EVALUATING THE IMPACT OF A REDUCTION IN CRUDE OIL PRICE ON THE PORTUGUESE ECONOMY WITH INPUT-OUTPUT BASED MODELS

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Abstract

As a result of a considerable expansion in supply, combined with a moderation of demand for fossil fuels, the international price of crude oil has decreased significantly along the second half of 2014 and beginning of 2015.

This paper presents the methodology and results for the evaluation of the impact, on the Portuguese economy, of reductions in the import price of crude oil, using a multisectoral (input-output based) model (MODEM 7) combined with an input-output (I-O) price model.

MODEM 7 is a multisectoral model (considering 85 products, produced by 85 homogeneous industries), which includes an input-output based block (determining output, employment and taxes and subsidies on products, as well as imports by products, assuming that supply is determined by final demand, in line with the classic input-output Leontief quantitative model). All components of final demand are exogenous, with the exception of private consumption, which is determined by private disposable income. The model includes also macroeconomic equations determining private disposable income and consumption, GDP, total employment and the unemployment rate as well as public finance equations allowing the determination of public deficit and debt. Most of the equations (702) are simultaneously determined.

All variables are defined at current prices, assuming that, for each model simulation, there are no price changes within each year. All equations are static, except for public debt. Model coefficients were estimated on the basis of the latest available system of I-O tables for Portugal (regarding 2008), as well as of other data from Portuguese national accounts and a reference simulation was performed for 2008, replicating the observed values for the Portuguese economy on that year.

As MODEM 7 does not include price equations, an input-output price model (disaggregated into the same 85 products and calibrated with the same system of I-O tables used for MODEM 7) was used to estimate total effects (direct and indirect) of the reduction in crude oil's import price on each product's price and on final demand deflators, using a cost-push assumption for price determination.

The price effects simulated with the price model for each crude oil price scenario were subsequently used to re-estimate MODEM's nominal input-output coefficients, assuming that I-O coefficients (for intermediate consumption) remained unchanged in real terms. Final exogenous demand was assumed to remain constant in nominal terms (equal to the, before oil price change, reference scenario), except for Change in Inventories and for Exports, which were assumed to remain constant in real terms for each product.

After these adjustments, simulations were performed with the adjusted MODEM and the impacts of the reduction in crude oil price were obtained through the comparison with the (before oil price change) reference simulation. These comparisons were made both in nominal and in real terms (after deflating nominal variables from each crude oil price scenario with the appropriate price deflators obtained from the I-O price model simulation).

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1. INTRODUCTION

As a result of a considerable expansion in supply, combined with a moderation of demand for fossil fuels, the international price of crude oil has decreased significantly along the second half of 2014 and beginning of 2015.

This paper presents the methodology and results for the evaluation of the impact, on the Portuguese economy, of reductions in the import price of crude oil, using a multisectoral (input-output based) model (MODEM 7) combined with an input-output (I-O) price model.

Section 2 describes MODEM 7 and section 3 presents the input-output price model and its use for the estimation of the effect of a reduction in the import price of crude oil on domestic prices. Section 4 explains the method and presents the results for the evaluation of the impact of the reduction in the oil price on the Portuguese economy through the recalibration and simulation of MODEM 7 and, finally, section 5 presents some concluding remarks. Appendixes 1 to 7 show details regarding MODEM 7 and the price model.

2. MODEM 7

2.1. General features

MODEM is a multisectoral (input-output based) model which was developed for Portugal with the purpose of evaluating the macroeconomic impact of public policies and of other exogenous demand and income shocks at the national, sectoral and regional levels, as well as the impact on public finance variables. Previous versions of this model are described in Dias and Lopes (2010b), for MODEM 6C and, in English, in Dias and Lopes (2009), for MODEM 6A.

Versions 1 (1992) to 6C (2010) were developed in the Portuguese Department of Foresight and Planning (DPP[1]) while version 7 was developed by the author in APA, in 2014.

The logic of the model is that supply is determined by demand, in line with the input-output, demand-pull, Leontief quantity model (Blair and Miller, 2009; Leontief, 1986) and all components of final demand are exogenous except private consumption, which is determined by disposable income.

The model is annual and all equations are static, except for public debt. The variables are defined at current prices and there are no price variables in the model, assuming that, for each model simulation, there are no price changes within each year.

The model contains a national block, used for impact simulation at the national level, and a regional block which permits to estimate the breakdown by regions of the national impacts simulated in the national block.

For the present exercise only the national block of the model was used and therefore only this block will be described in detail in this paper. A description of the regional block can be found in Dias and Lopes (2009) and in Dias and Lopes (2010b).

[1] DPP, a Portuguese Government department with functions in the areas of strategic and macroeconomic planning and policy evaluation, was abolished in 2012. Part of its functions were transferred to APA and, later on (in 2014), to the Prospective and Planning Services (SPP) of SG-MAOTE.

The main differences between MODEM 7 and MODEM 6A are:

- A new product disaggregation (85 products/homogeneous industries, instead of 59, of which six are energy products);
- A more detailed modeling of indirect taxes and of subsidies;
- Modeling of labor supply and of unemployment;
- Endogenisation of public expenditure with unemployment benefits;
- A new modeling approach for company disposable income;
- Introduction of environmental equations, determining CO_2 emissions;
- Use of more updated data for model calibration (including a system of input-output tables estimated for 2008).

2.2. The national block of MODEM 7

The main variables determined by MODEM 7's national block are:

- Sectoral (for 85 industries) and total Output, Gross Value Added and Employment (in full-time equivalents);
- GDP, disposable income, private consumption and imports (total and by products);
- Labor supply, total employment (number of individuals) and unemployment rate;
- Fiscal revenue, decomposed into direct and indirect taxes and social contributions;
- Public expenditure with subsidies on products, unemployment benefits and interest;
- Public deficit and debt;
- CO_2 emissions associated to combustion processes by industry, households and total.

The national block contains 810 equations, of which 702 are simultaneously determined. The following paragraphs describe model specification. The lists of model equations, variables and coefficients are presented in Appendixes 2 and 3 while the list of MODEM 7 products/industries is presented in Appendix 1.

2.2.1. Sectoral (input-output based) equations:

Output (equations 1), Imports (equations 11), Taxes on Products (equations 22) and subsidies on products (equations 30) are determined, for each product, by the corresponding (intermediate and final) demand, using matrices of technical coefficients decomposed into domestic production, import, tax and subsidy coefficients. Exceptions are the output for agricultural, forest and fishery products (sectors 1 to 3 of MODEM 7), which is exogenously determined, the adjustment between demand and supply for these products being made through imports (equations10).

Output of trade services (products 39 to 41 of MODEM 7) and output and imports of land and water transport services (products 42 and 43) have a specific treatment in the model concerning the determination of its final demand, considering that part of these services' output corresponds to trade and transport margins and so the output of these services is also determined by demand (at purchaser's prices) addressed to all products which include a trade or a transport margin in their purchaser's price.

Each component of final demand is decomposed into 85 products (corresponding to the activity sectors considered in the model) and, for each product, into five parts: the part satisfied by domestically produced goods at basic prices, the part corresponding to imported goods CIF; the parts corresponding to taxes and to subsidies on products (the last ones with a negative sign);

and the parts corresponding to trade and to transport margins. This decomposition can be made using coefficients estimated from systems of input-output matrices for the Portuguese economy. However, alternative coefficients may be used in the simulation of demand and price shocks, allowing for a different breakdown by products of demand and/or a different import or tax content of the demand for each product, compared to the reference scenario.

Gross value added (GVA) in each industry is obtained by multiplying the corresponding domestic output by a product transformation coefficient (equations 19).

Employment in each industry (full-time equivalent) is obtained through the division of the respective GVA by the labor productivity estimated for that industry (equations 20).

Total output, imports, GVA and employment (fte) are obtained through the summation of the respective values across all products (equations 34 to 37).

2.2.2. Labor market equations:

Total employment (number of individuals, equation 56) is obtained multiplying the volume of total employment (fte) by an exogenously determined factor.

Labor supply (PA, equation 55) is determined, not only by exogenous demographic factors (such as the size of labor age population and trends in the activity rate) but also by the existing labor opportunities (proxied by the level of total employment), which encourage or not the search for a job and migration movements.

Unemployment (equation 57) is obtained through the difference between labor supply and total employment (number of individuals).

2.2.3. Private consumption, disposable income and GDP:

Residents' private consumption, (CONS, equation 45), is determined by private (Households and Non-Profit Institutions Serving Households, NPISH) disposable income. Households' Final Consumption on the Territory (CT, equation 46) is obtained from CONS through the addition of Tourism Balance and the subtraction NPISH's consumption.

The equation for private disposable income (YD, equation 53) is an identity based on the fact that this income is equal to the difference between National Disposable Income (GDP plus the balances of factor income and of current transfers with the Rest of the World), and the sum of Government and Companies' disposable incomes.

Current transfers with the Rest of the World are exogenous (TREG, TREO, TD2S, ZPC, OZC, OTC) with the exception of taxes on products paid to the European Union (TPC, equation 62), which are modeled decomposed into Value Added tax and other taxes.

Value Added Tax paid to the EU (IVAC, equation 63) is determined by the final demand components representing the main basis of incidence of non-deductible VAT (Households consumption, GFCF and Changes in Valuables) multiplied by an exogenously determined factor.

Other taxes on products paid to the EU (OTPC, equation 64), which are taxes on imports, are a function of total imports.

A part of the balance of factor income with the RoW (equation 54) is an exogenously defined fraction of interest on public debt (the part that is paid abroad).

Companies' disposable income (YDSOC, equation 51) depends on Gross Operating Surplus (EBE) and on company direct taxation (TDSC).

Governments' disposable income is obtained from the difference between Government's total current revenue and total current expenditure (with the exception of public consumption).

Total Gross Operating Surplus (EBE, equation 52) is obtained residually, from the difference between total Gross Value Added and the sum of total compensations of employees with other taxes (net of other subsidies) on production.

GDP at market prices (Y) is obtained from the sum of final demand components and deduction of total imports (equation 50). GDP is also calculated through the sum of total GVA at basic prices with total taxes (net of subsidies) on products (equation 50a). Model specification and the method of calculation of model coefficients theoretically ensure that the results of both methods for GDP calculation are equal but this equation is included in the model simulation as a test (assigning a different name to the dependent variable), with the purpose of detecting any possible errors in model programming or in coefficient estimation.

2.2.4. Public finance equations:

The model has also a fiscal block allowing the simulation of the impact of policy or other shocks on public deficit and debt or, in alternative, the definition of a fiscal policy rule such as establishing a fixed amount for public deficit and making the adjustment through one of the existing variables in the model for public revenue or expenditure. The following paragraphs present the standard version of the equations in the fiscal block, used for the reference simulations, without a fiscal policy rule.

Government Total Balance (SGG, equation 74) is obtained through the difference between total revenue and total expenditure.

Public expenditure components are all exogenous with the exception of unemployment benefits, subsidies on products and interest on public debt.

Total public expenditure with unemployment benefits (SUBDES, equation 71) is obtained from the multiplication of the number of unemployed by an exogenously defined average benefit per unemployed.

The value of subsidies on products paid by the Government (ZPG, equation 67) is calculated through the difference between the global value of subsidies on products (equation 44), obtained from the sum, across all products, of subsidies simulated for each product and the subsidies on products paid by the EU (ZPC, an exogenous variable).

Interest expenditure on public debt (JURG, equation 73) depends on the level of public debt and on an average interest rate, defined exogenously.

Government capital transfers (TRKG) and current transfers with the rest of the world (TREG) are only considered in balance (revenue less expenditure) and are both exogenous.

The other components of public revenue (taxes, social contributions and property income) are all endogenous with the exception of capital taxes (TK) which are practically insignificant and so were made exogenous. Taxes and contributions are functions of the corresponding tax basis (or a proxy of it) multiplied by exogenous tax rates. Taxes are decomposed into four categories: direct taxes on Households plus NPISH, company direct taxes, taxes on products and other taxes on production.

Direct taxes on Households plus NPISH (TD, equation 58) and company direct taxes (TDSC, equation 59) are functions of the respective disposable incomes.

The value of taxes on products received by the Government (TPG, equation 61) is calculated through the difference between the global value of taxes on products (TP, equation 43), obtained from the sum, across all products, of taxes on products simulated for each product, and the taxes on products received by the EU (TPC, equation 62, explained above).

Other taxes on production received by the Government (OTG, equation 65) are calculated from the difference between the total amount of these taxes (OT, equation 42, obtained from the sum of these taxes across all industries) and the part of these taxes that is paid to the EU (OTC), which is treated as exogenous, given its insignificant value. For each industry, other taxes on production are calculated through the application of a tax coefficient to the respective output (equations 21).

Social contributions received by the Government (CSOCG, equation 88) are a function of total compensation of employees (REM, equation 41), which, in turn, are calculated from the aggregation of the respective values across all industries, obtained from the application of wage coefficients to each industry's output.

Government Property Income plus Gross Operating Surplus (REPG, equation 69) is a function of total Gross Operating Surplus generated in the economy.

The change in public debt (DIV, equation 72) depends on government total balance and on an exogenously defined variable (DAT) reflecting the flows affecting public debt but not public deficit.

2.2.5. Environmental equations:

Carbon dioxide emissions associated to combustion processes (ECO2, equations 75 to 77) are obtained through the application of emission factors to each industry's output and to households' consumption.

2.3. Model calibration and reference simulation

2.3.1. General features

Model coefficients are normally estimated for each of the years for which model simulations are necessary, on the basis of available statistical information from National Accounts (for past and present years) and considering scenarios for the Portuguese economy (for future years).

After estimating all the model coefficients for the national block, for a specific year, a model reference simulation is performed for that year using the national block in order to check the correctness of model specification and coefficients estimation, through the comparison of simulated and actual (or projected) values for each variable. Model calibration for each year is only accepted when all values match.

For the present exercise MODEM 7 was calibrated with 2008 data, on the basis of a system of symmetric input-output tables (85×85 products) estimated for Portugal for that year (Dias and Domingos, 2011), which was the most recent system of I-O tables available for Portugal at the time, and of other data from National Accounts, including the Environment Satellite Accounts, and a reference simulation was performed for that year (2008).

Further details regarding the methodology used for model calibration may be found in Appendix 5.

2.3.2 Estimation of the equation for Labor Supply

An econometric estimation was performed for the labor supply equation (equation 55 in Appendix 2), in order to estimate the parameter (cpand) relating labor Supply (PA) and total Employment (ND), using observed data for Portugal from 1981 to 2013. The main results of this estimation are presented in Appendix 4. For this estimation several explanatory variables were used which are exogenous in MODEM 7 (time: T, working age population: P1564 and the combination of both: P1564*T) besides total employment (ND), which is endogenous. Therefore, the following equation was estimated:

$PA = \alpha_0 + \alpha_1 \times \log(T) + \alpha_2 \times P1564 + \alpha_3 \times P1564*T + \alpha_4 \times ND + \varepsilon$

where ε is a residual stochastic variable with expected value equal to zero.

The equation for labor supply included in the model is: PA = PA0+cpand×ND, where PA0 represents the exogenous component of PA, i.e., comparing with the above formulation of the estimated equation:

$PA0 = \alpha_0 + \alpha_1 \times \log(T) + \alpha_2 \times P1564 + \alpha_3 \times P1564*T$ and $cpand = \alpha_4$

The estimated value for cpand is approximately 0.477, representing the increase in labor supply induced by one unit increase in total employment.

2.4. Impact evaluation with MODEM

The various versions of MODEM have been used in the past in the evaluation of demand and income shocks on the Portuguese economy, including those induced by large projects and public investment programs, including those co-financed by the European Union.

Examples of such studies are, at the national level, the evaluation of the impact of EXPO'98, which took place in Lisbon (DPP, 1996; Proença *et al*., 1998) and of the Government Investment and Development Programs, PIDDAC (Dias and Lopes, 2004), and, at the national and regional levels, the evaluations of the National Strategic Reference Framework implemented in 2008-2009 (Dias, Lopes and Martins, 2011) and of Regional Operational Programs (Dias and Lopes, 2001 and 2005).

Figure 1 presents a simplified model diagram showing the main channels of influence of exogenous demand and income shocks on macroeconomic variables.

Impact evaluation at the national level is made through the comparison of the results of two model simulations for each of the years to which the impacts refer to:

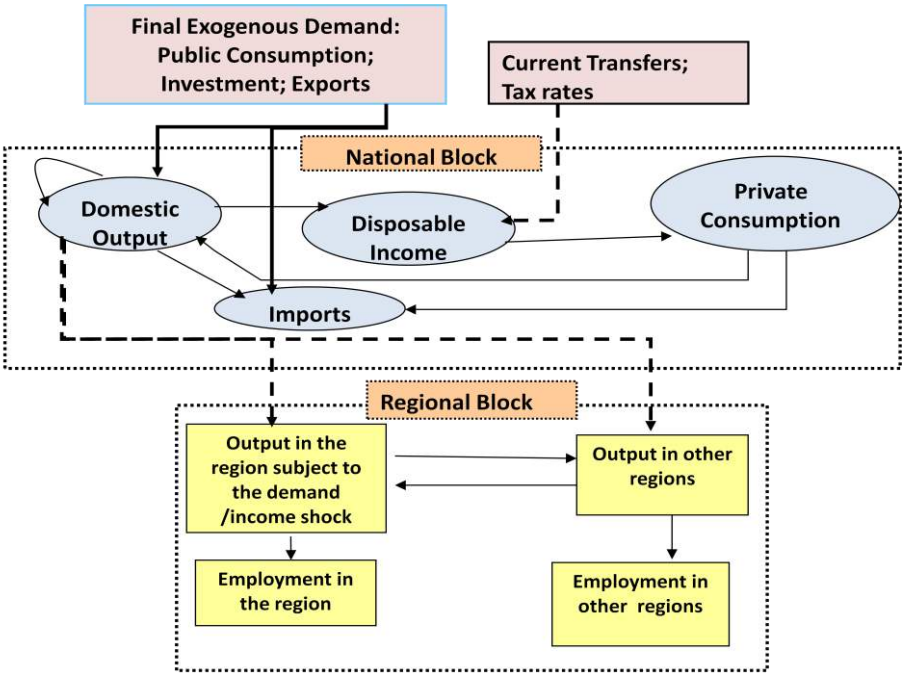
- a reference simulation, reproducing the observed or projected performance for the Portuguese economy;
- a simulation corresponding to what would happen to the economy in the absence (presence) of the exogenous shock subject to evaluation (depending whether the shock is already included or not in the reference simulation). This simulation is performed

after revising the values of the exogenous variables in order to exclude (include) the direct effect of the shock on them.

The macroeconomic impact of the shock is measured through the percent deviation between the two simulations for each model variable.

Figure 1

MODEM and the evaluation of the impact of exogenous demand and income shocks - a simplified diagram



3. THE INPUT-OUTPUT PRICE MODEL AND THE EVALUATION OF THE IMPACT OF A REDUCTION IN THE PRICE OF CRUDE OIL ON DOMESTIC PRICES

A reduction in the international price of crude oil determines, for oil importing countries, a decrease in the unit cost of this commodity with implications on production costs of all products.

As MODEM does not include price variables, an input-output price model was used to estimate the direct and indirect effects of a reduction in the price of imported oil on domestic prices and, subsequently, recalculate MODEM coefficients (at current prices), make new model simulations and compare the results from the new simulations with those from the reference simulation, at both current and reference scenario prices.

The input-output (I-O) Leontief price model is the dual of the input-output Leontief quantity model and while, in the quantity model, output is determined by final demand (demand-pull), in the price model, prices are determined by unit costs (cost-push). A basic description of the quantity and price I-O Leontief models is presented in chapter 2 of Miller and Blair (2009). Martins (2002) presents a more detailed description of the I-O price model.

The I-O price model allows us to determine the impact of an increase in the price of primary inputs (imported inputs, taxes and subsidies on inputs and value added) on production (basic) prices and on purchaser's prices for the various products.

Appendix 6 presents the details of the price model used in this study. The basic equation of the model is, for the case of a shock in import prices (equation 6a of Appendix 6):

$p' = pm' \times AM \times (I - AN)^{-1}$

where p' is the row-vector for production (basic) percent price increases resulting from the increase in import prices, pm' is a row-vector for the percent increase in import prices by products, AM is a (n×n) matrix for the imports coefficients and $(I–AN)^{-1}$ is the so-called "Leontief inverse" (matrix of output multipliers) (see Appendix 6 for a more detailed explanation).

We assumed that a decrease in the international price of crude oil would determine a reduction in the import price not only of crude oil (product no. 5 in MODEM 7 nomenclature, see Appendix 1) but also a reduction in the import price of product 17 (Coke and refined petroleum products) estimated to be 80% of the reduction assumed for the price of crude oil.

From the above equation we can easily deduct that the dimension of the percent change in domestic output prices is proportional to the percent change assumed for import prices.

4. EVALUATION OF THE IMPACT OF A REDUCTION IN CRUDE OIL PRICE ON THE PORTUGUESE ECONOMY

4.1. General features

After the calculation of the impact of each scenario for the import price of crude oil (and refined petroleum products) on domestic prices, we revised MODEM 7 nominal input-output coefficients (at current prices) for each one of the carbon tax alternatives, assuming that I-O coefficients remained unchanged in real terms, using the methodology described in Appendix 7.

The recalibrated MODEM 7 was then used for the simulation of the scenarios with the new oil prices.

In the simulations with the recalibrated MODEM we assumed that the output of industries 1 to 3 (Agriculture, Forestry and Fishing) , which is exogenous in the model, would remain unchanged in volume and so the respective nominal values were updated considering the estimated increases in the production prices for these industries.

For final demand, we assumed that it would remain unchanged in nominal terms, except for Households' Consumption (which is endogenously determined by the model), for Change in Inventories and for Exports (which we assumed that would remain constant in volume[2] for each product and were, therefore, nominally adjusted in function of the respective estimated price changes).

[2] Except for tourism exports, which we assumed to remain constant in nominal terms, and for exports associated to imports (export of transport and insurance services relative to imported goods), which are endogenous in MODEM 7 (with volumes depending on total import volume – see equation 9 in Appendix 2 – and the nominal values obtained from the multiplication of the respective export volumes by the corresponding export prices, estimated in the I-O price model).

The assumption of invariance in nominal terms for the other components of final demand (Public Consumption, Consumption of NPISH and investment) compared to the reference scenario may find a justification in the existence of a budget restriction associated to a price elasticity of demand = -1 for each product.

Table 1 present a summary of the results obtained with MODEM 7 simulations (after model recalibration) compared to the reference scenario, considering several possible levels for the crude oil price decrease.

The impacts on prices (deflators of GDP and of final demand components) presented in this table are based on the calculations from the input-output price model, with adjustments made after MODEM 7 simulations to change the territorial concept (used in the price model) to the residents' concept for households' consumption and for exports.

Given the assumptions and formulation of the input-output price model, the impact of a change in import prices on GDP deflator is zero because the change in the price of imports is totally balanced with the change in the final demand deflators in the GDP deflator equation (equation 8 of appendix 6).

It should be stressed that the estimated impacts are based in the assumption that the cost reductions obtained by producers and traders from the decrease in import prices are totally reflected on production and purchaser's prices, determining a generalized decrease in the price of products. If this not the case, then the estimated impacts may be over-valuated.

The reduction in prices allows an increase in the purchasing power of economic agents, including real households' disposable income, which motivates a growth in private consumption. Real public consumption and (private and public) investment, as well as tourism exports increase in real terms due to the decrease in their price deflators, as we assumed unchanged nominal values for these variables, compared to the reference scenario. As a result, GDP, employments and imports increase. However, due to the terms of trade appreciation, there is an improvement in the balance of goods and services, evaluated in nominal terms.

Public accounts also benefit from the improved economic situation, as fiscal and social contributions revenue expand and expenditure with unemployment benefits contracts (associated to the decrease in unemployment), as well as interest expenditure (due to a reduction in public debt associated with the improvement in public global balance).

Table 1
Impact of a reduction in the price of crude oil in the Portuguese economy
Evaluation with MODEM 7, combined with an I-O price model

deviation from the reference scenario

	percent change in import price of crude oil (in euros)			Approximate impact for each $US 10 fall in the price of crude oil per barrel (a)
	-25%(crude) -20% (refin)	-40%(crude) -32% (refin)	-50%(crude) -40% (refin)	
ECONOMIC IMPACT (%):				
Volume:				
GDP	0.7	1.2	1.5	0.30
Private Consumption	1.2	2.0	2.5	0.50
Public Consumption	0.3	0.4	0.5	0.10
Investment (GFCF)	0.5	0.8	1.1	0.21
Exports	0.1	0.1	0.2	0.04
Imports	0.7	1.1	1.4	0.28
Employment	0.6	1.0	1.3	0.26
Unemployment rate (percentage points)	-0.3	-0.5	-0.7	-0.13
Prices (deflators):				
GDP	0.0	0.0	0.0	0.00
Private Consumption	-0.7	-1.2	-1.5	-0.30
Public Consumption	-0.3	-0.4	-0.5	-0.10
Investment (GFCF)	-0.5	-0.8	-1.0	-0.21
Exports	-1.5	-2.4	-3.0	-0.60
Imports	-2.7	-4.4	-5.5	-1.10
Balance of Goods and Services (% of GDP)	0.5	0.8	1.0	0.20
IMPACT ON PUBLIC ACCOUNTS (10^9 €):				
Revenue:				
Taxes	0.34	0.55	0.69	0.14
Social Contributions	0.13	0.21	0.26	0.05
Expenditure:				
Unemployment benefits	-0.06	-0.10	-0.13	-0.03
Interest on public debt	-0.03	-0.04	-0.05	-0.01
Global Balance	0.59	0.96	1.20	0.24
Global Balance (% of GDP)	0.37	0.59	0.74	0.15
IMPACT ON CO_2 EMISSIONS (%):				
	0.8	1.3	1.7	0.33

(a) Considering a price per barrel of $US 99,70 in the reference scenario, an exchange rate (US dolars per euro) of 1,17 (the same in all scenarios) and assuming that the percent change on the average price of imports of refined petroelum products is 80% of the percent change in the import price of crude oil.

The only variables in the model presenting bad results are CO2 emissions, which register a growth due to the expansion in economic activity and in private consumption, and, probably, also to a more than proportional increase in the consumption of fossil fuels as their prices fall more intensely than average, therefore stimulating their consumption (although this effect was not considered in the model simulations).

The level of the impacts of oil price decreases is roughly proportional to the dimension of the import price change (and exactly proportional in the case of price variables). Therefore, we can say that, for each 10 percentage points of crude import price decrease in euros (or for each US$10 decrease in its price per barrel, which is the same if we consider a reference scenario of about US$100 and a constant dollar/euro exchange rate – as it is in last column of table 1), Portuguese GDP would increase by, approximately, 0.3%.

5. CONCLUDING REMARKS

The results presented in this study for the impact of a reduction of crude oil price on the Portuguese economy should be taken cautiously in consideration, given the following issues:

- These results are based on the assumption that all firms fully transmit the reduction in unit costs into their selling prices when, in reality, some will probably take the opportunity to improve, instead, their profit margins;
- Simulations were based in models calibrated for the Portuguese economy on the basis of observed data for 2008 which may conduct to some overestimation of the impact of oil price reductions as the energy intensity of the Portuguese economy has been falling down since then, particularly is which concerns oil products;
- The almost totally static nature of the models used (except for public debt) presumes that the impact of an external price shock is fully transmitted to the economy almost instantaneously (within a year) when, in reality, there may transmission lags for the various effects and cumulated impacts may be lower than those simulated with the combined I-O price model - MODEM 7 when the price reduction is not long-lasting or when it is not perceived as such by economic agents;
- The methodology used does not fully contemplate the demand-price interactions, such as the effect that the reduction in oil prices may have on the demand for oil products, particularly from households. Therefore, it is likely that the relative impact of oil price reductions on CO2 emissions, compared to the impacts on GDP, is under-valuated.

6. REFERENCES

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APPENDIX 1 – Products/industries considered in MODEM 7

M7	NPCN06	Product description
1	01	Products of agriculture, hunting and related services
2	02	Products of forestry, logging and related services
3	03	Fishing products; aquaculture products; support services to fishing
4	05	Coal and lignite
5	061	Crude petroleum
6	062	Natural gas produced
7	07+08+09	Other mining and quarrying products
8	10	Food products
9	11	Beverages
10	12	Tobacco products
11	13	Textiles
12	14	Wearing apparel
13	15	Leather and related products
14	16	Wood and cork products, except furniture; art. straw and plaiting materials
15	17	Paper and paper products
16	18	Printing and recording services
17	19	Coke and refined petroleum products
18	20	Chemicals and chemical products
19	21	Basic pharmaceutical products and pharmaceutical preparations
20	22	Rubber and plastics products
21	23	Other non-metallic mineral products
22	24	Basic metals
23	25	Fabricated metal products, except machinery and equipment
24	26	Computer, electronic and optical products
25	27	Electrical equipment
26	28	Machinery and equipment n.e.c.
27	29	Motor vehicles, trailers and semi-trailers
28	30	Other transport equipment
29	31	Furniture
30	32	Other manufactured goods
31	33	Repair and installation services of machinery and equipment
32	351+353	Electricity, steam and air conditioning
33	352	Natural gas distributed
34	36	Natural water; water treatment and supply services
35	37+38+39	Sewerage and waste services; materials recovery
36	41	Buildings and building construction works
37	42	Constructions and construction works for civil engineering
38	43	Specialised construction works
39	45	Wholesale and retail trade and repair serv. of motor vehic. and motorcycles
40	46	Wholesale trade services, except of motor vehicles and motorcycles
41	47	Retail trade services, except of motor vehicles and motorcycles
42	49	Land transport services and transport services via pipelines
43	50	Water transport services
44	51	Air transport services
45	52	Warehousing and support services for transportation
46	53	Postal and courier services
47	55	Accommodation services
48	56	Food and beverage serving services
49	58	Publishing services
50	59	Motion picture, video and TV progr. prod. Serv., sound rec. and music publ.
51	60	Programming and broadcasting services
52	61	Telecommunications services
53	62	Computer programming, consultancy and related services
54	63	Information services
55	64	Financial services, except insurance and pension funding
56	65	Insurance and pension funding serv., except compuls. Soc. security
57	66	Services auxiliary to financial services and insurance services
58	6801+6802	Real estate services (except imputed rents of owner-occupied dewllings)
59	6803	Imputed rents of owner-occupied dewllings
60	69	Legal and accounting services
61	70	Services of head offices; management consulting services
62	71	Architectural and engineering services; technical testing and analysis services
63	72	Scientific research and development services
64	73	Advertising and market research services
65	74	Other professional, scientific and technical services
66	75	Veterinary services
67	77	Rental and leasing services
68	78	Employment services
69	79	Travel agency, tour operator and related services
70	80	Security and investigation services
71	81	Services to buildings and landscape
72	82	Office administrative, office support and other business support services
73	84	Public administration and defence services; compuls. Soc. Security serv.
74	85	Education services
75	86	Human health services
76	87	Residential care services
77	88	Social work services without accommodation
78	90	Creative, arts and entertainment services
79	91	Library, archive, museum and other cultural services
80	92	Gambling and betting services
81	93	Sporting services and amusement and recreation services
82	94	Services furnished by membership organisations
83	95	Repair services of computers and personal and household goods
84	96	Other personal services
85	97	Services of households as employers of domestic personnel

APPENDIX 2

EQUATIONS OF MODEM 7 – NATIONAL BLOCK

Note: Unless otherwise specified, indexes *i* and *j* (identifying products/industries) assume the values 1 to 85 (corresponding to MODEM 7 products/industries listed in Appendix1). Summations are across all index values, unless otherwise specified. **Exogenous** variables are presented in **bold** characters.

1. SECTORAL EQUATIONS

1.1. Output, Expenditure and Employment

Domestic Output (except for Agriculture, Forestry and Fishing):

(1) $X_i = \sum_j an_{ij} \times X_j + CTN_i + GN_i + CS15N_i + IN_i + VEN_i + ACOVN_i + EXN_i \quad (i = 4,..,85)$

Private Consumption (households) of domestic goods and services:

(2) $CTN_i = an_{iC} \times CT \qquad (i = 1 \text{ to } 38 \text{ and } 42 \text{ to } 85)$ and:

$$CTN_k = \sum_{i \neq k} tmcc_i^k \times (a_{iC} \times CT) + (a_{kc} - at_{kc} - az_{kc} - am_{kc}) \times CT \qquad (k = 39 \text{ to } 41)$$

Consumption of domestic goods and services by Non-Profit Institutions Serving Households (NPISH):

(3) $CS15N_i = an_{ics15} \times \mathbf{CS15} \qquad (i = 1,...,85)$

Public Consumption of domestic goods and services :

(4) $GN_i = qn_{iG} \times \mathbf{G_i} \qquad (i = 1 \text{ to } 38 \text{ and } 42 \text{ to } 85)$ and

$$GN_k = \sum_{i \neq k} tmcg_i^k \times \mathbf{G_i} + [(a_{kG} - at_{kG} - az_{kG} - am_{KG})/(a_{KG})] \times \mathbf{G_k} \qquad (k = 39 \text{ to } 41)$$

Gross Fixed Capital Formation (GFCF) of domestic goods and services:

(5) $IN_i = qn_{iI} \times \mathbf{I_i} \qquad (i = 1 \text{ a } 38 \text{ and } 44 \text{ to } 85)$ and:

$$IN_k = \sum_{i \neq k} tmci_i^k \times \mathbf{I_i} + [(a_{kI} - at_{kI} - az_{kI} - am_{kI})/(a_{KI})] \times \mathbf{I_K} \qquad \text{for } k = 39 \text{ to } 41$$

$$IN_k = \sum_{i \neq k} tmtni_i^k \times \mathbf{I_i} + [(a_{kI} - at_{kI} - az_{kI} - am_{kI} - amtm_{kI})/(a_{kI})] \times \mathbf{I_k} \qquad \text{for } k = 42, 43$$

Change in Inventories of domestic goods:

(6) $VEN_i = an_{iVE} \times \mathbf{VE} \qquad (i = 1,...,85)$

Net Acquisition of Valuables of domestic goods:

(7) $ACOVN_i = an_{iv} \times \mathbf{ACOV} \qquad (i = 1 \text{ to } 38 \text{ and } 42 \text{ to } 85)$ and:

$$ACOVN_k = \sum_{i \neq k} tmcv_i^k \times (a_{iV} \times \mathbf{ACOV}) + [a_{kV} - at_{kV} - az_{kV} - am_{kV}] \times \mathbf{ACOV} \quad \text{for } k = 39 \text{ to } 41$$

Exports of domestic goods and services at basic prices:

(8) $EXN_i = qn_{iEX} \times EX_i$ (i =1 to 38 and 42 to 85) and:

$EXN_k = \sum_{i \neq k} tmcx_i^k \times EX_{\mathbf{i}} + [(a_{kEX} - at_{kEX} - az_{kEX} - am_{kEX})/(a_{kEX})] \times EX_{\mathbf{k}}$ for k =39 to 41

Exports FOB:

(9) $EX_i = \mathbf{EXS_i} + w_i \times qacif \times MT$ (i = 1,...,85)

Imports of products of Agriculture, Forestry and Fishing:

(10) $M_i = \sum_j a^*_{ij} X_j + a^*_{iC} \times CT + (a^*_{iI}/a_{iI}) \times \mathbf{I_i} + a^*_{iCS15} \times \mathbf{CS15} + GM_i +$

$+GN_i + VEN_i + VEM_i + ACOVN_i + ACOVM_i + EXN_i + EXM_i - \mathbf{X_i}$ (i = 1,2,3)

Imports of other goods and services:

(11) $M_i = \sum_j am_{ij} X_j + CTM_i + CS15M_i + GM_i + IM_i + VEM_i + ACOVM_i + EXM_i$ (i =4,...,85)

Private Consumption (households) of imported goods and services:

(12) $CTM_i = am_{iC} \times CT$ (i = 1,...,85)

Consumption of imported goods and services by NPISH:

(13) $CS15M_i = am_{ics15} \times \mathbf{CS15}$ (i = 1,...,95)

Public Consumption of imported goods and services:

(14) $GM_i = am_{iG} \times \mathbf{G}$ or (14') $GM_i = qm_{iG} \times \mathbf{G_i}$ (i = 1,...,85)

GFCF of imported goods and services:

(15) $IM_i = qm_{iI} \times \mathbf{I_i}$ for $i \neq 42, 43$ and

$IM_k = \sum_{i \neq k} tmtmi_i^k \times \mathbf{I_i} + [(a_{kI} - at_{kI} - az_{kI} - an_{kI} - amtn_{kI})/(a_{kI})] \times \mathbf{I_k}$ for k = 42,43

Change in Inventories of imported goods:

(16) $VEM_i = am_{iVE} \times \mathbf{VE}$ (i = 1,...,85)

Net Acquisition of Valuables of imported goods:

(17) $ACOVM_i = am_{iv} \times \mathbf{ACOV}$ ou (17') $ACOVM_i = qm_{iv} \times \mathbf{ACOV_i}$ (i = 1,...,85)

Exports of imported goods:

(18) $EXM_i = qm_{iEX} \times EX_i$ (i = 1,...,85)

Gross Value Added:

(19) $VAB_j = av_j \times X_j$ (j = 1,...,85)

Employment (full-time equivalent):

(20) $N_j = VAB_j / \mathbf{PROT_j}$ (j = 1,...,85)

1.2. Indirect taxes and subsidies

Other taxes on production:

(21) $OT_i = aot_i \times X_i$ (i = 1,...,85)

Taxes on products:

(22) $TP_i = \sum_j at_{ij} \times X_j + CTP_i + CS15TP_i + GTP_i + ITP_i + VETP_i + ACOVTP_i + EXTP_i$ (i = 1,...,85)

Taxes on products for Households' private consumption:

(23) $CTTP_i = at_{iC} \times CT$ (i = 1,...,85)

Taxes on products for NPISH' Consumption:

(24) $CS15TP_i = at_{iCs15} \times CS15$ (i = 1,...,85)

Taxes on products for Public Consumption:

(25) $GTP_i = qtp_{iG} \times \mathbf{G_i}$ (i = 1,...,85)

Taxes on products for GFCF:

(26) $ITP_i = qtp_{iI} \times \mathbf{I_i}$ (i = 1,...,85)

Taxes on products for Change in Inventories:

(27) $VETP_i = at_{iVE} \times \mathbf{VE}$ (i = 1,...,85)

Taxes on products for Net Acquisition of Valuables:

(28) $ACOVTP_i = at_{iV} \times \mathbf{ACOV}$ (i = 1,...,85)

Taxes on products for Exports:

(29) $EXTP_i = (at_{iEX}/a_{iEX}) \times EX_i$ (i = 1,...,85)

Subsidies on products:

(30) $ZP_i = \sum_j az_{ij} \times X_j + CZP_i + IZP_i + EXZP_i$ (i = 1,...,85)

Subsidies on products for Households' private consumption:

(31) $CTZP_i = az_{iC} \times CT$ (i = 1,...,85)

Subsidies on products for GFCF:

(32) $ITP_i = qzp_{iI} \times \mathbf{I_i}$ (i = 1,...,85)

Subsidies on products for Exports:

(33) $EXZP_i = (az_{iEX}/a_{iEX}) \times EX_i$ (i = 1,...,85)

2. SUMMING UP EQUATIONS

(34) $X = \Sigma X_i$ **Total Output**

(35) $VAB = \Sigma VAB_i$ **Total Gross Value Added**

(36) $N = \Sigma N_i$ **Total Employment (full-time equivalent)**

(37) $MT = \Sigma M_i$ **Total Imports CIF (excluding Tourism)**

(38) $IT = \Sigma \mathbf{I_i}$ **Total GFCF**

(39) $G = \Sigma \mathbf{G_i}$ **Public Consumption**

(40) $EXT = \Sigma EX_i$ **Exports (excluding Tourism)**

(41) $REM = \Sigma arem_i \times X_i$ **Compensation of Employees**

(42) $OT = \Sigma OT_i$ **Other taxes on production**

(43) $TP = \Sigma TP_i$ **Taxes on products**

(44) $ZP = -\Sigma ZP_i$ **Subsidies on products**

3. MACROECONOMIC EQUATIONS

3.1. GDP, Disposable Income and Final Expenditure:

(45) $CONS = \beta \times YD$ **Residents' Private Consumption (Households + NPISH)**

(46) $CT = CONS - CPE -$ **CS15** + **CEP** **Households' Consumption on the Territory**

(47) $CPE = \alpha \times CONS$ **Tourism Imports**

(48) $EX = EXT - qacif \times MT + CEP$ **Exports FOB (incl. Tourism)**

(49) $MF = MT \times (1 - qacif) + CPE$ **Imports FOB (incl. Tourism)**

(50) $Y = CONS+G+IT+$**VE**+**ACOV**$+ EX-MF$ **GDP (obtained from Expenditure)**

(50a) $Y = VAB + TP - ZP$ **GDP (obtained from Value Added)**

(51) YDSOC = ryds × EBE - TDSC **Companies' Disposable Income**

(52) EBE = VAB – REM – OT +**OZG** + **OZC** **Gross Operating Surplus**

Private Disposable Income (Households + NPISH):

(53) YD =REM+EBE+RF+**TREO**–YDSOC–TD–TDSC–CSOCG –REPG + TRIG + JURG

(54) RF=**RF0** - rf1×JURG **Balance of factor income with the RoW**

3.2 Labor Market

(55) PA = **PA0** + cpand×ND **Labor Supply**

(56) ND = ndn×N **Employment (number of individuals)**

(57) DESEMP = PA – ND **Unemployment**

3.3. Public Finances

(58) TD = rtdyd × YD **Direct Taxes on Households + NPISH**

(59) TDSC = rtdsy × YDSOC **Company Direct Taxes**

(60) TIG = TPG+OTG; **Indirect taxes received by the Government**

(61) TPG=TP-TPC **Taxes on products received by the Government**

(62) TPC=IVAC+OTPC **Taxes on products received by the EU**

(63) IVAC=rivac*(CT+I+ACOV); **VAT received by the EU**

(64) OTPC=rotpc*MT; **Other taxes on products received by the EU**

(65) OTG=OT-OTC; **Other taxes on production received by the Government**

(66) SUBG=ZPG+**OZG**; **Total Subsidies on production paid by the Government**

(67) ZPG=ZP-**ZPC**; **Subsidies on products, paid by the Government**

(68) CSOCG=tcsocg ×REM **Social Contribuitions received by the Government**

(69) REPG = repge × EBE **Government Gross Operating Surplus+Net Property Income**

(70) TRIG=**TRIG0**+SUBDES **Balance of Current transfers from the Government to private agents**

(71) SUBDES = **SUBU**×DESEMP **Unemployment Benefits**

(72) DIV = DIV(-1) – SGG + **DAT** **Public Debt**

(73) JURG = **RG** × DIV **Interest on public debt**

Government Total Balance:

(74) SGG = TD + TDSC + **TD2S** + CSOCG + TIG - SUBG + REPG – **G** – TRIG + **TREG** – JURG + **TK** + **TRKG** – **IG**

4. ENVIRONMENTAL EQUATIONS

CO_2 emissions, associated to combustion processes, resulting directly from productive ativities:

(75) $ECO2_i = cco2_i \times X_i$ (i= 1,…,85)

CO_2 emissions resulting directly from households' comsumption:

(76) $ECO2_c = cco2_c \times CT$

Total CO_2 emissions, associated to combustion processes:

(77) $ECO2 = \sum_i ECO2_i + ECO2_c$

APPENDIX 3

LIST OF MODEL VARIABLES AND COEFFICIENTS – NATIONAL BLOCK

Notes: The variables that are not identified as exogenous (in brackets) are endogenous. For simplification indexes (referring to products/industries - i,j,k) have been omitted in most cases.

Index F is used as a generic designation for final demand components: C (Households' final consumption in the territory), CS15 (NPISH's final consumption), G (Government final consumption), I (GFCF), VE (Change in inventories), V (Net acquisition of valuables) and EX (Exports FOB, from the territorial point of view).

1. VARIABLES:

ACOV – Net Acquisition of valuables **(exogenous)**

ACOVTP – Taxes on Net Acquisition of Valuables

ACOVN – Net Acquisition of Valuables of domestic goods at basic prices

ACOVM – Net Acquisition of Valuables of imported goods (CIF)

CEP – Exports of Tourism (**exogenous** by products)

CONS – Residents' Private Consumption (Households + NPISH)

CPE – Imports of Tourism

CS15 – Consumption of Non-Profit Institutions Serving Households (NPISH) **(exogenous)**

CS15TP – Taxes on Final Consumption by NPISH

CS15M – Consumption of imported goods by NPISH (CIF)

CS15N – Consumption of domestically produced goods by NPISH, at basic prices

CSOCG – Social Contributions received by the Government

CT – Households' Private Consumption on the Territory at purchasers' prices

CTM – Households' Private Consumption of imported goods (CIF), on the Territory

CTN – Households' Private Consumption of domestically produced goods, on the Territory, at basic prices

CTTP – Taxes on Households' Private Consumption on the Territory

CTZP – Subsidies on Households' Private Consumption on the Territory

DAT – Change in public debt not associated to public deficit **(exogenous)**

DESEMP – Number of unemployed

DIV – Public debt

EBE – Total Gross Operating Surplus (including mixed income)

ECO2 – Total carbon dioxide emissions, associated to combustion processes, directly associated to production and to households' final consumption.

$ECO2_c$ – Carbon dioxide emissions, associated to combustion processes, directly associated to households' final consumption.

$ECO2_i$ – Carbon dioxide emissions, associated to combustion processes, directly associated to production of product *i*.

EX_i – Exports (FOB) of product *i*

EX – Total Exports FOB, including Tourism

EXM_i – Exports of imported goods CIF (product *i*)

EXN_i – Exports of domestically produced goods at basic prices (product i)

EXS_i – Exports of product *i* after deducting CIF/FOB adjustment **(exogenous)**

$EXTP_i$ – Taxes on Exports of product *i*

EXT – Total exports (excluding Tourism)

$EXZP_i$ – Subsidies on Exports of product *i*

G – Public Consumption **(exogenous** by products**)**

GM – Public Consumption of imported goods, CIF

GN – Public Consumption of domestically produced goods at basic prices

GTP_i – Taxes on Public Consumption of product *i*

I – GFCF at purchasers' prices **(exogenous** by products**)**

IG – Public investment (GFCF) **(exogenous)**

IM – GFCF in imported goods, CIF

IN – GFCF in domestically produced goods, at basic prices

IT – Total GFCF at purchasers'prices

ITP_i – Taxes on product i used for GFCF.

IVAC – VAT paid to the EU.

IZP_i – Subsidies to product i used for GFCF.

JURG – Interest on public debt

M_i – Imports CIF of product *i*

MF – Total Imports FOB, including Tourism

MT – Total Imports CIF, excluding Tourism

N – Employment (Full-time equivalents)

ND – Employment (number of individuals)

OT – Other taxes on production (excluding taxes on products)

OTC – Other taxes on production received by the EU (**exogenous**).

OTG – Other taxes on production received by the Government.

OTPC – Other taxes on products (excluding VAT) received by the EU.

OZC – Other subsidies on production (excluding subsidies on products) paid by EU **(exogenous).**

OZG – Other subsidies on production (excluding subsidies on products) paid by the Government **(exogenous).**

PA – Labor supply.

PA0 – Exogenous component of PA **(exogenous).**

PROT – Labor productivity **(exogenous)**

REM – Compensation of employees

REPG – Government Gross Operating Surplus+Net Property Income

RF – Balance of factor income with the Rest of the World (RoW).

RF0 – Exogenous component of RF.

RG – Interes rate on public debt **(exogenous)**

SGG – Government Total Balance

SUBDES – Total value of unemployment benefits (paid by the Government).

SUBG – Subsidies to production paid by the Government (total).

SUBU – Average unemployment benefit per unemployed (**exogenous**).

TD – Direct Taxes on Households+NPISH

TDSC – Direct taxes on companies.

TD2S – Balance of direct taxes with the RoW (received by the Government and payed by Households) **(exogenous)**

TIG – Indirect taxes received by the Government (total).

TK – Capital taxes **(exogenous).**

TP – Taxes on products

TPC - Taxes on products received by the EU.

TPG - Taxes on products received by the Government.

TRE – Balance of private current transfers with the RoW **(exogenous)**

TREG – Balance of current transfers between the Government and the RoW (received less paid by the Government) **(exogenous).**

TREO - Balance of other current transfers with the RoW (received less paid by the national economy, excluding TREG, TD2S and transfers of indirect taxes and subsidies) **(exogenous).**

TRIG – Balance of current transfers between the Government and other internal agents (payed less received by the Government) **(exogenous).**

TRIG0 – Exogenous component of TRIG **(exogenous).**

TRKG – Balance of Government Capital transfers (received less paid) **(exogenous)**

VAB – Gross Value Added at Basic prices.

VE – Change in Inventories at purchasers' prices **(exogenous)**

VETP – Taxes on Change in Inventories.

VEM – Change in Inventories of imported goods CIF

VEN – Change in Inventories of domestically produced goods at basic prices.

X – Domestic Output at basic prices.

Y – Gross Domestic Product (GDP) at market prices.

YD – Private Disposable Income (Households + NPISH)

2. COEFFICIENTS:

$\mathbf{a^*_{iF}}$ – Share of product *i* (at basic prices) in total final demand of type F (at purchasers' prices) ($a^*_{iF} = an_{iF} + am_{iF}$);

$\mathbf{a^*_{ij}}$ – quantity of product *i* (at basic prices) necessary to produce one unit of product *j* (at basic prices) ($a^*_{ij} = an_{ij} + am_{ij}$);

$\mathbf{a_{iF}}$ - Share of product *i* (at purchasers' prices) in total final demand of type F (at purchasers' prices).

$\mathbf{a_{ij}}$ - Total technical coefficient of order (i, j), representing the quantity of product *i* (at purchasers' prices) necessary to produce one unit of product *j* (at basic prices).

$\mathbf{am_{iF}}$ - Share of imported product good *i* (CIF) in total final demand of type F (at purchasers' prices);

$\mathbf{am_{ij}}$ - Quantity of imported product *i* (CIF) used to produce one unit of product *j* (at basic prices);

$\mathbf{amc_{iF}}$ - Trade margin coefficient of order (i,F), representing the weight of trade margins on product *i* in total value of final demand of type F (at purchasers' prices).

$\mathbf{amc_{ij}}$ - Trade margin coefficient of order (i,j), representing the weight of the trade margin on intermediate product *i* in total value of production of product *j* (at basic prices).

$\mathbf{amt_{iF}}$ - Transport margin coefficient of order (i,F), representing the weight of transport margins on product *i* in total value of final demand of type F (at purchasers' prices).

$\mathbf{amt_{ij}}$ - Transport margin coefficient of order (i,j), representing the weight of transport margins on intermediate product *i* in total value of production of product *j* (at basic prices).

$\mathbf{amtm_{kF}}$ - Simetric of the share of transport margins satisfied by imports in total final demand of type F (at purchasers' prices).

$\mathbf{amtn_{kF}}$ - Simetric of the share of transport margins satisfied by domestic output in total final demand of type F (at purchasers' prices)

$\mathbf{an_{iF}}$ - Share of domestically produced good *i* (at basic prices) in total final demand of type F (at purchasers' prices);

$\mathbf{an_{ij}}$ - Quantity of domestically produced good *i* (at basic prices) used to produce one unit of product *j* (at basic prices);

$\mathbf{aot_i}$ - Share of Other Taxes on Production in the value of domestic output of product *i*, at basic prices.

$\mathbf{arem_i}$ - Share of compensations of employees in the value of domestic output of product *i*, at basic prices.

$\mathbf{at_{iF}}$ - Share of taxes on products paid for product *i* in total final demand of type F (at purchasers' prices).

at_{ij} - Share of taxes on inputs of product *i* in the value of domestic output of product j (at basic prices).

av_i - Product transformation coefficient for product *i* (share of GVA in the value of domestic output of product *i*, at basic prices).

az_{iF} – Share of subsidies on product i, in total final demand of type F (at purchasers' prices).

az_{ij} – Share of subsidies on inputs of product *i* in the value of domestic output of product j (at basic prices).

$cco2_i$ - CO2 emission coefficient (combustion) of industry i (kgCO2 per euro of output at basic prices).

$cco2_c$ - CO2 emission coefficient of households' final consumption (kgCO2 per euro of households' total consumption).

cpand – change in labor supply per unit of change in total employment (estimated coefficient).

ndn – ratio between Employment (number of individuals, ND) and Employment (full-time equivalent, N) .

qacif – CIF/FOB adjustment coefficient.

qm_{iF} – Share of Imports CIF in the value (at purchasers' prices) of final demand of type F for product *i*

qn_{iF} – Share of domestic output (at basic prices) in the value (at purchasers' prices) of final demand of type F for product *i* .

qtp_{iF} –Share of taxes in the value (at purchasers' prices) of final demand of type F for product *i*.

qzp_{iF} – Share of subsidies in the value (at purchasers' prices) of final demand of type F for product *i* .

repge – Share of REPG in total Gross Operating Surplus (EBE).

rf1 – Share of the interest on public debt that is paid to the RoW on total interest on public debt.

rivac – Ratio between VAT paid to the EU and its main basis of incidence (Households' consumption + GFCF + ACOV).

rotpc – Ratio between other taxes on products received by the EU (OTPC) and total imports CIF (MT).

rtdsy – Ratio between company direct taxes (TDSC) and company's disposable income (YDSOC).

rtdyd – Ratio between direct taxes (TD) and Households+NPISH' disposable income (YD)

tcsocg – Share of Social Contributions paid to the Government (CSOCG) in total Compensation of Employees (REM).

$tmcc_i^k$ – Trade margin rate of type k on households'consumption of product i.

$tmcg_i^k$ – Trade margin rate of type k on public consumption of product i.

$tmci_i^k$ – Trade margin rate of type k on GFCF of product i.

$\mathbf{tmcv}_i^k$ – Trade margin rate of type k on Net Acquisition of valuables of product i.

$\mathbf{tmcx}_i^k$ – Trade margin rate of type k on Exports of product i.

$\mathbf{tmtni}_i^k$ – Transport margin of type k on GFCF of product i, satisfied by domestic output.

$\mathbf{tmtmi}_i^k$ – Transport margin of type k on GFCF of product i, satisfied by imports.

$\mathbf{w_i}$ – Share of product *i* in total CIF/FOB adjustment

α – Share of Tourism Imports (CPE) in Private Consumption (CONS).

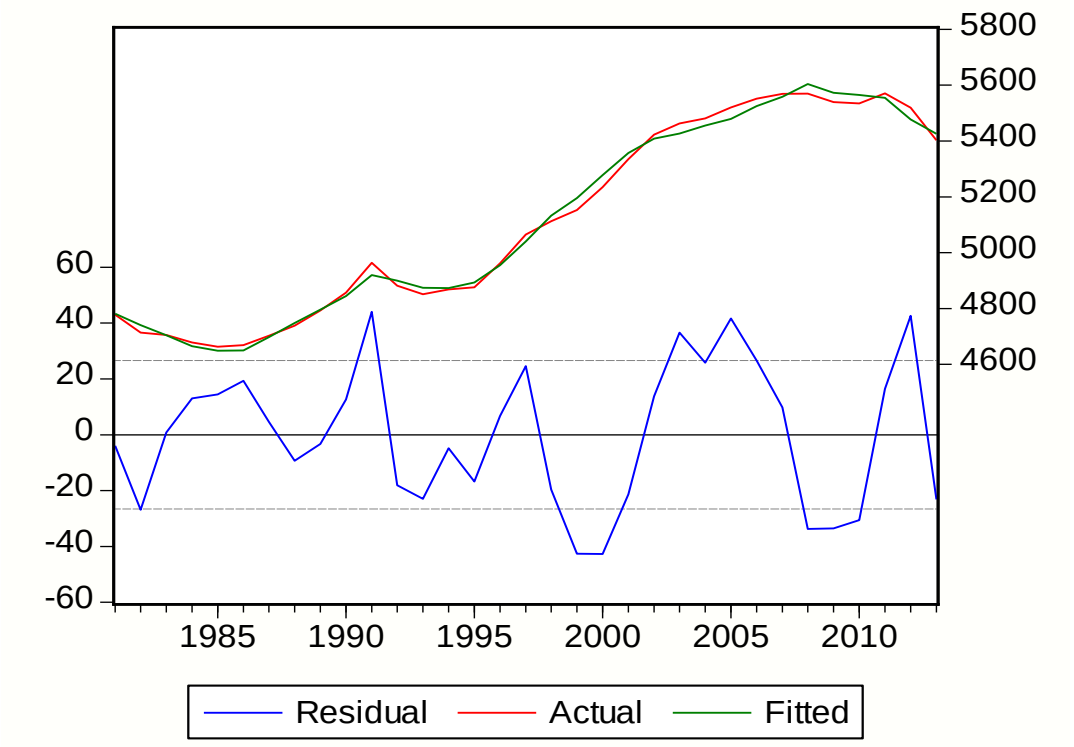
β – Average propensity to consume.

APPENDIX 4
ESTIMATED EQUATION FOR LABOR SUPPLY

Dependent Variable: PA
Method: Least Squares
Date: 03/25/14 Time: 17:18
Sample: 1981 2013
Included observations: 33

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3760.522	124.6593	30.16639	0.0000
LOG(T)	-699.1392	51.38528	-13.60583	0.0000
P1564*T	0.007605	0.000322	23.62053	0.0000
ND	0.477171	0.025399	18.78699	0.0000

R-squared	0.994597	Mean dependent var	5113.465
Adjusted R-squared	0.994039	S.D. dependent var	344.6832
S.E. of regression	26.61310	Akaike info criterion	9.513897
Sum squared resid	20539.46	Schwarz criterion	9.695292
Log likelihood	-152.9793	F-statistic	1779.613
Durbin-Watson stat	1.122522	Prob(F-statistic)	0.000000



APPENDIX 5

DETAILS OF MODEL CALIBRATION
(NATIONAL BLOCK OF MODEM 7 AND PRICE MODEL)

For the national block of MODEM 7 (in order to be used in the reference simulation) and for the input-output price model, **technical coefficients** for 2008 were calculated from the following set of symmetric input-output tables of 85 by 85 products and seven final demand categories (Dias and Domingos, 2011):

- FT : Total Flows at purchasers'prices;
- PN: Domestic Output at basic prices;
- M : Imports CIF;
- T: Taxes on products;
- Z: Subsidies, on products (with negative signs for each subsidy);
- MCk: Trade Margins of type k, for (using the numbering of MODEM 7 products, presented in the first column of Appendix 1) k =39 (trade of motor vehicles), 40 (other wholesale trade) and 41 (other retail trade) (three I-O tables);
- MCT: Total trade margins (MCT = MC39+MC40+MC41);
- MTNk: Transport Margins of type k, satisfied by domestic output, for k= 42 (land transport) and 43 (water transport) (two I-O tables);
- MTMk: Transport Margins of type k, satisfied by imports, for k = 42 and 43 (two I-O tables);
- MTT: Total transport margins (MTT= MTN42+MTN43+MTM42+MTM43).

Let MAT_{ij} or MAT_{iF} represent the elements of order (i,j) or (i,F) of the corresponding input-output table for MAT= the abovementioned I-O tables, X_j = domestic output of product j at basic prices, F= one of the seven final demand categories: C (Households' consumption), CS15 (NPISH's final consumption), G (Government final consumption), I (GFCF), VE (Change in inventories), V (Net acquisition of valuables), EX (Exports) and Ftot= total value (at purchasers' prices) of final demand of type F.

Technical coefficients were calculated using the following formulas (see Appendix 3 for coefficients definition/description):

$a_{ij}=FT_{ij}/X_j$

$a_{iF}=FT_{iF}/Ftot$

$an_{ij}=PN_{ij}/X_j$

$an_{iF}=PN_{iF}/Ftot$

$am_{ij}=M_{ij}/X_j$

$am_{iF}=M_{iF}/Ftot;$

$amc_{ij}=MCT_{ij}/X_j$

$amc_{iF}=MCT_{iF}/Ftot$

$amt_{ij} = MTT_{ij}/X_j$

$amt_{iF} = MTT_{iF}/Ftot$

$a^*_{ij} = an_{ij} + am_{ij}$

$a^*_{iF} = an_{iF} + am_{iF}$

$at_{ij} = T_{ij}/X_j$

$at_{iF} = T_{iF}/Ftot$

$av_i = VAB_i/X_i$

$arem_i = REM_i/X_i$

$aot_i = OT_i/X_i$

$amtm_{kF} = MTMk_{kF}/Ftot = (-\sum_{i \neq k} MTMk_{iF})/Ftot$

$amtn_{kF} = MTNk_{kF}/Ftot = (-\sum_{i \neq k} MTNk_{iF})/Ftot$

$az_{iF} = Z_{iF}/Ftot$

$az_{ij} = Z_{ij}/X_j$

It was also necessary to calculate **trade and transport margins' rates** for each product and component of final demand. These rates are used for the simulation of the output of industries supplying trade services (39 to 41) and of output and imports[3] of land (42) and water (43) transport services whenever the structure of some final demand components is different from the reference structure (based on I-O tables). This need derives from the fact that margin rates have a wide variation across the 59 product considered in the model (for example, they are null for Construction and Services).

Trade margin rate of type k on final demand of type F for product *i* was calculated by the following formula:

$tmcF_i^k = MCk_{iF} / FT_{iF}$ for F=C, G, I, V, EX; k = 39, 40, 41; $i \neq k$

Transport margin rates of type k on final demand of type F for product *i* , satisfied, respectively by domestic output and by imports wer calculated by the following formulas:

$tmtnF_i^k = MTNk_{iF} / FT_{iF}$ (satisfied by domestic output)

$tmtmF_i^k = MTMk_{iF} / FT_{iF}$ (satisfied by imports)

for F = C, I; k = 42, 43; $i \neq k$

The **shares** of **domestic output**, **imports**, **taxes** and **subsidies on** the value (at purchasers'prices) of each product's **final demand** are calculated by the following formulas:

$qn_{iF} = PN_{iF}/FT_{iF}$ (for i = 1 to 38 and 42 to 85);

[3] It should be noted that, while trade margins are entirely satisfied by domestic output, this may not be the case for transport margins, which can be partially satisfied by imports.

$qm_{iF} = M_{iF}/FT_{iF}$ (for i = 1 to 40 and 42 to 85);

$qtp_{iF} = T_{iF}/FT_{iF}$ (for i = 1 to 85);

$qzp_{iF} = Z_{iF}/FT_{iF}$ (for i = 1 to 85).

Labor productivity in each industry was calculated dividing the respective observed GOS by the corresponding observed employment volume (in full-time equivalent):

$PROT_i = VAB_i / N_i$

For the years for which this data is not available, productivities are estimated/projected on the basis on other available information or on scenarios for the Portuguese economy.

Carbon dioxide coefficients were calculated, for the present exercise, by the following formulas:

$cco2_i = ECO2_i / X_i$

$cco2_c = ECO2_c / CT$

The values for X_i and CT were taken from the symmetric I-O tables for Portugal, 2008 (Dias and Domingos, 2011), while the values for carbon dioxide emissions ($ECO2_i$ and $ECO2_c$) were estimated by the process described on section 3.

APPENDIX 6
DETAILS OF THE INPUT-OUTPUT PRICE MODEL

A.6.1. Impact of primary input price increases on production (basic) prices

The value of production (at basic prices) in each industry is equal to the sum of the respective intermediate consumptions with this industry's Gross Value Added.

Considering the terminology used for MODEM 7 and for its calibration (see appendixes 3 and 5), we can write the following equation for each industry j:

(1) $X_j = \sum_i (PN_{ij} + M_{ij} + T_{ij} + Z_{ij}) + VAB_j$

where X_j is the output (at basic prices) of industry (product) j, PN_{ij} is the intermediate consumption of domestically produced good i (at basic prices) by industry j, M_{ij} is the intermediate consumption of imported good i (CIF) by industry j, , T_{ij} and Z_{ij}, are, respetively, taxes and subsidies on intermediate consumption of good i (domestically produced and imported) by industry j and VAB_j is the Gross Value Added generated in industry j.

M_{ij}, T_{ij}, Z_{ij} and VAB_j are the so-called "primary inputs": imported inputs, taxes and subsidies on inputs and value added.

Dividing both members of equation (1) by X_j we obtain the equation for unit costs (technical coefficients), which add up to 1:

(2) $1 = \sum_i (an_{ij} + am_{ij} + at_{ij} + az_{ij}) + av_j$

In case of a price increase in any of the primary inputs, the input-output price model allows us to calculate its impact on each product's production (basic) and purchaser's price, assuming that production technical coefficients remain unchanged in real terms.

Let p_j, pm_{ij}, pt_{ij}, pz_{ij} and pv_j be the percent price increases for, respectively, industry (product) j's domestic output, imported inputs, taxes and subsidies on inputs and value added. We assume that each product's basic production price is the same irrespectively of its use and so we can write the following equation, pre-multiplying each term of equation (2) by the respective price increase:

(3) $p_j = \sum_i (p_i \times an_{ij} + pm_{ij} \times am_{ij} + pt_{ij} \times at_{ij} + pz_{ij} \times az_{ij}) + pv_j \times av_j$

Rearranging equation (3), we obtain, equivalently:

(4) $p_j - \sum_i (p_i \times an_{ij}) = \sum_i (pm_{ij} \times am_{ij} + pt_{ij} \times at_{ij} + pz_{ij} \times az_{ij}) + pv_j \times av_j$

Considering a system of equations similar to equation (4) for all products and using matrix notation, with **p** and **pv** being column vectors (n×1) for respectively p_j and pv_j values, ***i*** a unit vector (n×1), **pm**, **pt** and **pz** matrices (n×n) for all pm_{ij}, pt_{ij}, and pz_{ij} values, AN, AN, AM, AT and AZ matrices (n×n) for all an_{ij}, am_{ij}, at_{ij}, and az_{ij} coefficients, diag(AV) a diagonal matrix (n×n) for all av_j coefficients, the symbols ◦ and ' representing, respectively, Hadamard product

and matrix transposition, and suppressing some multiplication signs for simplification, we obtain :

(5) $p'(I-AN) = i'[pm \circ AM + pt \circ AT + pz \circ AZ] + pv'diag(AV)$

and finally:

(6) $p' = \{i'[pm \circ AM + pt \circ AT + pz \circ AZ] + pv'diag(AV)\}(I-AN)^{-1}$

Equation (6) expresses the general formula of the input–output price model for the determination of production price changes as a function of primary input price changes.

$(I-AN)^{-1}$ is the so-called "Leontief inverse", which is the matrix of output multipliers. The element of order (i,j) of this matrix represents the quantity of output of product i necessary to satisfy one unit of final demand for product j (domestically produced), considering both at basic prices.

In the case of the present study, equation (6) can be simplified as we assume that the only primary inputs that have changes are imports. Therefore, pt, pz and pv are, in this case, null matrices. Given the fact that crude oil is a commodity, we will also assume that the price change in its import price is the same across all uses and we will also assume that the only other import price that will change, as a direct result of the change in crude oil price, is for refined petroleum products (product no. 17 in MODEM 7 nomenclature, see Appendix 1), which we estimate to be (by simplification) a fixed percentage (80%) of crude oil import price change, independently of the sector of destination of the imports. Therefore, equation 6 simplifies to:

(6a) $p' = pm' \times AM \times (I-AN)^{-1}$

A.6.2. Impact of primary input price increases on final demand and GDP deflators

After calculating the impacts of primary input price increases on production prices, we can estimate the impacts on final demand deflators using the following formula:

(7) $pft = p' \times ANF + pmf' \times AMF + ptf' \times ATF + pzf' \times AZF$

where pft is a scalar representing the percent change of the (global) deflator of final demand of type F (at purchasers' prices), ANF, AMF, ATF and AZF are column-vectors (n×1) for the an_{iF}, am_{iF}, az_{iF} and az_{iF} coefficients (see appendixes 3 and 5 for coefficients' definition and method of calculation) and pmf, ptf and pzf are column-vectors (n×1) for the percent changes in the prices of, respectively, imports, taxes and subsidies for final demand of type F.

In the case of the present study ptf and pzf are null vectors and, assuming that pmf = pm, equation (7) simplifies to:

(7a) $pft = p' \times ANF + pm' \times AMF$

The impact on GDP deflator is subsequently calculated by the formula:

(8) $py = [\sum_{F}(pft \times Ftot) - \sum_{i}(pm_i \times M_i)]/Y$

for F = all components of final demand and Ftot, M_i and Y the values of total final demand of type F, imports of product i and GDP in the reference scenario.

A.6.3. Impact of primary input price increases on each product's purchasers' price, by types of final demand

After calculating the impact of primary input price increases on production (basic) prices, we can also calculate the impact on each product's purchasers' price, using the following formula:

(9) pf' = p'×QNF + pmf'×QMF + ptf'×QTF + pzf'×QZF

where pf', pmf', ptf' and pzf' are row vectors (1×n) for the percent changes of each product' s price for, respectively, final demand of type F, imports, taxes and subsidies on products (falling upon final demand of type F) and QNF, QMF, QTF and QZF are square matrices (n×n) representing unit direct contents of, respectively, domestic output, imports, taxes and subsidies for final demand of type F. The element of order (i,j) of each one of these matrices (qnf_{ij}, qmf_{ij}, qtf_{ij}, qzf_{ij}) represent, respectively, domestic output (at basic prices), imports (CIF), taxes and subsidies on product i, per unit of final demand of type F (at purchaser's prices) for product j (direct contents).

While QTF and QZF are diagonal matrices, QNF and QMF have some off-diagonal elements which are different from zero, in the rows corresponding to trade (rows 39 to 41 – see Appendix 1) and (land and water) transport (rows 42 and 43) products (for QNF) and to (land and water) transport products (for QMF), to account for the direct effects of final demand of a product, with trade and/or transport margins included in its purchaser's price, on the output (and also on imports, in the case of transports) of trade and transport products.

The elements of these matrices were calculated, for the present exercise, using the same system of input-output tables (for Portugal, 2008) used to calibrate MODEM 7 (Dias and Domingos, 2011). The methodology used for calculating these matrices is similar to the one presented in Dias (2011), with the necessary adaptations resulting from the change in products nomenclature and from the separation between Taxes and Subsidies on products made in this study.

It should be stressed that the diagonal elements of these matrices are also present in MODEM 7 specification, but using a slightly different terminology (on the right-hand side of the following identities, for F = G, I, V, EX):

$qnf_{ii} \equiv qn_{iF}$ (for i = 1 to 38 and 42 to 85);

$qmf_{ii} \equiv qm_{iF}$ (for i = 1 to 40 and 42 to 85);

$qtf_{ii} \equiv qtp_{iF}$ (for i = 1 to 85);

$qzf_{ii} \equiv qzp_{iF}$ (for i= 1 to 85).

For the trade and transport rows in the QNF matrix, we used the following method of calibration (using the methodology described in Dias, 2011, with the necessary adaptations):

qnf_{ii}= (PN_{iF} +MCi_{iF})/FT_{iF} for i = 39 to 41 (direct domestic output content of final demand addressed to trade sectors that does not correspond to trade margins[4])

qnf_{ij} =MCi_{jF}/FT_{jF} (trade margin rate of type i on final demand of type F for product j), for $i \neq j$ and i = 39 to 41 (trade sectors)

qnf_{ii}=(PN_{iF} +$MTNi_{iF}$)/FT_{iF} for i=42, 43 (direct domestic output content of final demand addressed to land and water transport sectors that does not correspond to transport margins[5])

qnf_{ij} =$MTNi_{jF}$/FT_{jF} (transport margin rate of type i on final demand of type F for product j), for $i \neq j$ and i = 42,43 (land and water transport sectors)

Similarly, and considering that one part of of the imports of land and water transport services corresponds to transport margins (satisfied by imports), we calculated the elements of the land and water transport rows in the QMF matrix in the following way:

qmf_{ii}=(M_{iF}+$MTMi_{iF}$)/FT_{iF} for i = 42, 43 (import contents of final demand addressed to land and water transport sectors which do not correspond to imported transport margins [6])

qmf_{ij} =$MTMi_{jF}$/FT_{jF} (transport margin rate of type i, satisfied by imports, on final demand of type F, for product j), for $i \neq j$ and i = 42, 43 (land and water transports).

Comparing the elements of QNF and QMF which correspond to trade and transport margins, we have following equivalence with MODEM 7 parameters:

$qnf_{ij} \equiv tmcF_j^i$ for $i \neq j$ and i = 39 to 41 (trade sectors)

$qnf_{ij} \equiv tmtnF_j^i$ for $i \neq j$ and i = 42, 43 (land and water transports)

$qmf_{ij} \equiv tmtmF_j^i$ for $i \neq j$ and i = 42, 43 (land and water transports)

In the case of the present study, **ptf** and **pzf** are null vectors and, assuming again that pmf = pm, equation (9) simplifies to:

(9a) pf' = p'×QNF + pmf'×QMF

[4] Note that MCi_{iF} and $MTNi_{iF}$ have negative values when i = trade/transport sectors, which are equal to the symmetric of the total value of the respective margins applied to the various products (*vide* Dias, 2009, page 4, 3rd paragraph). Therefore the sums (PN_{iF} +MCi_{iF}) and (PN_{iF} +$MTNi_{iF}$) represent the part of sector i's domestic output that does not correspond to margins of type i.

[5] *Vide* previous note.

[6] Note that $MTMi_{iF}$ has a negative value when i = land and water transport sectors, which is equal to the symmetric of the total value of the respective transport margins (satisfied by imports) applied to the various products (*vide* Dias, 2009, page 4, 3rd paragraph). Therefore the sum (M_{iF} +MTM_{iF}) represents the part of sector i's imports that does not correspond to imported transport margins of type i.

APPENDIX 7
METHODOLOGY FOR MODEM7 RECALIBRATION AFTER A PRICE SHOCK

After the calculation of the impact of an increase in the price of primary inputs on production prices, we can revise MODEM 7 nominal input-output coefficients (at current prices), assuming that I-O coefficients remain unchanged in real terms, through the following formulas (using the upper index 0 for original values and 1 for revised values, used in the simulations with the carbon tax) (see appendixes 3 and 5 for coefficients definition/description and for the method of their calculation for the reference scenario):

$an_{ij}^{1} = an_{ij}^{0} \times (P_i/P_j)$ (coefficients for domestic *inputs*);

$am_{ij}^{1} = am_{ij}^{0} \times (PM_i/P_j)$ (coefficients for imported inputs);

$az_{ij}^{1} = az_{ij}^{0} \times (PZ_{ij}/P_j)$ (coefficients for subsidies on products);

$at_{ij}^{1} = at_{ij}^{0} \times (PT_{ij}/P_j) = (at_{ij}^{0} + \Delta T_{ij}/X_j^{0})/P_j$ (coefficients for taxes on products);

$a_{ij}^{1} = an_{ij}^{1} + am_{ij}^{1} + at_{ij}^{1} + az_{ij}^{1} + amc_{ij}^{0} + amt_{ij}^{0}$ (total technical coefficients);

$av_j^{1} = av_j^{0} \times PV_j/P_j$ (value added coefficients);

$arem_j^{1} = arem_j^{0} \times PREM_j/P_j$ (coefficients for compensation of employees);

$aot_j^{1} = aot_j^{0} \times POT_j/P_j$ (coefficients for other taxes on production)

$tmcF_i^{k(1)} = tmcF_i^{k(0)} \times (a_{iF}^{0} / a_{iF}^{1})$ (trade margin rates)

for: i = (1,…,85); j = (1,…,85; F) with F (final demand component) = C, G, CS15, I, V, VE, EX; P_i and P_j = production (basic) price indexes for product *i* or *j* or final demand (of type F) deflator (at purchasers' prices) in the scenarios with the increase in primary input prices (considering the prices in the reference scenario =1; note that $P_i = 1+ p_i$); PM_{ij}, PT_{ij}, PZ_{ij} , PV_j , $PREM_j$ and POT_j are the price indexes (considering the prices in the reference scenario =1; note that $PM_{ij}=1+pm_{ij}$, etc., etc.) for, respectively, the following primary inputs: imports, taxes, subsidies, value added, labor (evaluated through the compensation of employees) and other taxes on production, relative to input i for industry (or final demand) j; ΔT_{ij} = additional tax on product i used by industry (or final demand component j (estimated direct effect); X_j^{0} = output of industry j, at basic prices (or total values of final demand of type F, at purchasers prices), in the reference scenario; $amc_{ij}^{0} + amt_{ij}^{0}$ = coefficients of trade and transport margins for product i, used by industry (or final demand) j, calculated for the reference scenario.

Note that the above formulas, combined with the method for production and final demand price determination in the input-output price model (equations 3 and 9 in Appendix 6) , ensure that the revised technical coefficients still add up to one in each industry and for each final demand component:

$\sum_i (an_{ij}^{1} + am_{ij}^{1} + at_{ij}^{1} + az_{ij}^{1}) + av_j^{1} = 1$ (sum for i=1 to 85), for all j.

In the case of the **present study** all **price indexes for primary inputs are** equal to **1 except for imports (PM_i)** and so the above formulas simplify accordingly.