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Abstract

In this paper we illustrate the empirical strategy to extend the macro-econometric model of the italian economy to the energy sector and we show a first set of preliminary estimation results. We build an energy block in MeMo-It that interacts with the demand side of the economy. In particular, we model the demand of energy products and the dynamic of their relative prices in order to be able to evaluate the impact of energy policy measures on the Italian economy.

Keywords: Neo-Keynesian model, macroeconomic modeling, energy and environmental policy modeling
JEL: O44, E20, E27

[a] Istat, Econometric Studies and Economic Forecasting Division, [b] University of Bologna. Special thanks to Daniela Fantozzi for data collection and to the colleagues from Environmental National Accounts Division. The views expressed in this paper are solely those of the author and do not involve the responsibility of their institutions. Paper presented at *Giornate della ricerca in Istat 2014*, Rome, 10-11 November 2014

1. Introduction

In this paper we illustrate the empirical strategy to extend the ISTAT Macroeconometric model (MeMo-It) to energy and environmental features to evaluate related policy measures on the Italian economy. We model the linkages between economic activity, energy demand and prices, and carbon emissions in the framework of MeMo-It (Bacchini et al, (2013)). We develop MeMo-It in two steps: first, we build an energy block that interacts with the demand side of the economy; then, we extend both the supply and the demand side of the system to account for the role of carbon emission. The paper is structured as follows. In the next section we review the literature on Energy-Environment-Macro modeling, then we provide an overview of the main developments of MeMo-It to account for the demand of energy resources by firms and households. In section IV we take a look at energy data and related measurement issues, while section V reports a first set of estimation results. Section VI concludes and illustrate our next steps to incorporate carbon emission in 2E-MeMo-It.

2. Literature review

The aim of this section is to provide a general overview of the current approaches to economy-energy-environment models and to show how 2E-MeMo-It relates to this literature. We do not offer an exhaustive summary of all existing models for which we suggest Chawla et al (2012). There is a large variety of energy and environment modeling approaches. A widely used modeling paradigm distinguishes between top-down and bottom-up models according to the approach adopted to represent the interactions between the energy system and the economy (Bohringer, C. and T. Rutheford (2006)). Bottom-up models evaluate the system looking at very disaggregated variables and may be regarded as partial equilibrium models focused on sectoral and technological details. They are well suited to the analysis of specific changes in technology and energy policies at the industry level but they fail to account for price distortions, economy-wide interactions and income effects. Top-down models instead examine the aggregate economy and represent macroeconomic linkages between aggregate production, consumers and government sector. Most of them are based on the general equilibrium framework through which they try to capture endogenously macroeconomic impacts (change in GDP, consumption, investments, prices, unemployment etc.) of specific energy policy instruments (i.e. carbon tax). Top-down models are best suited for predictive purposes, since their past behavior can be easily extrapolated into the future. On the other hand, top-down models fail to capture the extent of technological developments since they model technology changes as the result of a price substitution along a given production isoquant. There are also several hybrid models aiming at combining the technological explicitness of bottom-up models with the economic robustness of top-down models (see Hudson and Jorgenson, (1974) and Bergman (1990)).

Moving to the subset of macroconomic-energy models at the country level they can also be grouped according to the framework adopted to represent the economic system into Neo-Keynesian and Computable General Equilibrium models (CGEM). Neo-Keynesian models provide a more truthful representation of the actual functioning of the economy accounting explicitly for the sluggish adjustments of prices and quantities. This allows to model permanent or transitory under-optimum equilibrium (i.e. the presence of involuntary unemployment) increasing the degree of accurateness of the model. 2E-MeMo-It has been designed following the new-keynesian principles as will be clarified in the next section.

On the other hand, Neo-Keynesian models do not allow an high degree of disaggregation that is not easily combined with the explicit representation of the mechanisms of adjustments. CGEM are instead suitable for an high level of detail, usually distinguishing between type of consumers, countries and goods, in a tractable framework. CGEM are widely used to analyze the economic impact of energy and environmental policies since they often account for a large number of sectors (GREEN, 11 sectors; GEMINI-E3, 18 sectors; IMACLIM-S 10 sectors)[1]. However, CGEM are supply models founded on the very restrictive assumption of perfect price flexibility that insures full and optimal

[1] See Burniaux et al., (1992), Bernard and Vielle, (2008) and Ghersi and Thubin, (2009) respectively

use of resources and guaranties the equilibrium, but does not allow for real-life disequilibria[2]. Another strand of the energy macroeconometric literature is focused on the cointegration analysis of the relationship between energy and GDP at the aggregate level (see for example Belke et al. 2011 for a review). This empirical literature, proposes a panel vector error-correction specification for the trivariate model (including prices), and provides mixed and conflicting evidence about the energy consumption-growth nexus.

3. Empirical strategy

Our aim is to develop MeMo-It to create a new policy tool to evaluate the impact of energy and environmental policy measures on the Italian economy. Our strategy is organized in two main steps: first we will extend MeMo-It to account for the demand of energy products and the dynamic of their relative prices. Then, in a second step, we will include an environmental module starting from the carbon emissions (see for example Reynes et al. 2011). The reference framework to build our energy-environment model is MeMo-It. Thus in the following section we will revise the main characteristics of Memo-It and we will illustrate how we will extend the model to account for energy and environment.

3.1 From MeMo-It to 2E-MeMo-It

MeMo-It belongs to a suite of economic forecasting models developed by Istat, where it plays a fundamental role in the modeling framework ensuring the overall consistency in the system. The model is composed by 53 stochastic equations and 78 identities, and represents a New Keynesian economic system including households, firms, public administration, and a foreign sector. It is an annual model that uses two sets of external (exogenous) information over the forecasting period. The first set refers to the main variables that characterize the development of the international scenario, such as trade growth, exchange rates, ECB interest rates, and the oil price. The second set instead includes annual estimates of key GDP components obtained from short-term models based on monthly and quarterly data available at the time of forecast. The main characteristic of MeMo-It is that it is strongly grounded in empirical information (data-based model) in order to assess the data-admissibility of the theoretical assumptions, and does not assume explicit micro-foundations of weak-form. Further, it has been thought as a simple and easy tool to be introduced to the users and it is timely updated with the most recent release of National Accounts. This allows to deliver updated forecasts always coherent with the last vintage of NA figures.

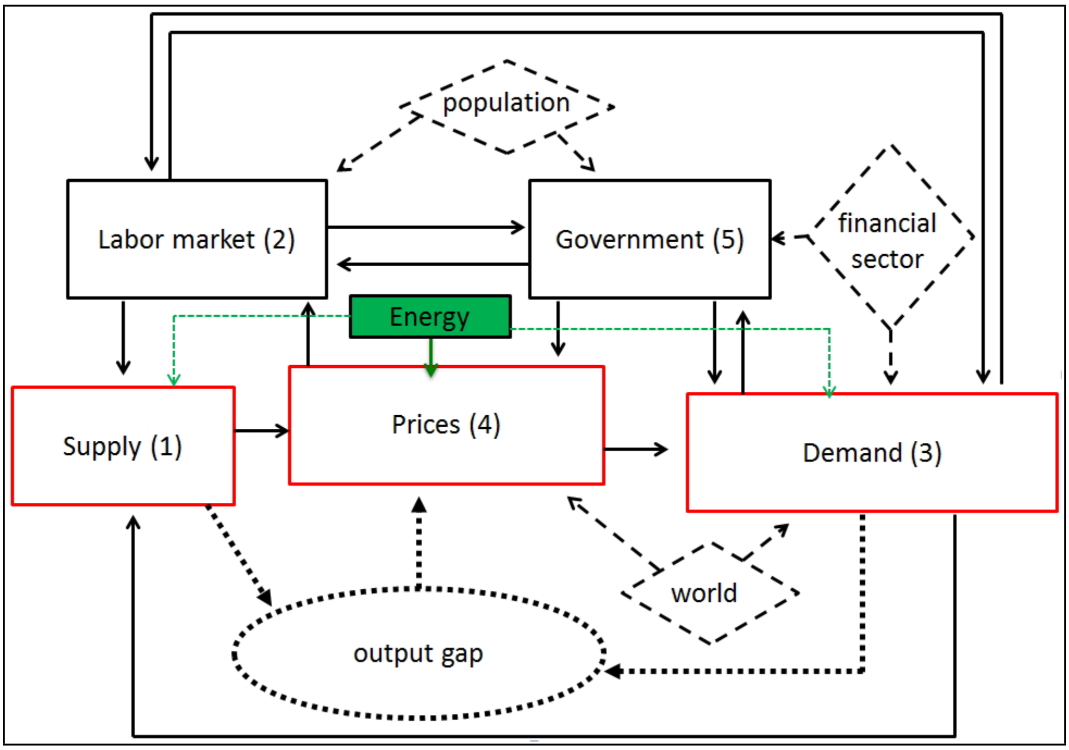
The diagram in Figure 1 outlines the first development of MeMo-It to incorporate the demand and supply of energy inputs. At this stage, MeMo-It is structured into five main blocks supply side, labor market, demand side, prices, and Government. Further, as can be seen in the Figure, there are three (rhombuses) main sources of external information for the age- and gender-structure of the population, the ECB policy interest rate (in the financial sector) and global variables, such as world demand, exchange rates, oil price and other import prices. The arrows identify the main transmission channels across blocks.

As mentioned above, MeMo-It is substantially based on the New-Keynesian approach where the supply side of the economy plays a central role. Accordingly, the underlying key assumption is that in the short-run the economic activity is mainly driven by the demand side, while in the long run the economic system converges to potential output given by the supply side. Prices react to the output gap and, in this way, they accounts for the disequilibrium of supply and demand. The dotted arrows in the lower portion of Figure 1 represent the interactions arising from such disequilibrium (between the supply and demand rectangles) with the output gap (in the oval circle) which, in turn, affects the prices rectangle. In turn, price changes feedback into demand variables rectangle and into wages in the labor sector rectangle. Real wages and employment affect income distribution and households consumption (in the demand rectangle). Consumption and incomes in the demand rectangle are the tax bases which, combined with (exogenous) rates, define different forms of taxation

[2] See Bhattachryya (1996) for an overview of CGE models.

in the Government rectangle. Direct taxation and public transfers generate income redistribution that affects the demand, while indirect tax and social security contributions influence prices and labor cost. Finally, investments and output in the demand rectangle interact with the supply side through the accumulation of capital stock (lower arrow), and employment in the labor market rectangle (upper arrow).

Figure 1 - Developing 2E-MeMo - 1st step



The economy-energy-environment model (2E-MeMo-It) has been developed in the same spirit of MeMo-It focusing on data coherency and timeliness with the SEEA. As shown in Figure 1, the energy block interacts with the demand and the supply side of the economy via firms demand of energy inputs and household demands of final energy products, and affecting the price system (green arrows).

3.2 Building 2E-MeMo-It

In this section we illustrate the structure of the energy block that is composed by two different energy product demand functions and two price equations. We model the firm's demand of energy inputs, the household's consumption of energy products and their relative price functions through behavioral equations able to explain both short and long run dynamics. The demand of energy inputs is specified as follows:

$$F_t^{ED} = F(P_t^E, DD_t) \tag{1}$$

where P are the prices of intermediate energy inputs and DD is the domestic demand. All variables are at time t. Then P_t^E is assumed to be a function of domestic and international prices of energy products as well as of specific fiscal variables. The estimating equation is:

$$P_t^{EI} = F(P_t^{OIL}, P_t^{GAS}, P_t^{EL}, P_t^{OTH}, P_t^{IMP}, T_t) \tag{2}$$

where superscripts refer to individual energy assets: OIL (Brent price in dollar per barrel, from OEF model), GAS and EL are Gas and Electricity prices, while OTH refers to other energy products, IMP are the prices of Imported energy inputs and T are government taxes.

Household's demand of energy products is assumed to be influenced by fuel, electricity and gas prices, and by disposable income (YD) and can be written as:

$$H_t^{ED} = F(P_t^{GAS}, P_t^{EL}, P_t^{FUEL}, YD_t) \tag{3}$$

and the corresponding price is:

$$P_t^{EF} = F(P_t^{GAS}, P_t^{EL}, P_t^{FUEL}, P_t^{OIL}, T_t, EXP_t) \tag{4}$$

where T is VAT on consumprion and Govt. direct purchases and EXP refers to total exports. we assume that energy prices are the main transmission channels between the energy block and the economic system. Energy prices affect firms investment decisions and the demand for labour. In particular, intermediate and final energy prices are assumed to interact with the economic system as defined in MeMo-It through firm's investment in machinery and equipment, firm's demand for labor, and household consumption of energy products. The above structure allows to evaluate the effects of energy policies on business and household sectors through their impact on the demand of production inputs as well as on the final demand for energy products.

4. Data and measurement issues

A key element to develop an economy-energy-environment model is the availability of appropriate data and indicators on energy products and environment. The main reference to produce statistical information on energy and environmental phenomena is the System of Environmental-Economic Accounting (SEEA) containing internationally agreed standard concepts, definitions and classifications to produce internationally comparable statistics. The SEEA framework provides the accounting rules to produce data SNA coherent indicators and descriptive statistics to monitor the synergies between the economy and the environment for policy purposes. Recently the SEEA has been revised by the UN Statistical Commission to include three sub-systems on Energy, Water and Land and Ecosystems to provide more detailed information on these areas.

The Italian Statistical Institute produces energy and environmental data according to the SEEA. In particular, ISTAT elaborates material-flow accounting (MFA) and National Accounts Matrix including Environmental Accounts (NAMEA). To model supply and demand of energy we need data on both quantities and prices.

The main data source for firm's demand of intermediate energy inputs, households's final energy consumption and the corresponding energy prices are the Supply and Use Tables (SUT) annually released by National Accounts. Notice that the prices integrated in the SUT system refer to the national accounts deflators.

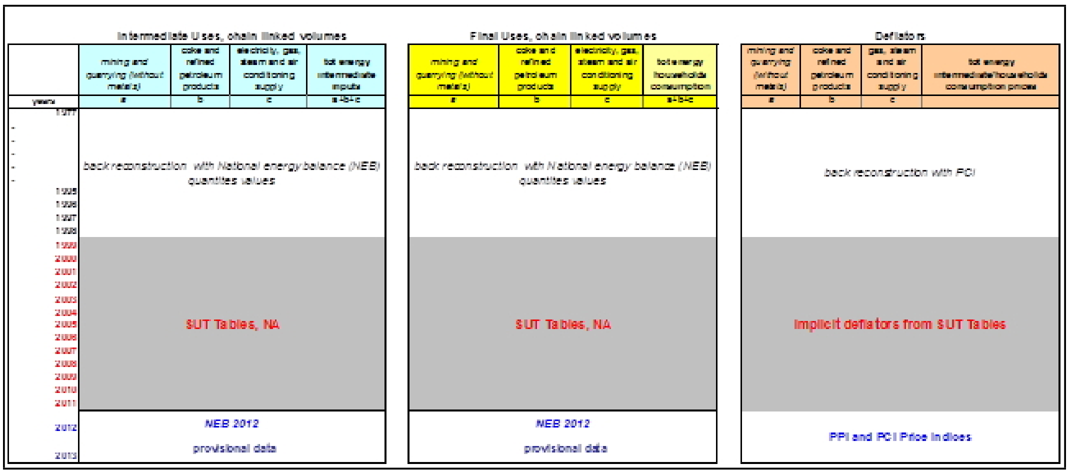
We explicitly account for the following energy assets referring to the NA product classification (CPA 2008): mining and quarrying (only for the part that includes coal, crude oil, and natural gas); coke and refined petroleum products; electricity, gas, steam and air conditioning supply. However, the information provided by NA refer only to the period 1995-2011 for current price variables, 1999-2011 for chain-linked and the related deflators. To include the energy block in MeMo-it we need to built a comprehensive dataset covering the extended time period 1970-2012. To this end we integrate the information from the USE tables with additional sources. A relevant source of information to extend the time series for quantities and prices of energy products, such as gas, oil and electricity, are: the National Energy Balance (NEB)[3], the Italian electricity transmission operator (Terna), the producer price index of industrial products and the consumption price index of energy products (Istat).

Each energy product can be demanded for intermediate or final uses. In order to identify the intermediate and final demand we resort to specific quotas gathered from NEB.

[3] See $http://dgerm.sviluppoeconomico.gov.it/dgerm/ben.asp$

Finally we have updated the dataset up to the current year (2013), relying on the Terna forecasting scenarios for electricity, and on the available monthly indicators (Ministry of Economic Development). Figure 2 provides a snapshot of the database architecture.

Figure 2 - Database structure



5. Modeling demand and prices of energy products: estimation results

As shown above, the energy block is composed by four equations: firm's demand of intermediate energy inputs, household demand of energy products and two corresponding price equations [4]. In a first stage, we have tested for the presence of common components of firm's and household's energy demand, energy prices and an indicator of internal total demand.

The results suggest that the series are integrated of order 1 so we also test whether a long-run relationship among them exists. We investigate the cointegration between the common components using standard time series tests such as the Johansen reduced rank approach (Johansen,1995). Intermediate energy demand and domestic demand are weakly correlated with the corresponding energy prices thus suggesting the existence of a long run relationship.

Apparently, household demand of energy products is not integrated of order 1 while the opposite is true if we test the demand of each individual energy asset.

To get a sense of the dynamic behaviour of firm's and households demand of energy products and their main components, Figures 3 and 4 show their rates of change over the sample period.

Equations 1 to 4 have then been estimated by means of two stage least squares. Estimation results are shown in figure 5 and 6.

6. Conclusion and further steps

In this paper we have illustrated our empirical strategy to extend the macro-econometric model of the Italian economy to the energy sector. Details of the dataset and empirical results will be presented at the seminar

Future step of the project are: - Fully Integration in Memo - Simulation of energy policy scenarios - Model performance in the long run - Development of the environmental module - Integration of environmental module in MeMo-it - environmental policy simulations

[4] At this stage,we model energy consumption without distinguishing among different energy assets but referring to an energy aggregate including gas, oil, and electricity.

Figure 3 - Energy intermediate inputs Y-Y growth rate

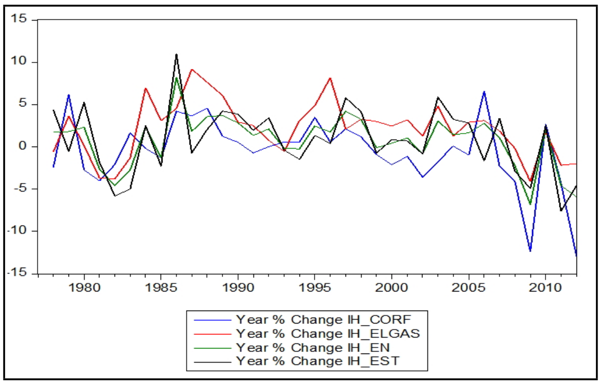


Figure 4 - Energy final inputs Y-Y growth rate

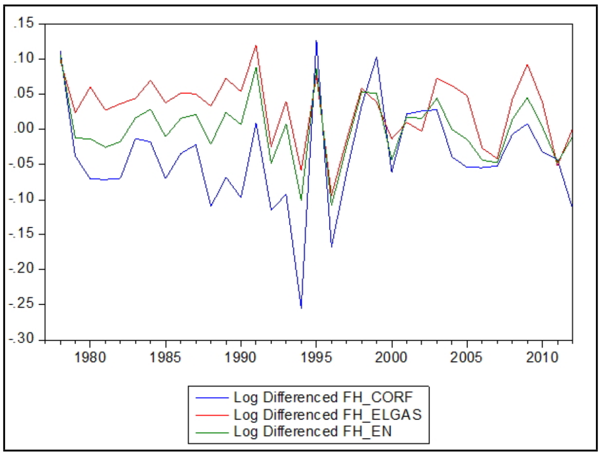


Figure 5 - Demand equations

Dependent Variable: DLOG(IH_EN)
Method: Two-Stage Least Squares
Date: 01/24/14 Time: 03:47
Sample (adjusted): 1979 2012
Included observations: 34 after adjustments
DLOG(IH_EN)=C(3)*DLOG(PINT_EN)+C(4)*DLOG(DDO)+C(5)*D1986
+C(6)*D2009+C(7)*D1993
Instrument specification: DLOG(IH_EN(-1)) DLOG(PINT_EN(-1))
DLOG(DDO(-1)) D1986 D2009 D1993
Constant added to instrument list

	Coefficient	Std. Error	t-Statistic	Prob.
C(3)	-0.115954	0.045562	-2.544971	0.0165
C(4)	0.961207	0.210270	4.571294	0.0001
C(5)	0.040400	0.020670	1.954478	0.0603
C(6)	-0.046909	0.020102	-2.333570	0.0268
C(7)	0.047560	0.021794	2.182198	0.0373

R-squared	0.682783	Mean dependent var	0.006464
Adjusted R-squared	0.639029	S.D. dependent var	0.031259
S.E. of regression	0.018781	Sum squared resid	0.010229
Durbin-Watson stat	1.841472	J-statistic	1.738308
Instrument rank	7	Prob(J-statistic)	0.419306

Dependent Variable: LOG(FH_EN/POP_T)
Method: Two-Stage Least Squares
Date: 01/24/14 Time: 03:47
Sample (adjusted): 1978 2012
Included observations: 35 after adjustments
LOG(FH_EN/POP_T)=C(1)+C(2)*LOG(PFIN_EN)+C(3)*D1991+C(4)
*LOG(YDHN(-1)/POP_T(-1))+C(5)*D1997
Instrument specification: C LOG(FH_EN(-1)/POP_T(-1)) LOG(PFIN_EN)
LOG(YDHN(-2)/POP_T(-2)) D1991 D1997

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	1.039294	0.128515	8.086945	0.0000
C(2)	-0.224111	0.047328	-4.735257	0.0000
C(3)	0.093286	0.029618	3.149634	0.0037
C(4)	0.128183	0.031944	4.012677	0.0004
C(5)	-0.088773	0.029728	-2.986191	0.0056

R-squared	0.625309	Mean dependent var	0.391622
Adjusted R-squared	0.575351	S.D. dependent var	0.044777
S.E. of regression	0.029179	Sum squared resid	0.025542
Durbin-Watson stat	2.072692	J-statistic	0.988668
Instrument rank	6	Prob(J-statistic)	0.320068

Figure 6 - Prices equations

Dependent Variable: DLOG(PINT_EN)
Method: Two-Stage Least Squares
Date: 01/24/14 Time: 03:47
Sample (adjusted): 1982 2012
Included observations: 31 after adjustments
DLOG(PINT_EN)=C(2)*DLOG(XO)+C(3)*DLOG(OIL)+C(5)*DLOG(PINT_ELGAS)
Instrument specification: DLOG(XO(-1)) DLOG(OIL(-1)) DLOG(PINT_ELGAS(-1)) D1986 DLOG(PINT_CORF)
Constant added to instrument list

	Coefficient	Std. Error	t-Statistic	Prob.
C(2)	0.718806	0.246184	2.919796	0.0068
C(3)	0.104001	0.049135	2.116630	0.0433
C(5)	0.707344	0.120937	5.848848	0.0000

R-squared	0.805167	Mean dependent var	0.062645
Adjusted R-squared	0.791250	S.D. dependent var	0.088960
S.E. of regression	0.040645	Sum squared resid	0.046257
Durbin-Watson stat	1.925523	J-statistic	6.074069
Instrument rank	6	Prob(J-statistic)	0.108062

Dependent Variable: DLOG(PFIN_EN/PV)
Method: Two-Stage Least Squares
Date: 01/24/14 Time: 03:47
Sample (adjusted): 1991 2012
Included observations: 22 after adjustments
DLOG(PFIN_EN/PV)=C(3)*DLOG(OIL/PV)+C(5)*DLOG(PFIN_ELGAS/PV)+C(4)*DLOG(TIVA)
Instrument specification: DLOG(PFIN_EN/PV) DLOG(OIL(-1)/PV(-1)) DLOG(OIL(-2)/PV(-2)) DLOG(PFIN_ELGAS(-1)/PV(-1)) LOG(TIVA(-1))
Constant added to instrument list

	Coefficient	Std. Error	t-Statistic	Prob.
C(3)	0.130426	0.035970	3.625991	0.0018
C(5)	0.725013	0.142768	5.078247	0.0001
C(4)	0.485118	0.194034	2.500168	0.0217

R-squared	0.781400	Mean dependent var	0.008398
Adjusted R-squared	0.758389	S.D. dependent var	0.056659
S.E. of regression	0.027850	Sum squared resid	0.014737
Durbin-Watson stat	1.434549	J-statistic	1.919744
Instrument rank	6	Prob(J-statistic)	0.589230

References

Bacchini F., et al (2013), "Building the core of the ISTAT system of models for forecasting the Italian economy: MeMo-It", Rivista di statistica ISTAT - Italian National Institute of Statistics - (Rome, ITALY), vol. 15(1), pages 17-45.

Bergman, Lars. "Energy and environmental constraints on growth: a CGE modeling approach." Journal of Policy Modeling 12.4 (1991): 671-691.

Bohringer, Christoph, and Thomas F. Rutherford. "Combining bottom-up and top-down." Energy Economics 30.2 (2008): 574-596.

Chawla, M., and Pollitt, M. G. (2012). Energy-efficiency and environmental policies and income supplements in the UK: Their evolution and distributional impact in relation to domestic energy bills (N. 1256). Univ. of Cambridge.

Hudson, Edward A., and Dale W. Jorgenson. "US energy policy and economic growth, 1975-2000." The Bell Journal of Economics and Management Science (1974).

Reynes F., Y. Yeddir-Tamsamani and G. Callonnec, (2011) "Presentation of the Three-ME model: Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy", OFCE WP n 2011-10.