{1-\beta_g}}$$

(3.76)

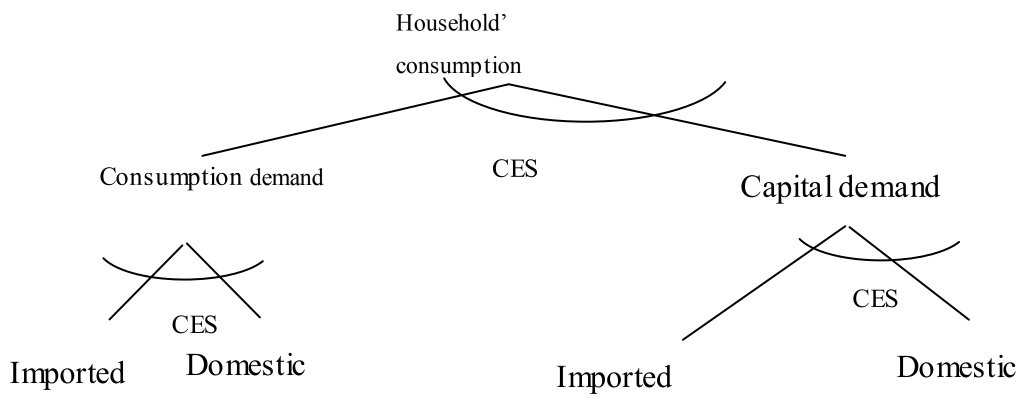
National supply, however, can be shown as a CET function as follows where PXg is the export products' price (PXg):

$$PS_g = \left\{ \psi_{dg} PD_g^{\,\frac{v_g-1}{v_g}} + \psi_{mg} P_{Xg}^{\,\frac{v_g-1}{v_g}} \right\}^{\frac{v_g}{v_g-1}}$$

(3.77)

Considering the nested structure, the households' expenditure can be shown within a MCP problem. This model separates consumer demand from capital demand. The nested households' expenditure in shown in figure 3-7

Figure 3-7 : Nested households consumption structure



WELHL stands for the households' welfare. . Hicksian welfare index is applied in the model to evaluate the household welfare as a result of CO_2 tax. However, the price index of the expenditure portfolio is stated in NCES form (Nested Constant Elasticity of Substitution). In future relations, the consumer products will be shown with subscript *con* and price *PD* while capital products will be shown with subscript *kgd* and price *PKGD*.

$$WELH\left[\left(1+Ctax_h\right)\left(\omega_{con}CPI^{1-\gamma}+\omega_{inv}PKGD^{1-\gamma}\right)^{\frac{1}{1-\gamma}}-PW\right]=0,$$

$$WELH\geq 0,\ \underbrace{\left(1+Ctax_h\right)\left(\omega_{con}CPI^{1-\gamma}+\omega_{inv}PKGD^{1-\gamma}\right)^{\frac{1}{1-\gamma}}}_{\text{CES unit expenditure function}}\geq \underbrace{PW}_{\text{ksian welfare price index}}$$

(3.78)

$$CPI=\left(\sum_g \omega_g PD_g^{\ 1-\sigma_h}\right)^{\frac{1}{1-\sigma_h}}$$

(3.79)

$$PKGD=\left(\sum_g \theta_{g,kgd} PD_g^{\ 1-\pi}\right)^{\frac{1}{1-\pi}}$$

(3.80)

3.6.2 Intermediate Goods' Demand

Demand and supply functions are derived using our assumptions about nested CES functional forms and optimizing behavior. Overall demand for a commodity is generally the sum of manufacturers' and households' demands. In current model, demand for intermediate good in any sector is a function of domestic price of good (PD), import price of good (PM), activity level of the sector (Z), substituted goods' price (θ) and the share of goods in cost (θ,ω). The initial demand is shown by $\overline{Q}$.

$$D_{j,s} = (1 - Ctax_s) Z_s \overline{Q}_{j,s} \theta_{j,s} \omega_{\text{int},s}$$

$$\theta_{j,s} = \left(\frac{P_{KLM,s}}{PINT_s} \right)^{\sigma_{klm,s}} \left(\frac{PINT_s}{PD_g} \right)^{\sigma_{\text{int},s}}$$

(3.81)

Consumption demand of households is a function of relative prices, income, elasticity parameters and share parameters.

$$CD_{g,h} = \frac{Y_h.\theta_g.W_{con}}{PW} \left(\frac{PW}{CPI} \right)^{\gamma} \left(\frac{CPI}{PD_g} \right)^{\sigma_h}$$

(3.82)

Where, w_{cons} is consumption level index, and income is income level. Finally, the households' capital demand for capital goods is a function of PD, purchasing power, and goods' share in investment expenditure portfolio.

$$ID_g = \frac{Y_h.\theta_{g.kgd}.W_{inv}}{PW} \left(\frac{PW}{PKGD} \right)^{\gamma} \left(\frac{PKGD}{PD_g} \right)^{\pi}$$

(3.83)

A government allocates its resources to governmental (public) expenditure (GOVEXP) and governmental (public) savings (GOVSAV). If the total revenue resources of a government are Y_g we will have:

$$Y_{gov} = GOVEXP - \sum_h TRN_{h,gov}$$

$$Y_{gov} = P_K.K_{gov} + TAX_M + TAX_S - TRN + CTAX$$

$$TAXM = \sum_g txm_g.QM_g.PM_g$$

$$TAXS = \sum_s txs_S.Q_S.PO_S$$

$$CTAX = \left(\sum_s Ctax_s Z_s.PO_g\right) + Ctax_h.CD_g.CPI_g$$

(3.84)

Where GOVEXP and TRN show current governmental expenditure and government's transferred payment to other institutes, respectively. TAX_S and TAS_M are tax of sectors and tax of imports, respectively. Considering nested structure, governmental expenditure can be explained by a MCP problem. WELGOV stands for government expenditure level.

$$WELGOV\left[\left(\sum_g K_g PD_g^{1-\sigma gov}\right)^{\frac{1}{1-\sigma gov}} - GPI\right] = 0$$

(3.85)

$$CD_{g,gov} = \frac{Y_{gov}.K_g}{GPI}\left(\frac{GPI}{PD_g}\right)^{\sigma_{gov}}$$

(3.86)

Where $\boldsymbol{CD_{g.gov}}$ is the government demand for goods and commodity g.

3.6.3 Import and Optimization Behavior

Generally, economic agents try to minimize the purchasing cost of goods and services. The goods and services can be supplied from domestic products or they can be imported. This model assumes that there is an imperfect substitution between domestic goods and services and imported ones. This assumption is stated within an Armington aggregating function.

$$\min PD_g.QD_g + PMg.QM_g$$

$$QTS_g = \left(\varphi_d^{1/\beta} QD_g^{\frac{\beta-1}{\beta}} + \varphi_m^{1/\beta} QM^{\frac{\beta-1}{\beta}}\right)^{\frac{\beta}{\beta-1}}$$

(3.87)

where PD is the price index of national supply of goods and PM is the price index of imported goods. QTS, QM and QD are total quantity national supply, total quantity of imported goods and total quantity of national supply of domestic goods, respectively. The subscript *m* implies imported goods while the subscript *d* implies national supply. Also, φ and β are the share parameter and the elasticity of substitution between imported and domestic goods respectively. Within this framework the imported goods' demand is :

$$QM_g = \varphi_{m,g} QTS_g \left(\frac{\left(\varphi_{d,g} PDg^{1-\beta} + \varphi_{m,g} PM_g^{\;1-\beta} \right)^{\frac{1}{1-\beta}}}{PM_g} \right)^{\beta}$$

$$PM_g = PFX.PFM_g$$

(3.88)

In the above relation, PFX is the foreign exchange rate and PFM is the global price of good g. This term implies that the import rate of a good decreases as the foreign exchange rate/global price of good increases. Note that the total demand of a good is the sum of demands obtained from institutes and different activities. Therefore, total demand and consequently importing level decreases as institutes' revenue and the activity of manufacturers increase.

3.6.4 Export and Optimization Behavior

In the next step, economic agents look for an optimal value for domestic supply and export. Domestic supply-export structure follows a CET (constant elasticity) functional form. In other words, it is assumed that a product is either supplied to domestic markets or exported. In this way, the manufacturers' problem is:

$$\max PD_g.QD_g + PXg.QX_g$$

$$QTS_g = \left(\varphi_d^{1/\lambda} QD_g^{\frac{\lambda-1}{\lambda}} + \varphi_m^{1/\lambda} QX^{\frac{\lambda-1}{\beta}} \right)^{\frac{\lambda}{\lambda-1}}$$

(3.89)

where PX, QX and QD are export price, total quantity of export and total quantity of national supply respectively. Also, λ and φ are elasticity parameter and share parameter, respectively. Therefore, the optimal export supply is:

$$QX = \theta_{x,g} QTS_g \left(\frac{\left(\theta_{d,g} PX_g^{1-\lambda} + \theta_{x,g} PD_g^{1-\lambda} \right)^{\frac{1}{1-\lambda}}}{PX_g} \right)^{\lambda}$$

$$PX_g = PFX.PXF_g$$

(3.90)

where PFX and PXF are foreign exchange rate and global price of export respectively.

3.6.5 Commodity Market Equilibrium Condition

Other supply and demand functions are obtained similar to export and import. In most CGE models, the market clearing conditions for good market, labor market, capital market, and foreign exchange market may be extracted from zero-profit conditions.

Market clearing conditions should be hold in every good and service category. Equilibrium condition of every good and service is stated by demand and supply parity. In other words, market equilibrium for good g is satisfied when in a given period of time the value of the good g supplied equals to the value of economic demand of it. Regarding domestic products, the supply is carried out by producer sections and the demand is the sum of domestic and export demands. The total supply of commodity g to the economy is:

$$QTO_g = QIM_g + QNO_g + \sum_s QFO_{g,s}$$

(3.91)

Where: QTA, QIM, QNO and QFO are the total supply of a good, total import quantity, the total quantity of inventory supply, and the total quantity of different activities' products respectively. However, a good is demanded by households, government, investors, foreign sector (export) and manufacturing activities. Thus, we total demand of the economy for commodity g is:

$$QTO_g = QP_g + QG_g + \sum_k QI_{k,g} + QX_g + \sum_s QF_{g,s}$$

(3.92)

where QP, QG, QI, QX and QF are the demand of private sectors' households, government demand, investors demand for forming a fixed capital, export and intermediate demand of enterprises, respectively. In the event of a equilibrium market of good g we have:

$$QIM_g + QNO_g + \sum_s QFO_{g,s} = QP_g + QG_g + \sum_k QI_{k,g} + QX_g + \sum_s QF_{g,s}$$

(3.93)

In the mentioned elements, demand and supply level are derived from optimization behavior of economic agents.

3.6.6 Equilibrium (Clearing) Condition in Markets for Factors of Production

Again, clearing condition has been considered in the market for factors of production. Therefore, the supply of a factor of production should be equal to its demand. Institutes are the owners and suppliers of factors of production. In contrast, manufacturing activities are the suppliants. Therefore, for each factor of production we have:

$$\sum_h QOE_{f,h} = \sum_s QFE_{f,s}$$

$$L_H = \sum_S Z_s.\overline{Q_s}.W_{kl,s}.\theta_{l,s}\left(\frac{PO_s}{PKL_s}\right)^{\sigma_{klm}}\left(\frac{PKL_s}{PL_s}\right)^{\sigma_{kl}}$$

$$K_H + K_{GOV} = \sum_S Z_s.\overline{Q_s}.W_{kl,s}.\theta_{k,s}\left(\frac{PO_s}{PKL_s}\right)^{\sigma_{klm}}\left(\frac{PKL_s}{PK_s}\right)^{\sigma_{kl}}$$

(3.94)

where QOE and QFE are the inventory of production factor *f* near household *h* and the demand of section s for the factor of production *f* respectively.

3.7 Casting the General equilibrium model into GAMS

In this section we briefly review two popular programming languages can be used in modeling general equilibrium problems. One is the GAMS which was originally developed by Alex Meeraues for solving linear, nonlinear and integer problems.(Rutherfrod,..). GAMS stand for "Generalized Algebraic Modeling System (GAMS)". It should be noted that, coding in GAMS environment is tedious and complicate procedure for modeler to correctly specify nonlinear equations into algebraic relations thus in the early 80s , Thomas Rutherford developed a higher level of GAMS language as painless way to reduce work of model formulation and programming errors as well as analyze complicated systems of nonlinear inequalities. He called it MPS/GE which stands “Mathematical Programming System for General Equilibrium”. This method allows modelers to focus on economics rather than coding.

MPS/GE specifically is designed to solve Arrow –Debreu economic equilibrium models. The format of this approach is based on *competitive equilibria* (Cretegny, L., et al., 2004).
MPS/GE use PATH solver which is an implementation of a stabilized Newton method for solving Mixed Complementary Problem (MCP). The MCP is a certain kind of mathematical problem and useful for expressing systems of nonlinear inequalities and equations that occur in many branch of science. The term mixed means that mathematical problem consists of equalities with unbounded variable as well as inequalities. The term of complementary refers to complementary slackness between system variables and system conditions (Rutherford and Sigrist 2010).
As a subsystem of GAMS, the MPSGE makes computable general equilibrium modeling accessible to any economists who wish to avoid complex nonlinear formulation.
The curvature of isoquant is determined by *s*, the elasticity of substitution between inputs (s:1 corresponds to a Cobb-Douglas production function). Default value for elasticity is zero.
In this research we used the MPSGE language to solve the nonlinear equations of Italy CEG model.

Chapter 4

4.1 The CGE model database: Social Accounting Matrices (SAM)

In this chapter we describe the data sources t that we used in building the model.

As stated earlier, the core of CGE model is macroeconomic data like social accounting matrix that gives a comprehensive economy-wide picture of the value of transactions in the circular flow of national income and spending in economy usually for one year.

A CGE models' database can be organized into a square matrix of data called a social Accounting Matrix (SAM) and really is nothing more than double-entry book keeping like input-output (I/O) table. A SAM is the integration of input-output table and national income accounts.

A SAM describes transactions between agents. Each agent in the economy has both a row account across the board and one column account down it, both identically numbered.

Therefore, each cell in SAM matrix describes the expenditure by agents' column account to the account of its row, where what is incoming into one account must be outgoing from another account. As a result the incomes of an account become visible along its row and its expenditure along its column. Column sum record each agents 'spending and row sum record its total income. A SAM is balanced when total spending is equal to the total income for every agent.

A balanced SAM database is mandatory condition for each CGE model in initial point because this equilibrium of model will be disturbed by shocks. Table 4-1 shows a standard macro SAM structure. (The material in this section draws heavily from Anguita and Wagner (2010).

Table 4-1 Standard macro SAM structure used in CGE model

	Activities	commodities	Factors	Enterprises	Households	Government	Capital	ROW	TOTAL
Activities		Sales			Home consumption				Total domestic production
commodities	Intermediate inputs	Marketing margins			Private consumption	Government consumption	Investment expenditures	Exports	Total marketed supply
Factors	Value added								Total factor income
Enterprises			Capital income			Transfers			Total enterprise income
Households			Lobar income	Retained earnings	Inter household transfers	Transfers		Remittances	Total household income
Government	Indirect taxes	Import tariffs		Corporate taxes	Income tax			Foreign grants	Total government income
Capital				Corporate saving	Household saving	Government saving		Foreign saving	Total saving
Rest of the world (ROW)		Imports.	Factor income paid to ROW	Enterprise income paid to ROW		Government income paid to ROW			Total foreign exchange outlays
TOTAL	Total cost of production	Total absorption	Total value added	Total enterprise expenditure	Total household expenditure	Total government expenditure	Total investment	Total foreign exchange earnings	

Table 4-2 Traditional SAM layout

Receipts	Industry	Factor	Institutions	Exports	Total
Industry	S_{11}	0	S_{13}	S_{14}	X_1^d
Factor	S_{21}	0	0	S_{24}	X_2^d
Institutions	S_{31}	S_{32}	S_{33}	S_{34}	X_3^d
Imports	S_{41}	S_{42}	S_{43}	S_{44}	X_4^d
Total	x^{sT}_1	x^{sT}_2	x^{sT}_3	x^{sT}_4	

Source: Anguita and Wagner (2010)

Matrices:

S_{11-} Intermediate transaction matrix ,S_{21-}Value added matrix,

S_{31-} sales taxes matrix, S_{41-} Imports

S_{32-} Distribution matrix, S_{42-} Factor imports

S_{13-}Final demand matrix,S_{33-} Transfer matrix, S_{43-}institutional import matrix

S_{14-} Industry export matrix,S_{24-} Factor export matrix, S_{34-} Institutional export matrix

S_{44-} Transshipment matrix

Column totals

x^{sT}_1-Total outlay or agents expenditures, x^{sT}_2-Total factor expenditures

x^{sT}_3-Total institution expenditures, x^{sT}_4-Total export

Row totals

x^d_1-Total industry output , x^d_2-Total factor income, x^d_3-total institutional income

x^d_4-total imports

4.1.1 Basic SAM accounts

Each SAM consists of four main accounts and can be described briefly as follows:

Industry accounts: the industry accounts describe the production processes that purchase intermediate inputs from the commodities account and also the services of primary factors and payments to the labor and capital that it employed. An activity account can be separated to subdivide by modeler. For example manufacturing activity can be disaggregated into pollutant and green sectors. The ith element of this vector is:

$$(x^d_1)_i = \sum_{g=1}^{4}\sum_{j}(S_{1g})_{ij}$$

4.1)

The row vector (total industry outlay) denotes the column sum of industry expenditure. The jth elements of this vector can be written as follows:

$$(x_1^{s^T})_i = \sum_{k=1}^{4} \sum_{i} (S_{k1})_{ij}$$

4.2)

Factor accounts: Factor consists of resource endowments of labor and capital which are used to combine with intermediate inputs for activity. Labor maybe divided into skilled and unskilled workers. Production activities pay wages and rent to labor and capital respectively, therefore the row sum represents total factor income. The ith element of this vector is:

$$(x_2^{d})_i = \sum_{g=1}^{4} \sum_{j} (S_{2g})_{ij}$$

4.3)

The row of this account denotes the column sum of factor expenditure and can be Expressed as:

$$(x_2^{s^T})_i = \sum_{k=1}^{4} \sum_{i} (S_{k2})_{ij}$$

4.4)

Institutions accounts: the institutional account comprises households, government, enterprises and capital investment. The row of this account denotes sum of institutional income. Mathematically:

$$(x_3^{d})_i = \sum_{g=1}^{4} \sum_{j} (S_{3g})_{ij}$$

4.5)

The sum of institution account records total institutional expenditures that can be defined mathematically:

$$(x_3^{s^T})_i = \sum_{k=1}^{4} \sum_{i} (S_{k3})_{ij}$$

4.6)

Rest of the world accounts: this account is comprised export and import that describes trade and investment flows between country and rest of the world (ROW). The column account reports total export or total trade receipts from the rest of the world, mathematically:

$$(x_4^d)_i = \sum_{g=1}^{4} \sum_{j} (S_{4g})_{ij}$$

4.7)

And row account reports total import which is gross payments to the rest of the world. The ith element of this vector is:

$$(x_4^{s^T})_i = \sum_{k=1}^{4} \sum_{i} (S_{k4})_{ij}$$

4.8)

As we discussed earlier in each account, total income equals total expenditure, that is: $x_k^d = x_k^{s^T} \; ; \forall k$

4.9)

And finally it should be noted that, the accounts included in SAMs can differ in dimension across CGE models.

4.1.2 SAM development

Table 4-3 illustrates the industry-by-industry SAM given in table4-2 based on an aggregation depicted by Thorbecke (1998). First we should distinguish between endogenous and exogenous expenditures, receipts accounts. It is possible to move household sector from final demand column and labor input row and make them exogenous in the table. This is known as closing model respect to households (Miller and Bliar, 2009) thus the endogenous account, S, is usually composed of the production,S_{11},factors S_{21} as well as household and institution accounts capturing the circular flow of production. The exogenous accounts usually is consists of the government, capital investment plus rest of the world. On the demand side we know that:

$$x_d = \left(I - S\hat{X}^{-1}\right)^{-1} f$$

4.10)

Where $\hat{X}$ is defined as a diagonal matrix whose diagonal elements are total outlays or total outputs. Assuming a small exogenous change ($denotes\ by\ \Delta$) in the final use vector Δf , the corresponding change in the output vector Δx_d can be obtained as follows:

$$\Delta x_d = \left(I - S\hat{X}^{-1}\right)^{-1}\Delta f$$

4.11)

Using equation (10) to predict the change in output Δx_d , given in change in final demand Δf. Endogenous account of aggregated industry-by-industry SAM can be shown as a subset of table4-2

Table 4-3 Endogenous accounts of aggregated industry

Receipts	**Industry**	**Expenditures factor**	**HH,Ent**
Industry	S_{11}	0	S_{13}
Factor	S_{21}	0	0
HH,Ent	S_{31}	S_{32}	S_{33}

Source: Anguita and Wagner (2010)

Then technical coefficient matrix,SX^{-1}, in equation (9) and (10) is given by equation (11).We can re-write as matrix form:

$$A = SX^{-1} = \begin{pmatrix} A_{11} & 0 & A_{13} \\ A_{21} & 0 & 0 \\ A_{31} & A_{31} & A_{33} \end{pmatrix}$$

4.12)

Equation (10) can be written using equation (11) as:

$$R_a = (I - A)^{-1}f = R_a f$$

4.13)

Where $R_a = (I - A)^{-1}$ denotes the SAM's total requirement matrix or multiplier matrix.

Waugh (1950) proposed the technique of a power series approximation[1] to the matrix inversion. The power series is:

$$(I - A)^{-1} = I + A + A^2 + A^3 + \cdots . A^K + \cdots . \qquad 4.14)$$

A satisfies certain conditions[2] that are usually met in input output table .Inserting equation (13) into (10), we obtain:

$$\Delta x_d = (I - A + A^2 + A^3 + \cdots . A^k)\Delta f \qquad 4.15)$$

Removing parentheses, this is :

$$\Delta x_d = \Delta f + A\Delta f + A^2\Delta f + A^3\Delta f + \cdots . A^k\Delta f \qquad 4.16)$$

From equation (15) we can see that, the effect of an exogenous change in final demand vectors, this cause an initial effect of the same amount on output vector (Δf).

Suppose Δf is related to industry j, it means there is demand from industry j to other sectors whose outputs are employed as intermediate goods in sector j (direct effect) but those new inputs also requires intermediate consumption of additional inputs (indirect effects). As direct and indirect industrial effects are initiated firms pay wages to labor service who, in turn, spend some part of the income to buy locally produced goods and services which drive the induced effect (found from a model that is closed with respect to households). The sum direct, indirect and induced effects are often called total effects.

Equation (15) indicates that, when exponent increase, the corresponding effect decrease, which means that each time the latter indirect effects calculating less that in the previous indirect effects. By applying Multiplier we are able to estimate the overall change in the economy due to changes in final demand that will be discussed in the next section.

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[1] The algorithm is approximated because we cannot sum the whole power series.

[2] A is non-negative, productive and (I-A) is singular (all eigenvalues of matrix A < | 1 |)

4.2 I/O and SAM multiplier

In this section we are going to present the most important results concerning multipliers in Italy. SAM multiplier analysis provide a strong tool for economic analysis and enables to estimate the macroeconomic policies effects of initial exogenous shocks for example change in final demand like increase in households consumption on the whole of economic system. Similar to macroeconomic (Keynesian) multipliers, I/O multiplier and SAM multiplier provide a technique to describe properly economic policy impacts on different sectors. Multipliers are basically a ratio of total impacts to initial impacts (Anguita and Wagner, 2010).In fact, multiplier coefficients are able to determine which sectors have the greatest effects on economic activity and which, the smallest. Miller and Blair (2009) contend that one of the main applications of I/O and SAM is to answer the question on how a given economic sector will respond to impulse changes in elements that are exogenous to the model.

Input output multiplier focuses on inter industry transactions so it is “open model” whereas “closed model” like SAM based model are able to include consumption linkage as well. The accounts in SAM are categorized into two accounts; endogenous accounts like: primary factors, households, production activities, and exogenous account. The endogenous accounts are consumption transactions, which involve households, enterprise, and government institutions; and they give us some useful information about household income, consumption as well as income distribution.

Computable general equilibrium (CGE) models also help policy maker to assess the policy effects on the economy among different agents within an economic system. The core of CGE models database is SAM, thus the question that may arise here is; what is difference between SAM based analysis and computable general equilibrium analysis? The short answer is whilst multiplier models are fixed price models; CGE models are flexible price models.

There are two general types of multipliers in I / O models. Types of multipliers that depend on how other variables in the model are treated .Type I or simple multiplier is defined as direct and indirect effects that are derived from open I/O table whereas type II or total multipliers are derived from closed I/O table by considering direct and indirect effects plus induced effects. The total effects can be defined in open I/O model as the direct plus indirect, and in closed I/O model as the direct plus indirect plus induced effects.

By reffering to the equation (12) the jth sector’s SAM accounting multiplier $\mathrm{SAM}^{(\mathrm{AM})}$ is calculated summing the columns of the accounting multiplier matrix, $\mathrm{R}_{\mathrm{aij}}$:

$\text{SAM}_j^{(AM)} = \sum_j (R_a)_{ij} \;_{;\text{for all } j}$

4.17)

Where R_a demotes an element of SAM's accounting multiplier matrix. Thus a SAM accounting multiplier is calculated for each industrial activity, primary factor of production, household, and enterprises.

4.3 Data

As noted already, the critical data that determine the structure of a CGE model are contained in Social Accounting Matrices (SAMs). The data for the modeling were derived from the worldwide input–output (IO) tables and trade database prepared by the Global Trade Analysis Project (GTAP). Also at this part, a brief description is presented to illustrate how to transform the data from the GTAP database (73× 73) into a SAM (16×16). In the Italy SAM, in order to facilitate the analysis and interpretations of simulation results, 57 activities accounts are aggregated into five activity accounts including: i) Agriculture and mining, ii) Manufacturing iii) Utility and construction, iv) Transportation and communication, v) Services

Table 4-4 Concordnace between GTAP, WIOD and author aggregation code

GTAP classification	WIOD	Author aggregation
paddy rice, wheat, cereal grains , vegetables, fruit, nuts, oil seeds sugar cane, sugar beet, plant-based fibers, crops, cattle, sheep, horses animal products, raw milk, wool, silk-worm cocoons.	C1	Agriculture and mining (1)
forestry, fishing, coal, oil, gas, minerals.	C2	
meat: cattle, sheep, goats, horse, meat products , vegetable oils and fats, dairy products, processed rice, sugar, food products , beverages and tobacco products, textiles, wearing apparel, leather products, wood products, paper products, publishing, petroleum, coal products, chemical, rubber, plastic prods, mineral products , ferrous metals, metals , metal products, motor vehicles and parts, transport equipment , electronic equipment, machinery and equipment , manufactures .	C3-C16	Manufacturing (2)
electricity, gas manufacture, distribution, water, construction	C17+C18	Utility and
trade, transport , sea transport, air transport, communication	C19-C27	Transportation and communication (4)
financial services , insurance, business services, recreation and other services, public administration/defense/health/educate, dwellings	C28-C35	Services (5)
skilled labor, unskilled labor	------	Labor
capital, land, resources	------	Capital

Similar aggregation follows in the commodity accounts, also five production factors are aggregated into two factors-labor and capital; and one household type. Table 4-5 shows the summary of this aggregation and presents Italy's macro SAM in reference year 2004.

Table 4-5 Italy's SAM 2004

			Activities					Commodities					Factors								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1-Agriculture	0	0	0	0	0	69009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69009
2-Manufacturing	0	0	0	0	0	0	1098028	0	0	0	0	0	0	0	0	0	0	0	0	0	1098028
3-Utility & Construction	0	0	0	0	0	0	0	239574	0	0	0	0	0	0	0	0	0	0	0	0	239574
4-Transportation & Communication	0	0	0	0	0	0	0	0	541460	0	0	0	0	0	0	0	0	0	0	0	541460
5-Services	0	0	0	0	0	0	0	0	0	973501	0	0	0	0	0	0	0	0	0	0	973501
6-Agriculture	4971	68773	5489	910	5164	0	0	0	0	0	0	0	0	0	25889	310	228	5574	0	0	117308
7-Manufacturing	10535	458952	66489	49597	70875	0	0	0	0	0	0	0	0	0	293450	456	130029	312799	0	0	1393183
8-Utility & Construction	1207	24420	10166	11872	29976	0	0	0	0	0	0	0	0	0	15001	105	151134	2103	0	0	245984
9-Transportation & Communication	3745	126243	14921	67585	40634	0	0	0	0	0	0	0	0	0	255181	1125	25004	32588	0	7216	574243
10-Services	2987	83729	16917	71390	117872	0	0	0	0	0	0	0	0	0	344127	328179	7361	37068	0	0	1009631
11-Labour	20597	115792	38522	84811	259706	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	519429
12-Capital	23827	153622	65047	230000	319062	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	791559
13-Tax	1139	66497	22023	25295	130210	665	2997	0	0	0	196889	53881	0	0	97988	0	20017	0	0	0	617602
14-Regional household	0	0	0	0	0	0	0	0	0	0	322540	535683	617602	0	0	0	0	0	0	0	1475825
15-Household	0	0	0	0	0	0	0	0	0	0	0	0	0	1031638	0	0	0	0	0	0	1031638
16-Government	0	0	0	0	0	0	0	0	0	0	0	0	0	330175	0	0	0	0	0	0	330175
17-Investment	0	0	0	0	0	0	0	0	0	0	0	201995	0	114012	0	0	0	0	0	0	333773
18-Rest of the world	0	0	0	0	0	44743	283867	6410	32782	36130	0	0	0		0	0	0	13801	0	3966	403933
19-Margin Import	0	0	0	0	0	2891	8291	0	0	0	0	0	0		0	0	0	0	0	0	11181
20-Margin Export	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	11181	0	11181
Total	69009	1098028	239574	541460	973501	117308	1393183	245984	574243	1009631	519429	791559	617602	1475825	1031638	330175	333773	403933	11181	11181	11788216

Source: GTAP, Constructed by author

4.4 Microeconomic and Macroeconomic data in a SAM

SAM's microeconomic data consists of all information about economic agents in detail. For example data on production reports the amount spent by each sector on each type of primary factors as well as each tax. The expenditure of each agent on each type of goods is described by domestic demand.

A SAM database presents some of the macroeconomic indicators in the row sum and column sum place. For example the column sum of rest of the world report total export of goods and services.

In the following, some of Italy' key macroeconomic indicators will be calculated. All accounts are in million of US dollar.

4.4.1 Italy's Gross Domestic Products for 2004

The section of this research explains some economy key indicators and how they are measured. Let us begin with gross domestic product. We calculated Italy's GDP using data from the Italian SAM which is shown in table 4-5. GDP could be calculated both in income and expenditure side.

GDP from the income side is shown by the following relation:

GDP=Factor income +Tax revenue = 1.060.788+617.032=1.677.820 Million of US dollar or 1.6 77 Trillion of US dollar.

Also, GDP from expenditure side is introduced by the following equation:

GDP= Total private consumption+ total investment expenditure+ total government expenditure+ total export- total import

Thus Italy's GDP from the expenditure side is:

1.031.638+333.773+330.175+397.348-415.114=1.677.820

Some SAM may have accounts for 300 or more sectors in economy and more than 5 primary factors; thus to fully understand and not to lose the detailed information for such large economy dimension becomes more challenging and complex.

In order to get an overview of an economy without skipping detailed information, a modeler can construct a "structure table" (Burfisher 2011) to describe the economy in terms of shares. This approach will enable the modeler to identify most important parts of the economy.

Tables 4-6, 4-7, 4-8 and 4-9 show the structure table for Italy's economy in 2004. All data are adjusted for rounding

Table 4-6 Structure table –Factor cost shares

	Industry shares in GDP	Factor shares in industry factor costs	
		Labor	Capital
Agriculture & mining	3%	63%	37%
Manufacturing	23%	51%	49%
Utility & construction	8.5%	45%	55%
Transportation & communication	21.5%	34%	66%
Services	44%	53%	47%

Source : GTAP and author calculations

Table 4-7 Structure table-Industry shares in factor employment

	Factor shares in industry factor employment	
	Labor	Capital
Agriculture & mining	4%	2%
Manufacturing	22%	20%
Utility & construction	7%	8%
Transportation & communication	16%	29%
Services	50%	41%

Source : GTAP and author calculations

Table 4-8 Structure tabel- Commodity shares in domestic demand and trade

	Commodity Shares in:					
	Domestic Demand				Trade	
	Intermediate Demand	Private Household Consum.	Government Consump.	Investment Demand	Ex	Im
Agriculture & mining	21%	3%	0%	0%	1%	11%
Manufacturing	49%	33%	0%	41%	79%	70%
Utility & construction	5%	2%	0%	48%	0%	2%
Transportation & communication	15%	26%	0%	8%	10%	8%
Services	10%	36%	100%	3%	9%	9%

Source: GTAP and author calculations

Table 4-6 a shows that services share in GDP is the most important sector in the economy, thus it would be logical that any change in the services share will have greater effect on the economy as compared to the rest of the sectors. For example any policy shock in agricultural sector would not have significant effects on Italian economy.

Moreover, table 6a clearly show that about 44% of GDP and 50% labor and 41% of capital employment are related to service account thus Italy has relatively service economy. Also agriculture sector is labor intensive whereas transportation and communication sector are absolutely capital intensive.

Table 4-7 shows about 50% of Italy's labor employed in service sector so any change in this sector would likely have a larger impact on national employment and wages.

Let's take a look at briefly into tax issue in the SAM. By following Burfisher (2011) we classified tax into five broad types as follows:

- *"Trade taxes are levied on imports and exports.*
- *Production taxes are paid by production activities based on their output.*
- *Sales taxes are paid by domestic firms on their intermediate input purchase, and by consumer and investors on their purchase of final goods and services.*

- *Factor use taxes are paid by production activities based on their factor inputs.*
- *Income taxes are paid by factors or households based on income earned from wages and rents".*

For each of the five taxes, we can find the relevant data in the SAM, and then calculate those taxes by the following relations:

Trade taxes for imports for example can be defined as: import tariff / (trade margin import + import)

Production taxes can be expressed as: production tax / gross value of production

Sales taxes can be shown by: commodity sales tax / pretax value of commodity purchase

And finally factor use taxes can be written as: factor tax / pretax factor payment

It is useful for tax policy maker to review the tax data in SAM. We start to extend structure table by calculating and adding Italy's taxes data. Table 4-9 reports the various tax and tariff rates in Italian economy. It should be noted that, table 4-5 shows Italy SAM which is aggregated, thus some of the relevant data can be traced in disaggregated SAM.

Table 4-9 Tax structural table

	Tax Rate				
	Import Tariff	**Export Tax**	**Production Tax**	**Sales Tax**	**Factor use Tax**
Agriculture & mining	1.4%	-0.02%	-2.3%	18%	4.1%
Manufacturing	1%	0%	0.4%	14.8%	18.2%
Utility & construction	0%	0%	2.2%	47.1%	15.9%
Transportation & communication	0%	0%	-5.3%	7.2%	11.7%
Services	0%	0%	1.8%	7.1%	19%

Source : GTAP and author calculations

From table 4-9 we can see that, the Italy's import tariff rates are highest on agriculture products (1.4%) then manufacturing goods (1%) and zero for rest of them. It should be noted that, tax can be negative (i.e., subsidies) like production tax on agriculture (-2.3%) and transportation (-5.3%) sector.

4.5 The analysis of I/O and SAM multipliers

A comparison of closed and open model in Table 4-10 and 4-11shows that the type II multipliers are bigger in magnitude from the type I multipliers. The reason is that, type II multipliers include the induced effects due to change in household expenditures earned from direct and indirect effects. Table4-10 highlights the estimated I/O and SAM multipliers for output and income in Italy's economy. By summing the columns of the SAM total requirement matrix we can calculate SAM accounting multipliers which is calculated for industrial activity, production factors and household (table4-12). In simple terms the higher the multiplier, the stronger its ability to create multiple impacts in the economy. Type I output/ output and type II output/ output multiplier are found by summing the jth column of the open and closed Leontief inverse matrix respectively. Output/output multiplier gives us information that one unit of for example, dollar or industry's output will generate a dollar worth of additional output in the economy.

Among the 5 major sectors, the Manufacturing Industry yields the largest output/output multiplier of 2.51$ in closed models, 3.04$ in open model and 4.48 $ in SAM based model. In other words for every 1.00$ sale in manufacturing sector for example, total revenue generated by 2.51$, 3.04$ and 4.48 $ in open closed and SAM based model respectively. The utility and construction sector as well as agriculture sector constitute the second and third most important output generating industries with all multipliers respectively. From the other side, a change in output of the sectors will generate additional income to household. In order to quantify the impact of change in each sector's output on household, income multiplier is needed. Agriculture sector is found to be the most important income generating sector with the highest income multiplier of 0.38 in open model, 0.53 in closed model and 0.80 in SAM based model.

Table 4-10 Type I multipliers in open model

		AGR	MFG	Utilcons	Transpocom	Services
Type I	**Output/Output**	1.70	2.51	2.03	1.69	1.51
	Income/Output	0.38	0.27	0.27	0.26	0.34
	Income/Income	1.27	2.52	1.70	1.63	1.28

Table 4-11 Type II multipliers in closed model

	-	AGR	MFG	Utilcons	Transpocom	Services	HH
Type II	**Output/Output**	2.34	3.04	2.53	2.12	2.06	1.55
	Income/Output	0.53	0.43	0.41	0.35	0.46	-
	Income/Income	1.78	4.10	2.54	2.25	1.71	-

Source: GTAP and author calculations

Table 4-12 SAM multipliers

		AGR	MFG	Utilcon	Transpocom	Ser.	Labor	Capital	HH
SAM	**Accounting**	7.33	7.62	7.15	7.32	6.47	4.91	6.87	6.30
	Output/Output	3.87	4.48	4.01	3.86	3.42	-	-	-
	Income/Output	0.80	0.69	0.67	0.66	0.70	-	-	-
	Value added/Output	1.92	1.73	1.73	1.89	1.69	-	-	-
	Income/Income	2.68	6.52	4.16	4.23	2.61	-	-	-

Income / income multiplier estimate the total income effect due to the change in wage income. The type I income / income multiplier defines as the ratio of the direct plus indirect income effects to the direct alone (Moore and Petersen 1955) and type II is a ratio of direct plus indirect plus induced effects to direct effect (Anugita and Wagner,2010). According to the table 4-10, when the manufacturing sector realizes a 1.00 $ change in income, the total income will change by 2.52 $ and 4.10 $ in open and closed model respectively. SAM value added/ output multiplier shows the value added generated for the economy that results from the increase final demand a particular sector output. Table 4-12 reports agriculture and mining have highest value added/ output multiplier among the five major sectors. Table 4-12 summarized all information regarding multipliers in each sector.

It should be noted that, SAM income /output, SAM value added/output and SAM income/income multiplies are calculated for only industry accounts and illustrated on table 4-12.

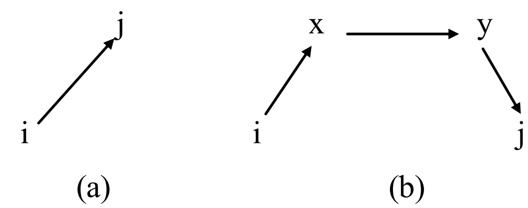
"The multiplier analysis is useful when interest lies in estimating the impact of changes in final demand but ignores the role of supply" (Gravino, 2012). In the next section we are going to discuss about the linkages in economy

4.6 Backward and Forward linkage analysis

In input output table, industrial sectors are dependent on each other because they need input from other sectors in their production process. Any particular sector has two kinds of effects on its downstream and upstream sector.

For better understanding suppose sector j is affected by sector i; this effect could be direct i-j (a) or indirect (b) by other sectors like x and y (i-x-y-j).

Figure 4-1 Direct and indirect sector linkage



Based on input output model, when sector j increases its output, it means there is demand from sector j to other sectors whose outputs are employed as intermediate goods in sector j. In input output literature, this demand from upstream sectors is called backward linkage or input provision that can be expressed by the following ratio:

Backward linkage = $\frac{Value\ of\ total\ intermediate\ inputs\ for\ sector\ j}{value\ of\ j' s\ total\ output}$

4.18)

Direct effect in backward linkage is given by the sum of jth column in technical coefficient matrix. According to Chenery and Watanabe (1958) the strength of backward linkage can be expressed by the following relation:

$BL(d)_j = \sum_i^n a_{ij}$)

4.19)

It should be noted that simple backward linkage is equal with simple output multiplier in open input output model. According to Rasmussen (1957) total backward linkage for sector j is the column sum of the jth Leontief matrix. $(I - A)^{-1}$.

$$BL(t)_j = \sum_i^n l_{ij}$$

4.20)

Where l_{ij} is the ijth element of Leontief inverse matrix.

Also, he proposed the following relationship for normalization of backward linkage and called it power dispersion index:

$$\overline{BL(d)}_j = \frac{BL(d)_j}{\frac{1}{n}\sum_j^n BL(d)_j} = \frac{\sum_{i=1}^n a_{ij}}{1/n\ \sum_{j=1}^n aij \sum_{i=1}^n aij}$$

4.21)

Where the numerator of fraction is j's backward linkage and denominator is average of all backward linkage. A sector with high backward linkages means that expansion of its production is more beneficial to the economy than other sectors. From the other side, forward linkage addresses the relationship between a sector and its lower sectors that are using its products.

Forward linkage = $\frac{Value\ of\ total\ intermediate\ sales\ by\ sector\ i}{valuse\ of\ i's\ total\ output}$

4.22)

This linkage was first proposed by Chenery and Watanabe (1958).Forward linkage can be expressed as follows:

$$FL(d)_j = \sum_{j}^{n} b_{ij}$$

4.23)

b_{ij} is output generated in sector j if total outlays of sector i are increased by one unit
Beyers (1976) and Jones (1976) suggested the Ghosh method is more appropriate for direct forward linkage and in consequence, b_{ij} is row sum of Ghosh matrix.
In addition, the strength of total forward linkage can be calculated by the row sum of Ghosh inverse matrix that is $(I-B)^{-1.}$

$$FL(t)_j = \sum_{i}^{n} g_{ij}$$

4.24)

Where g_{ij} is the ijth element of Ghosh inverse matrix.

The parallel to equation 4.21 power dispersion index of forward linkage is computed as:

$$\overline{FL(d)}_j = \frac{FL(d)_j}{\frac{1}{n}\sum_j^n FL(d)_j} = \frac{\sum_{j=1}^n b_{ij}}{1/n \sum_{j=1}^n bij \sum_{i=1}^n bij}$$

4.25)

Where the numerator of fraction is i's forward linkage and denominator is average of all forward linkages.

4.6.1 Classifying Backward and Forward Linkage Results

The normalized values of forward and backward linkages of five main sectors in the economy of Italy are collected in table4-13. In case on normalized backward linkage (either direct or total) two strongest (above average) are manufacturing and utility & construction in that order. The two strongest (above average) forward linkages (either direct or total) are agriculture & mining and manufacturing sector in that order. The results are arranged in tables 4-13, 4-14.

By calculating normalized form of backward and forward linkage, we are able to identify the most important sectors in economy. Any sector, which has both backward and forward linkage indicators greater than one is classified as a key sector and play an important role in the development strategy of country. Linkage indicators for all sectors [1] are classified into four zones that are summarized in table 2 × 2 below.

[1] (1) : Agriculture and mining, (2): Manufacturing, (3): Utility and construction, (4): Transportation and communication , (5): Services

Table 4-13 Classification of backward and forward linkage

		Direct or total Forward linkage	
		Low(<1)	High(>1)
Direct or Total Backward Linkage	Low(<1)	(I) generally independent **(4,5)**	(II)dependent on interindustry demand **(1)**
	High(>1)	(IV) dependent on Interindustry supply **(3)**	(III) generally dependent **(2)**

Source: Miller and Blair (2009) and author calculation

Table 4-14 Linkage results, Italy 2004 data

	Sector	$BL(d)$	$BL(t)$	$\overline{BL(d)}$	$\overline{BL(t)}$	$FL(d)$	$FL(t)$	$\overline{FL(d)}$	$\overline{FL(t)}$
1	AGR (1)	0.34	1.70	0.79	0.90	1.24	3.81	2.11	1.70
2	MFG (2)	0.69	2.51	1.61	1.33	0.60	2.28	1.02	1.01
3	Utilcon (3)	0.48	2.03	1.10	1.08	0.32	1.61	0.55	0.72
4	Transpocom (4)	0.37	1.69	0.86	0.89	0.47	1.96	0.80	0.87
5	Serv. (5)	0.27	1.51	0.63	0.80	0.30	1.57	0.51	0.70

Source: Miller and Blair (2009) and author calculation

The value of the linkages are calculated for Italy's economy and summarized in table 4-14. We realized that sector (2) that is manufacturing is the key sector among Italy's industries that need special attention by the policy maker in the country. Other dependency indicators ranking are also shown.

4.7 Summary of SAM and Italy's SAM analysis

The social accounting Matrix provides a systematic framework for modeling the circular Income-output flow of a region's economy (Thorbecke 1985). In addition the most common feature of compiling this database is to provide a predictive tool for estimating policy impacts for multi-industry/multi-sectoral through the application the SAM-multipliers (Ciaschini and Socci 2006).

The matrix structure provides useful information about the foundation of Italy's economy. A SAM data consist of all information about economic both in macro and micro level. At this paper some of Italy's key macroeconomic indicator as well as "structure table" in order to identify most important part of economy are calculated and reported.

I/O multiplier and SAM multiplier provide a technique to analysis properly policy issues impacts on different sectors of economy. In fact, multiplier coefficients are able to determine which sectors have the greatest effects on economic activity and which the smallest. Among the 5 major sectors, the Manufacturing Industry yields the largest output/ output multiplier in closed, open and SAM models.

Regarding the linkages effects between sectors, the largest forward linkage is found for agriculture followed by other sectors, manufacturing, transportation & communication utility& construction, services; While the largest backward linkage is for the manufacturing and smallest for services. Manufacturing sector had both normalized backward and forward linkage greater than one so this sector is the key sector among Italy's industries in 2004.

The present work enables policy makers to make rational decision to gain better results by supporting and protecting- subside or decreasing tax-key sectors in the economy. However we aware that our approach may have some limitations like fixed input output coefficient, fixed technology which are extremely important thus our results need to be interpreted and used cautiously. Our recommendation for future study would therefore be modeling like computable general equilibrium (CGE) model that capture the supply and demand relationships between

A variety of economic agents and institutions with prices that providing the common flow of information to coordinate the system.

Chapter 5

"The greatest enemy of knowledge is not ignorance, it is illusion of knowledge".

Daniel J.Boorstin

5.1 Model Simulation and Results analysis

Generated results from a numerical simulation model are discussed at this chapter. It should be noted that, there are always doubts on reliability of simulation results due to depending to the some specific assumptions that might not be exactly true.

The simulations accomplished are based on year 2004 Social Accounting Matrix of the Italian economy where the original 57 production sectors are aggregated into five sectors. The sectors are: (1) agriculture and mining, (2) manufacturing, (3) utility and construction (4) transportation and communication, and (5) services.

The model is calibrated to obtain the actual baseline solution. As we mentioned in chapter 3 Calibration process is selecting parameter values in such a way that once the model is replicated benchmark data with these parameter values and equilibrium is computed.

The next step is exogenous variable which is carbon tax parameter should be changed in simulation phase under different scenarios to compute new equilibrium (new policy equilibrium).

To test the model, we conduct two scenarios. Scenario 1 examines the impact of carbon tax without revenue recycling. This scenario is implemented with the carbon tax imposed on domestic products. Implementation of this scenario would allow us to see the possible impact of carbon tax on reduction of CO2 emission and on various economic variables such as domestic production, exports, imports, private consumption, and GDP. The tax policy scenarios that we examine include the adoption of 5,10,20,50 and 100 dollar the use of energy products. The other relevant scenario for the revenue-recycling mechanism is to give a uniform lump-sum transfer to all households.

Scenario 2 simulates the combined effect of imposition of carbon tax and the revenue generated from CO2 tax recycled back to consumers to compensate tax pressure on the economy. This scenario is simulated see the impact of carbon tax on the macroeconomic and environmental variables in the Italian economy.

5.1.1 Independent carbon tax scenario

A summary of the simulation results appear in table5-1 which shows the impact of carbon tax on carbon emission and effects on macroeconomic variables. It should be noted that the effects of the carbon tax presented are for the short run. In the long run substitution will occur by shifting resources from energy intensive technologies to less energy intensive technologies also carbon tax imposition may increase fossil fuels price and encourage energy intensive industries for energy efficiency and will lead to energy saving. (Wang, J., et al. 2009).

Our results show that imposing a carbon tax will leads to a reduction in GDP. For the first level of nested Cobb- Douglas production function the carbon tax of 5 $/tCO2, 10$/tCO2, 20$/tCO2, 50/tCO2 and100$ /tCO2, the real GDP reduces by 0.02%, 0.03%, 0.07%, 0.20% and 0.40 % respectively. But the amount of the reduction is relatively lower than energy reduction and CO2 emissions. For example, a carbon tax 100$/tCO2 results in 0.40% GDP loss, but CO2 emissions are reduced by 5%. The causation is as follows: Carbon tax imposes restriction on the use of fossil energy as an intermediate input in production process and, with decline in the primary factor utilization therefore there is a reduction in GDP compared to baseline situation.

Introduction of carbon tax will change positively all the prices level for example A 20 $ tax would result in 0.10 percent increase in the consumer price index.

The simulation results also show that carbon tax has adverse effect on household consumption (Income effect) and welfare. The tax of 5 $/tCO2, 10$/tCO2, 20$/tCO2, 50$ /tCO2 and100$ /tCO2, the household consumption reduces by 0.10%, 0.30%, 0.60%, 1.40% and 2.7 0 % from the benchmark respectively.

It can be seen from 5-1 the impact of carbon tax would be different for government income.

However, a carbon tax raises government income with amount of 5 $/tCO2, 10$/tCO2, 20$/tC, 50/tCO2 and100$ /tCO2 increasing government income by 0.40%, 0.90%, 1.80%, 4.40% and 8.50% from the benchmark respectively. A 20$ carbon tax would result 7.455 million us dollar revenue to the government.

Carbon tax has a negative impact on agriculture, manufacturing, transportation, communication and services import while positive impact on utility and construction import. The highest impact is related to the agriculture, transportation and communication sectors while it is smaller for manufacturing and services.

Table 5-1 Percentage changes of macroeconomic variables , energy usage and CO2 emissions under different tax rate Cobb Douglas production function (S:1)

Carbon Tax Dollar/Tone	0	5	10	20	50	100
GDP	0%	-0.02%	-0.03%	-0.07%	-0.20%	-0.40%
Household consumption	0%	-0.10%	-0.30%	-0.60%	-1.40%	-2.70%
Government consumption	0%	0.40%	0.90%	1.80%	4.40%	8.50%
Import Agriculture	0%	-0.20%	-0.50%	-0.90%	-2.20%	-4.30%
Import Manufacturing	0%	-0.10%	-0.30%	-0.60%	-1.40%	-2.80%
Import Utility & construction	0%	0.40%	0.80%	1.60%	3.90%	7.70%
Import Transportation & communication	0%	-0.20%	-0.50%	-0.90%	-2.20%	-4.40%
Import Services	0%	-0.10%	-0.20%	-0.50%	-1.30%	-2.60%
Export Agriculture	0%	-0.20%	-0.40%	-0.70%	-1.80%	-3.50%
Export Manufacturing	0%	-0.20%	-0.40%	-0.80%	-2.00%	-4.00%
Export Utility & construction	0%	-0.70%	-1.40%	-2.90%	-6.90%	-13.20%
Export Transportation & communication	0%	-0.10%	-0.20%	-0.40%	-1.00%	-1.90%
Export Services	0%	0.20%	0.40%	0.80%	1.90%	3.70%
CO2 emissions (kt)	0	-1063	-2120	-4216	-10355	-20120
Energy Consumption	0%	-0.30%	-0.50%	-1.10%	-2.60%	-5.00%

This decline of imports could be due to increased prices of imports relative to domestic prices.

Export of agriculture, manufacturing, transportation, communication as well as utility and construction are negatively influenced by carbon tax whereas this impact is positive for services sector. Utility and construction sector is influenced substantially by carbon tax among other sectors.

Simulation results on energy consumption under different scenarios are shown in table5-1 as well. There is a clear decline in CO2 emissions and energy consumption under carbon tax policy.

Total CO2 emissions in CES nested production function are predicted to be 1239,2471,4909,12033 and 23255 kilo tone under carbon tax rates of 5, 10, 20 ,50 and 100 dollar per ton CO2 respectively. In the simulations, the carbon taxes have particularly influenced energy use. Energy was reduced by 0.30%, 0.60%, 1.20%, 3.0% and 5.9% lower than baseline scenario under tax rates which is mentioned above.

Naturally, a carbon tax is a cost to producer thus imposing such tax will leads to increase in energy price consequently, the production sectors will negatively affected, more significantly for sectors whose emission intensity is high. The magnitude of which depends mainly on their carbon content in inputs and outputs. The loss in output of goods and services is referred to as the distortionary impact of "deadweight loss".

The detailed supply impacts of the carbon tax scenario are presented in Table5-2.

From tables, it can be apparently seen that the production of all sectors except services decrease, also the energy production sectors will be most impacted. Basically, introducing carbon tax raises government income and governmental expenditures go toward general public services like education, healthcares, security and so on, for this reason services sector get benefit from carbon tax. Utility and construction sector which experience a significant decline in output is relatively both energy and emissions intensive. The manufacturing, agriculture, transportation and communication sectors constitute the second, third and fourth rank in terms of both energy intensity and reduction in their products due to carbon tax.

Table 5-2 Percentage changes of supply (production) under different tax rate Cobb-Douglas production function (S:1)

Carbon Tax Dollar/	0	5	10	20	50	100
Agriculture	0%	-0.2%	-0.4%	-0.8%	-1.9%	-3.7%
Manufacturing	0%	-0.2%	-0.4%	-0.8%	-1.9%	-3.8%
Utility & construction	0%	-0.4%	-0.9%	-1.8%	-1.4%	-8.4%
Transportation & communication	0%	-0.1%	-0.3%	-0.5%	-1.3%	-2.5%
Services	0%	0.1%	0.2%	0.5%	1.1%	2.2%

Change in the carbon taxes leads to substitution and scale effects in the energy intensive sectors to modify their consumption pattern in fossil fuels against other input. Energy intensive sectors in Sweden, Finland and Slovenia use hydropower and nuclear energy power consequently they are less sensitive to carbon energy taxes (Andersen, 2010).However, switching to use of alternative fuels as a result of carbon tax on input prices, would also depend on whether markets are local or international.

5.2 Sensitivity analysis

The calibration of computable general equilibrium model and simulation results are conditional on many assumptions also may be sensitive to the parameter values chosen. For example correctness of the exogenous elasticities that applied to calibration is one such

assumption. Those elasticities may be obtained from "coffee table conversation" (i.e., expert opinion) as arbitrary values or econometrics techniques (Harrison and Vinod, 1992). Clearly, the simulation results may have highly influenced by the choice of values of the parameters.
At this research, in order to calculate values of coefficients we employ specific calculation method called "calibration". Calibration technique allows us to compute values of coefficients based on one period of data on the SAM thus it is impossible to test calibrated values with statistical techniques. This is usually due to; we have limited available data as well as large number of coefficient and variables to estimate so this leads to insufficient degree of freedom if we apply econometric techniques. This can be advantage of calibration methods compared with econometrics techniques.

Some parameters including the share parameters, transform coefficients in all CES and CET functions are obtained from SAM and some other parameters whose values cannot be calibrated by SAM like elasticity substitution in all CES production function and Armington function are then obtained from search of literature.

The elasticity between imported products and domestic supply (Armington function) is set equal to 4 following Wissema and Delink (2006).

Ferrari and Manca (2008) estimates CES production function using Generalized Maximum entropy (GME) method based on a Regional Environmentally Extended SAM (RESAM) for Sardinia 2001, Italy. They conclude elasticity substitution between value added and intermediate goods with 12 sectors lie within range 0.345 and 0.483 thus CES nested production function for Italy should employ instead of the Cobb-Douglass function which considers that substitution elasticity between value added and intermediate goods may not be equal to one. Therefore, the simulation results in table 5-3 and 5-5 would be more close to Italian economy.

However CGE models and calibration method has been widely criticized because modelers are not able to test the robustness of the estimated parameter as well as lack of the model validation (Mckitrick, 1998; Jorgenson, 1984) consequently there is big concern for reliability of the simulation results.

In order to check robustness of simulation results with respect to the assumed values for some key parameters Harrison et al. (1993) propose some kind of systematic sensitivity analysis.
The purpose of the sensitivity analysis is to check how robust the model results are with regards to certain variations in key parameter values and other assumptions that may

significantly dominant the final results, in particular the elasticities. Sensitivity analysis is integral part of any quantitative economic analysis that applies CGE model.

After identifying key parameters which should be examined, Hosoe et al. (2010) suggest to set the following criteria to evaluate the robustness of the simulation results. The first criterion refers to the sign of the sectoral output changes which should be unchanged in different cases. The second criterion indicates that the ordering of the output changes should be sustained in all cases.

Table 5-3 Percentage changes of macroeconomic variables , energy usage and CO2 emissions under different tax rate Lower elasticity of substitution (S: 0.5)

Carbon Tax Dollar/	0	5	10	20	50	100
GDP	0%	-0.01%	-0.02%	-0.03%	-0.08%	-0.20%
Household consumption	0%	-0.10%	-0.30%	-0.60%	-1.40%	-2.80%
Government consumption	0%	0.50%	0.1%	0.2%	4.90%	9.60%
Import Agriculture	0%	-0.20%	-0.40%	-0.70%	-1.80%	-3.50%
Import Manufacturing	0%	-0.10%	-0.20%	-0.40%	-1.10%	-2.10%
Import Utility & construction	0%	0.50%	0.90%	1.80%	5.40%	9.00%
Import Transportation & communication	0%	-0.20%	-0.40%	-0.80%	-2.10%	-4.10%
Import Services	0%	-0.10%	-0.20%	-0.40%	-1.00%	-2.10%
Export Agriculture	0%	-0.10%	-0.30%	-0.60%	-1.40%	-2.70%
Export Manufacturing	0%	-0.20%	-0.30%	-0.70%	-1.60%	-3.20%
Export Utility & construction	0%	-0.70%	-1.30%	-2.60%	-6.30%	-12.10%
Export Transportation & communication	0%	-0.10%	-0.10%	-0.30%	-0.70%	-1.40%
Export Services	0%	0.20%	0.40%	0.90%	2.10%	4.20%
CO2 emissions (kt)	0%	-888	-1772	-3526	-8676	-16906
Energy Consumption	0%	-0.20%	-0.40%	-0.90%	-2.20%	-4.20%

We carry out sensitivity analysis by varying the elasticity of substitution in the nested production function and by changing the carbon tax rates in the policy scenarios. We define a higher-elasticity case with 50% higher values and a lower-elasticity case with 50% lower value for substitution parameters. The results of sensitivity analysis are shown in the tables

5-3, 5- 4, 5-5, 5- 6 and illustrate that the simulation results satisfy both criterion and prove to be robust with respect to most parameter value.

Table 5-4 Percentage changes of macroeconomic variables , energy usage and CO2 emissions under different tax rate Higher elasticity of substitution (S: 1.5)

Carbon Tax Dollar/	0	5	10	20	50	100
GDP	0%	-0.03%	-0.05%	-0.10%	-0.30%	-0.60%
Household consumption	0%	-0.10%	-0.30%	-0.60%	-1.40%	-2.70%
Government consumption	0%	0.40%	0.80%	1.6%	3.90%	7.50%
Import Agriculture	0%	-0.30%	-0.50%	-1.1%	-2.60%	-5.10%
Import Manufacturing	0%	-0.20%	-0.40%	-0.7%	-1.80%	-3.60%
Import Utility & construction	0%	0.30%	0.70%	1.3%	3.30%	6.50%
Import Transportation & communication	0%	-0.20%	-0.50%	-1.0%	-2.40%	-4.70%
Import Services	0%	-0.10%	-0.30%	-0.6%	-1.50%	-3.00%
Export Agriculture	0%	-0.20%	-0.40%	-0.9%	-2.20%	-4.30%
Export Manufacturing	0%	-0.20%	-0.50%	-1.0%	-2.40%	-4.70%
Export Utility & construction	0%	-0.80%	-1.60%	-3.1%	-7.50%	-14.20%
Export Transportation & communication	0%	-0.10%	-0.20%	-0.5%	-1.20%	-2.40%
Export Services	0%	0.20%	0.30%	0.7%	1.60%	3.20%
CO2 emissions (kt)	0%	-1239	-2471	-4909	-12023	-23255
Energy Consumption	0%	-0.30%	-0.60%	-1.20%	-3.00%	-5.90%

Table 5-5 Percentage changes of supply (production) under different tax rate Lower elasticity of substitution (S: 0.5)

Carbon Tax Dollar/	0	5	10	20	50	100
Agriculture	0%	-0.10%	-0.30%	-0.60%	-1.50%	-2.90%
Manufacturing	0%	-0.20%	-0.30%	-0.60%	-1.50%	-3.00%
Utility & construction	0%	-0.40%	-0.80%	-1.50%	-3.80%	-7.30%
Transportation & communication	0%	-0.10%	-0.20%	-0.40%	-1.00%	-2.00%
Services	0%	0.10%	0.30%	0.60%	1.40%	2.60%

Table 5-6 Percentage changes of supply (production) under different tax rate higher elasticity of substitution (S: 1.5)

Carbon Tax Dollar/	0	5	10	20	50	100
Agriculture	0%	-0.2%	-0.5%	-0.9%	-0.3%	-4.5%
Manufacturing	0%	-0.2%	-0.5%	-0.9%	-0.3%	-4.5%
Utility & construction	0%	-0.5%	-1.0%	-2.0%	-4.9%	-9.5%
Transportation & communication	0%	-0.2%	-0.3%	-0.6%	-1.5%	-2.9%
Services	0%	0.1%	0.2%	0.4%	0.9%	1.7%

5.2.1 Carbon tax revenue recycling scenario

Policy maker need to be aware about unintended adverse effects of imposing carbon tax on households and industries thus try to design less distortionary tax system. There are at least three options to utilize carbon tax revenues. Revenue generated by carbon tax can be (1) recycled back to consumer and vulnerable industries to reduce deadweight loss, (2) subsidies energy renewable (3) help to reduce the government deficit and lower inflation. Such recycling impacts will vary, depending on how the revenues are used. The macroeconomic results of the recycled tax revenue policy to consumer are shown in table5-7. There might be still a small income effect but substitution effect will to continue to be valid. The results show that GDP is modestly negative impacted also losses in household welfare as well as deadweight loss clearly minimized whereas reduction in CO_2 emissions and energy are (much) smaller, as compared to emission and energy reduction be without the revenue recycled.

Table 5-7 Percentage changes of macroeconomic variables , energy usage and CO2 emissions under different tax rate Cobb-Douglass production function (S:1)

Carbon Tax Dollar/Tone	0	5	10	20	50
GDP	0%	-0.02%	-0.04%	-0.08%	-0.20%
Household consumption	0%	0%	0%	0%	0%
Government consumption	0%	-0.10%	-0.20%	-0.20%	-0.80%
Import Agriculture	0%	-0.10%	-0.30%	-0.50%	-1.30%
Import Manufacturing	0%	-0.10%	-0.10%	-0.20%	-0.50%
Import Utility & construction	0%	0.50%	1.00%	1.90%	4.80%
Import Transportation & communication	0%	-0.10%	-0.20%	-0.50%	-1.20%
Import Services	0%	-0.30%	-0.50%	-1.00%	-2.50%
Export Agriculture	0%	-0.10%	-0.20%	-0.30%	-0.80%
Export Manufacturing	0%	-0.10%	-0.20%	-0.40%	-1.00%
Export Utility & construction	0%	-0.60%	-1.30%	-2.50%	-6.10%
Export Transportation & communication	0%	0.00%	0.00%	0.00%	0.00%
Export Services	0%	0.10%	0.10%	0.30%	0.70%
CO2 emissions (kt)	0%	-742	-1482	-2951	-7269
Energy Consumption	0%	-0.20%	-0.40%	-0.70%	-1.80%

The percentage changes of supply (production) are shown in table5-8 and demonstrate that the output losses in sectors are lower when tax revenues are recycled. Not surprisingly, like first scenario high carbon intensity industries which are utility and construction are experienced the most significant losses.

Table 5-8 Percentage changes of supply (production) under different tax rate Cobb-Douglas production function (S: 1)

Carbon Tax Dollar/	0	5	10	20	50	100
Agriculture	0%	-0.1%	-0.2%	-0.4%	-0.9%	-1.8%
Manufacturing	0%	-0.1%	-0.2%	-0.4%	-0.9%	-1.8%
Utility & construction	0%	-0.4%	-0.7%	-1.4%	-3.5%	-6.7%
Transportation & communication	0%	0%	-0.1%	-0.1%	-0.3%	-0.6%
Services	0%	0%	0.0%	0.0%	-0.1%	-0.2%

Although, carbon tax would have a negative effect on the household welfare and industries outputs but on the other side Ecotax increase environmental quality and human health as well as climate benefits by energy use reduction. In short a clear-cut answer does not exist to the question of effects of carbon tax on economy but we can expect, if carbon tax revenues are recycled appropriately, the negative impacts on economic growth will not substantial.

Generally, The probable benefits and / or harms from imposing carbon tax to the economy will depend on the choice of model and assumptions underlying it as well as particular circumstances, such as, carbon tax designing, the reaction of polluting firms to charge, where the tax revenues go, how the revenues are used, all of which will vary from region to region and country to country.

As reviewed in section 2.6 several attempts have been made to simulate the effects of a carbon tax on whole economy. The present findings seem to be consistent with other research which found the carbon tax policy could achieve reasonable environment targets with a relatively small impact on GDP and consumption.

5.3 DISCUSSION

Italy ratified the Kyoto protocol on June 2002. The Kyoto protocol commits Italy to reduce its GHG emissions by about 6.5% with respect to 1990 level by 2008-2012. According to UNFCCC Italian green house gas emissions excluding LULUCF were 519.1 MtCO_2eq in base year. The Kyoto target is therefore set at 485.3 Mt CO_2eq. From the base year emissions Italy's assigned amount in accordance with Article 3, paragraphs 7 and 8 is 2,426.5 MtCO_2eq. The most important GHG in Italy was CO_2 contributing averagely 84.1 per cent to total.

Table 5-9 provides GHG data as well as CO_2 for all years of the commitment period. The Kyoto protocol has fixed the base year (1990) CO_2 emissions for Italy to 436 million. Thus in order to meet Kyoto target Italian sectors should reduce CO_2 emission around 1.2 million in each followed year.

Table 5-9 GHG and CO_2 Italy's emission (Million tone)

Year	GHG	Actual CO_2	CO_2 Target linear reduction	Difference	Kyoto assigned CO_2 emission	Difference
	1	2	3	(2-3)	4	(2-4)
1990	519.1	434.7	434.7	0.0		
1991	520.6	434.2	433.5	0.7		
1992	517.8	433.9	432.3	1.6		
1993	511.3	427.2	431.1	-3.9		
1994	503.6	419.9	429.9	-10.0		
1995	530.3	444.9	428.7	16.3		
1996	524.0	438.3	427.5	10.8		
1997	530.5	442.4	426.3	16.1		
1998	541.9	453.5	425.1	28.5		
1999	548.3	458.8	423.9	35.0		
2000	551.2	462.3	422.7	39.6		
2001	557.1	468.3	421.5	46.8		
2002	558.3	470.5	420.3	50.3		
2003	573.6	486.6	419.1	67.5		
2004	576.8	489.4	417.9	71.5		
2005	574.3	488.1	416.7	71.4		
2006	563.4	483.5	415.5	68.1		
2007	555.1	475.4	414.3	61.2		
2008	540.6	463.7	413.1	50.6	407.6	56.1
2009	490.1	414.8	411.9	3.0	407.6	7.2
2010	499.4	425.0	410.7	14.3	407.6	17.4
2011	486.6	413.4	409.5	3.9	407.6	5.8

2012	460.1	386.7	408.3	-21.6	407.6	-20.9

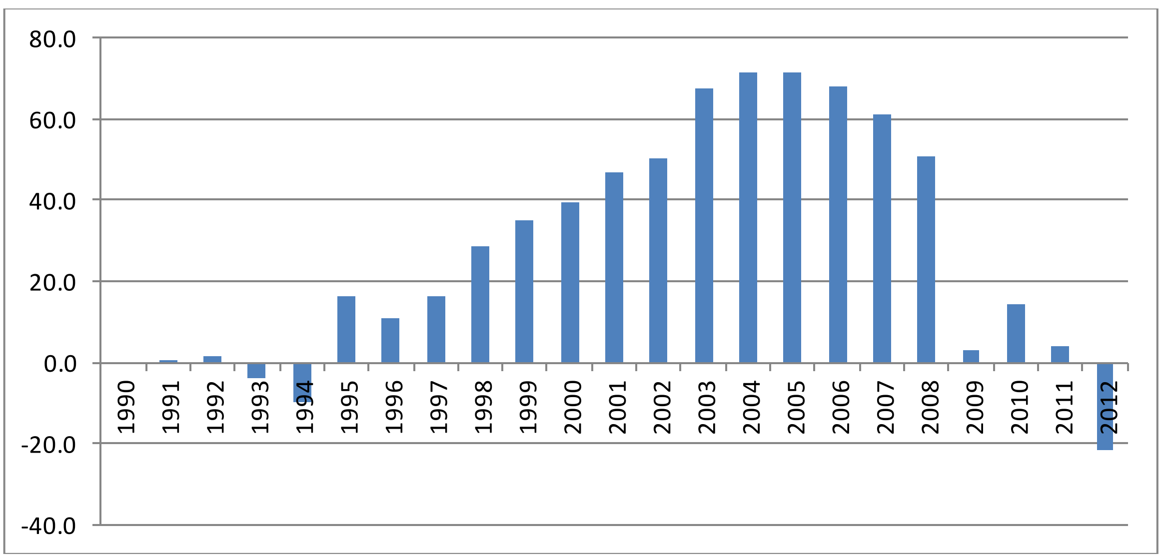
Source: European Environment Agency and author calculations

The bar chart shows the actual CO_2 emissions gap with Kyoto linear reduction target. As can be seen from chart between 1990 and 1994 there was a moderate fall in the CO_2 emissions; Then there was upward trend during the period 1995-2006 and gradually decreases between 2005 till 2008 and sudden fall in 2009. The sharp CO_2 emission was at its highest level in 2004 and the lowest level in 2012.

Our simulation results show by imposing CO_2 tax between 5 and 10 dollar per tCO_2 (18.35 and 36.7 dollar per carbon) Italy could meet the Kyoto target for CO_2 gas by 2012 and this rate should rise through time gradually to meet second commitment (CP2) target as well.

However, as reported by European Environment Agency (2014) Italy' GHG is not fully on track towards its burden-sharing target and need to purchase additional international credits before the end of the true-up period.

Figure 5-1 Actual CO2 gap with Kyoto linear reduction target



5.4 CONCLUSION AND RECOMMENDATION

The main goal of this research was to analyze the impact of a carbon tax policy for reducing of CO_2 emission and on various macroeconomic economic variables i.e. GDP for Italian economy by using a top down static CGE model. To be able to understand the above impacts, this research considered two policy scenarios: the independent carbon tax and the tax revenue redistributed back to consumers.

The results of five carbon tax rates from 5 dollars t/CO_2 to 100 dollars t/CO_2 were compared.
Despite no general agreement in the literature about the impact of environmental taxes on economy, but according to the majority of scholars, economy variables i.e. household income and output of producer would be influenced negatively by levying CO_2 tax more significantly for sectors whose emission intensity is high. An introduction carbon dioxide tax leads to a reduction in domestic production in most sectors due to high energy cost and lower domestic demand. The magnitude of which depends mainly on their carbon content in inputs and outputs.

The most adversely affected sector is utility and construction because this sector is the largest domestic contributor of CO_2 emissions. According to WIOD the utility and construction sector produces about 35 % of carbon dioxide in Italy. By contrast, imposing CO_2 tax could reduce carbon emissions and improve overall environmental quality without obstructing economic growth.

The analysis showed that, under revenue recycling strategies, losses in household welfare as well as deadweight loss clearly minimized as compare to independent carbon tax scenario.

Our simulation results show by imposing CO_2 tax between 5 and 10 dollar per tCO_2 for different scenarios Italy could meet the Kyoto target for CO_2 gas by 2012.

A number of important limitations need to be considered to this research. First we applied a static CGE model which ignores dynamics of capital accumulations in economy. Second problem with static CGE model is that technological change also not captured in this model.

We have aggregated all of household into one single agent thus we did not consider income distribution in among different types of Italian households so it is another limitation of this research. In future disaggregation households into different income class is therefore recommended.

The current study has only examined CO_2 tax impacts on economy and did not include other options for reduction carbon emission like tradable permits which can be sold in the international market and provide the additional benefits for economy and environment. In this respect it is important to emphasize that this research does not state that a carbon tax is only way and right policy to combat CO_2; Cap and trade program even command and control along carbon dioxide tax could be more efficient policy to curb carbon emissions.

We have to take into account there is no “magic bullet” to reduce CO_2 emission nationally and globally but most of scholar believe that CO_2 tax –despite its drawback-emerge as easiest and flexible approach (Hsu, 2011). A carbon tax should be start at a modest rate and increase in time.

At last but not least word, the global warming problem will not be fixed solely by applying a carbon tax or a cap and trade system. According to IPCC prediction, the size of the global economy expand 12-26 fold by 2100, which means that, our world will face with very large amount of CO_2 even with remarkable energy intensity and market based instruments.

Thus, technology advancement as well as market based instruments like taxes would not be sufficient for better environmental quality because the increase in the scale of final consumption is still substantial (consumerism).

In order to have more sustainable world, parallel to the technological improvement and market based environmental instruments, fundamental changes in consumption as well individual lifestyle especially in wealthiest countries, REDD[1], must be pursued to transit to a green economy otherwise this temporary enjoyment lead to tragic pain in future.

[1] Reducing Emissions from Deforestation and Forest Degradation

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Appendix 1 : Activity abbreviation

Agr	Agriculture
Mng_Extr	Mining & Extraction
Pcf	Processed Food
LMnf	Labor-Intensive Manufactures
CMnf	Capital-Intensive Manufactures
Util_Cns	Utilities and Construction
Trans_Comm	Transportation & Communication
Svces	Private Financial & Other Serv
Osg	Public Services
Dwe	Dwelling

Agr	Agriculture
Mng_Extr	Mining & Extraction
Pcf	Processed Food
LMnf	Labor-Intensive Manufactures
CMnf	Capital-Intensive Manufactures
Util_Cns	Utilities and Construction
Trans_Comm	Transportation & Communication
Svces	Private Financial & Other Serv
Osg	Public Services
Dwe	Dwelling

Appendix 2: The concordance between WIOD, GTAP, OECD and ISIC rev.3.1 code

harmonized Sector	ISIC Rev.3.1 code	WIOD sector	OECD sector	GTAP sector
1	01-05	C1	AGR	prd, wht, gro, v_f, osd, c_b, pfb, ocr, prc, ctl, oap, rmk, wol, fsh, frs
2	10-14	C2	MIN	coa, oil, gas, omn
3	15-16	C3	FOD	cmt, omt, mil, sgr, ofd, vol, b_t
4	17-19	C4-C5	TEX	tex, wap, lea
5	20	C6	WOD	lum
6	21-22	C7	PAP	ppp
7	23	C8	PET	p_c
8	24-25	C9-C10	CHM, RBP	crp
9	26	C11	NMM	nmm
10	27-28	C12	MET, FBM	i_s, nfm, fmp
11	29	C13	MEQ	otn
12	30-33	C14	ITQ, ELQ, CMQ, SCQ	ele, ome
13	34-35	C15	MTR, TRQ	mvh
14	36-37	C16	OTM	omf
15	40-41	C17	EGW	ely, gdt, wtr
16	45	C18	CON	cns
17	50-55	C19-C22	WRT, HTR	trd
18	60, 63	C23, C26	TRN	otp
19	61	C24		wtp
20	62	C25		atp
21	64	C27	PTL	cmn
22	65-66	C28	FIN	ofi, isr
23	70-74	C29-C30	REA, RMQ, ITS, RDS, BZS	obs
24	75, 80, 85	C31-C33	GOV, EDU, HTH	osg
25	90-95	C34-C35	OTS, PVH	ros

Note: GTAP Sector 57, "DWE" are not part of ISIC

Appendix 3: GAMS codes