EVALUATING THE IMPACT OF A CARBON TAX IN PORTUGAL CONSIDERING ALTERNATIVE ASSUMPTIONS FOR PRICE ELASTICITY OF DEMAND

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Abstract

In 2015 we presented a paper to the 23rd Input-Output Conference, Mexico City (paper no. 85 in the conference page) with the methodology and results for the evaluation of the macroeconomic, fiscal and environmental impact of the introduction of a carbon tax in Portugal, using a multi-sector macroeconomic model (MODEM 7) combined with an input-output (I-O) price model, considering different levels and scopes for this tax as well as alternative ways of recycling the additional corresponding public revenue. This evaluation was made considering an implicit assumption of zero price elasticity of demand shares (vertical technical coefficients), at constant prices, for intermediate consumption and for households' final demand. While this assumption may be considered acceptable for intermediate consumption (in the short-term), given a certain inertia in production technology response to price changes, it is more questionable for private consumption.

In this paper we present an alternative evaluation of the impact of the carbon tax for the Portuguese economy and environment, considering the assumption that the relative price elasticity of households' real share of each product on total consumption is equal to -1. We describe the methodological changes made to consider this new assumption and compare the results with those obtained from the previous zero price elasticity assumption for private consumption. An improvement is also made and presented regarding the method for estimating the impact of the carbon tax on CO2 emissions.

Both MODEM 7 and the I-O price model consider 85 homogenous industries and were calibrated using a system of symmetric I-O tables and other recent macroeconomic and environmental data available for Portugal, from official sources.

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1. INTRODUCTION

In 2015 a paper was presented to the 23rd Input-Output Conference (Dias, 2015) with the methodology and results for the evaluation of the macroeconomic, fiscal and environmental impact of the introduction of a carbon tax in Portugal, using a multi-sector macroeconomic model (MODEM 7) combined with an input-output (I-O) price model. This evaluation was made considering an implicit assumption of zero relative price elasticity of demand shares (vertical technical coefficients), at constant prices, for intermediate consumption and for households' final demand. While this assumption may be considered acceptable for intermediate consumption (in the short-term), given a certain inertia in production technology response to price changes, it is more questionable for private consumption.

In this paper an alternative evaluation of the impact of the carbon tax is presented, considering the assumption that the relative price elasticity of households' real share of each product on total consumption is equal to -1 (instead of zero) and we compare the results with those obtained from the previous exercise.

We describe the methodological changes made to consider this new assumption (regarding the method used for MODEM 7 recalibration after a price shock) and compare the results with those obtained from the previous zero price elasticity assumption for private consumption. An improvement is also made and presented regarding the method for estimating the impact of the carbon tax on CO_2 emissions.

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 new carbon tax on production (basic) prices and on purchaser's prices for the various products as well as on final demand and GDP deflators. Section 4 explains the method and presents the results for the evaluation of the economic, fiscal and environmental impact of a carbon tax, considering alternative assumptions for price elasticity of demand and, finally, section 5 presents some concluding remarks. Appendixes 1 to 7 show details regarding the models used and their calibration and recalibration after a price shock.

2. MODEM 7

2.1. General features

MODEM is a multisectoral (input-output based) model 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 the Portuguese Environment Agency (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 this paper. A description of the regional block can be found in Dias and Lopes (2009) and in Dias and Lopes (2010b).

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

[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 the Portuguese Environment Agency (APA) and, later on (in 2014), to the Prospective and Planning Services (SPP) of the General Secretary of the Ministry of Environment (Portugal).

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.

The above description corresponds to the standard version of the model, used in reference simulations. For variant simulations using a fiscal policy rule, equation 74 is rearranged, with public deficit becoming an exogenous variable (moved to the right-hand side of the equation) and with the variable chosen for adjustment becoming the dependent variable (on the left-hand side of the equation).

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 of fossil fuels.

2.3. Model calibration and reference simulation

2.3.1. General features

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

For the present and previous exercises, concerning the carbon tax impact evaluation (Dias, 2014 and 2015) 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:

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

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. Policy evaluation with MODEM

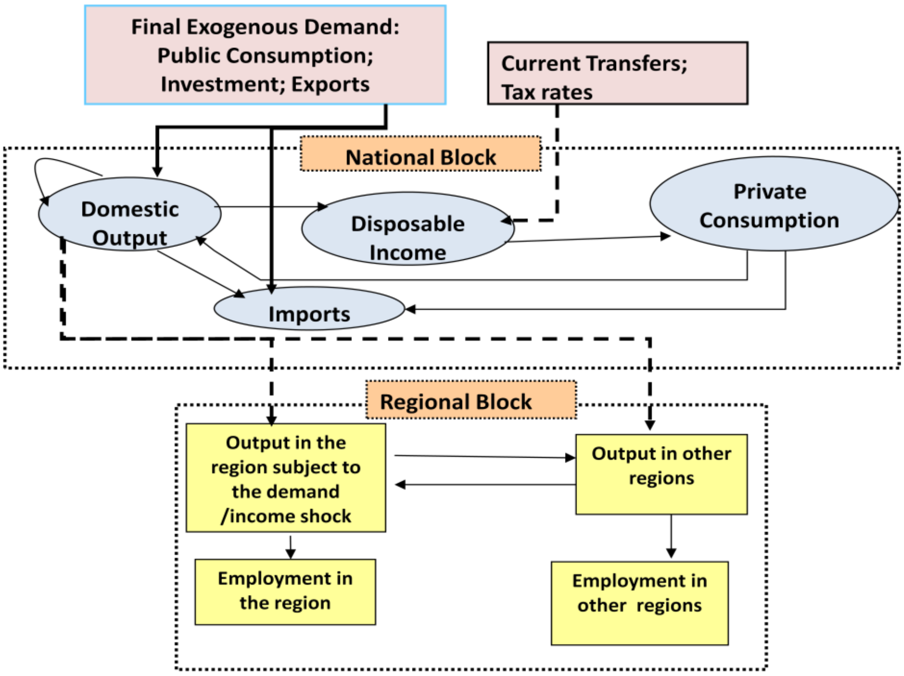
The various versions of MODEM have been used in the past in the evaluation of demand and income shocks on the Portuguese economy, including those induced by large projects and public investment programs, including those co-financed by the European Union.

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.

Figure 1

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



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.

3. THE INPUT-OUTPUT PRICE MODEL AND THE EVALUATION OF THE IMPACT OF A NEW CARBON TAX ON PRICES

A carbon tax applied to CO_2 emissions resulting from fossil fuel combustion implies, as a primary effect, the increase in fossil fuel prices.

As MODEM does not include price variables, an input-output price model was used to estimate the direct and indirect effects of this tax on 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 purchasers' prices for the various products.

In the present study we have used the price model to determine the impact of an increase in taxes on fossil fuels on prices.

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 fiscal shock (equation 8 of Appendix 6):

$$p' = UFS'(I\text{–}AN)^{-1}$$

where p' is the row-vector for production (basic) percent price increases resulting from the new tax, UFS' is a row-vector for unit fiscal shocks (total tax increase on inputs per unit of output, in each industry) and $(I\text{–}AN)^{-1}$ is the so-called "Leontief inverse" (matrix of output multipliers) (see Appendix 6 for a more detailed explanation).

In order to calculate the impact on prices of the new tax, is was necessary to estimate the UFS vector. The AN matrix had already been calculated with the purpose of MODEM 7 calibration.

The j^{th} element of UFS is (equation 7 of Appendix 6):

$$UFS_j = (\sum_i \Delta T_{ij})/X_j$$

where ΔT_{ij} is the additional tax charged on input i, used by industry j as a result of the new carbon tax and X_j is the output of product j, in the reference scenario (before the introduction of the new tax).

Details of the method of estimation of fiscal shocks (ΔT_{ij}), resulting from a carbon tax, are presented in section 3 of Dias (2015), considering various possible levels of the tax rate (euros per ton of CO2 emissions), combined with different assumptions regarding sectoral tax incidence.

After the estimation of these fiscal shocks (ΔT_{ij}), the impact of the carbon tax on production and purchasers' prices was estimated for each product and final demand component using the formulas of the I-O price model, presented in Appendix 6.

4. EVALUATION OF THE ECONOMIC, FISCAL AND ENVIRONMENTAL IMPACT OF A NEW CARBON TAX

4.1. Recalibration and revision of exogenous variables of MODEM

After the calculation of the impact of the carbon tax on prices, we needed to recalibrate MODEM 7, *ie,* to revise the model nominal input-output coefficients (at current prices) for each one of the carbon tax alternatives and according to the assumptions considered for the price elasticity of real coefficients. We also needed to revise the values of some exogenous variables which were directly affected by the price changes resulting from the carbon tax.

The formulas for model recalibration are described in detail in Appendix 7.

In both Dias (2015) and in the subsequent simulations presented in the current paper we assumed that price elasticity for real intermediate demand was zero, considering there was a certain inertia in production technology response to price changes (at least in the short term).

For households' final consumption, which is endogenous in MODEM, we also assumed a zero relative price elasticity of real demand shares in Dias (2015) while in the present paper an alternative assumption was also considered: a relative price elasticity of households' real share of each product on total consumption equal to -1 (instead of zero).

In fact, the zero price elasticity for households' consumption may be considered somehow unrealistic, at least for products that that are not essential or for which there are other alternatives. This is the case (for example) of fossil fuel consumption for use in private transportation because it may be reduced through the use of other means of transportation (such as public transports, electric cars, walking, bicycles) or through car sharing.

The reason for considering only these two alternative assumptions for (relative) price elasticity of real demand (zero and -1) was because we could find relatively easy ways (algebraic formulas) to implement model recalibration.

In fact, if we assume that real demand is not affected by price changes (the zero price elasticity assumption), then I-O vertical coefficients (real demand shares) should remain unchanged in real terms (after a price shock) and nominal coefficients should be revised through the multiplication of the real coefficients by the respective price indexes (calculated in the I-O price model). On the other hand, if we assume that price elasticity of demand (relative real demand response to relative price changes) is equal to -1, then nominal vertical coefficients should remain unchanged (see proof in Appendix 7).

However, model recalibration is not as simple as it may seem from the above paragraph description, even considering only these two assumptions, because in any recalibration of I-O coefficients it is necessary to respect a number of intra and inter-matrix identities (see Appendix 7 for details).

Concerning MODEM 7 exogenous variables, we assumed (in both Dias, 2015 and in the present exercise) that the output of industries 1 to 3 (Agriculture, Forestry and Fishing), 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 exogenous components, we assumed (in both Dias, 2015 and in the present exercise) that they would remain unchanged in nominal terms (demand for each product at purchaser prices), except for Change in Inventories (because it is an adjustment variable between supply and demand and so we assumed it would remain constant in volume and determined its total nominal value through the multiplication by the respective deflator).

The justification for keeping the other components of final exogenous demand constant in nominal terms may be either by the assumption of a price elasticity of demand = -1 (for example, in the case of Exports) or by the existence of a budget restriction (in the case of Public Consumption and Investment).

The different versions of recalibrated MODEM 7 were then used for the simulation of the scenarios with the new carbon tax.

4.2. Comparison of results with different price elasticity assumptions for households demand

Table 1 presents the results of the simulations (made in 2015) for the case of a carbon tax rate of 35€/tCO2 (the EU ETS price projected for 2030 in: European Commission, 2014) applied only to non-ETS sectors, not exempt from the already existing tax on oil products, ISP (according to the terms of the green fiscal reform implemented in Portugal in 2015[2]), taken from table 7 of Dias (2015), which have the implicit assumption (H1) of zero relative price elasticity of households real consumption shares.

Table 2 presents the results of alternative simulations considering the assumption (H2) of relative price elasticity of real households' consumption shares = -1.

Both tables present various options for recycling the additional revenue derived from the carbon tax (besides those considered in the green fiscal law) including a reduction in other taxes, an increase in certain types of public expenditure and also the "no revenue recycling" option :

- No revenue recycling, implying a reduction in public deficit and debt, compared to the reference scenario;
- Reduction in personal income tax;
- Reduction in company taxes;
- Increase with expenditure with education services (investment in human capital);
- Increase in expenditure with R&D;
- Increase in investment in infrastructures;
- Increase in fiscal incentives to projects promoting energy efficiency.

[2] According to this law, the carbon tax rate in year *t* is calculated through the average of EU ETS prices observed from July(t-2) to June(t-1) and it is applied only to non-ETS sectors that are not exempt from the already existing tax on petroleum and energy products (ISP). This law also mentions the principle of fiscal neutrality (revenue recycling) through the reduction of personal or company income tax or the increase in fiscal incentives to projects promoting energy efficiency. However, there has been no formal (legal) consignation (to date) of this tax revenue to any specific purposes. The carbon tax rates in force in 2015, 2016 and 2017 were, respectively, 5.09, 6.67 and 6.85€/tCO2. However, this tax represents only a small amount of total taxes charged on fossil fuel consumption in Portugal (probably less than 5% of total ISP).

Table 1

Impact of a Carbon Tax - Portugal

H1: relative price elasticity of households consumption = 0

(35€/tCO2, applied to non-ETS, not exempt from tax on oil products)

(Evaluation with MODEM 7, combined with an I-O price model)

deviation from the reference scenario

	Revenue recycling options (a)						
	Reduction in public deficit (no revenue recycling)	Tax reduction (b)		Increase in public expenditure (c)			
		Personal Income Tax	Company tax	Education (investment in human capital)	R&D (d)	Investment in Infrastructures	Fiscal incentives to investment in energy efficiency
ECONOMIC IMPACT (percent deviation):							
Real Impact (volumes):							
GDP	-0.66	-0.10	-0.66	0.67	0.39	0.17	-0.24
Private Consumption	-1.07	0.13	-1.06	-0.03	-0.28	-0.49	-0.77
Public Consumption	-0.17	-0.17	-0.17	4.17	3.51	-0.17	-0.17
Investment (GFCF)	-0.39	-0.39	-0.39	-0.39	-0.39	2.79	1.95
Exports	-0.31	-0.31	-0.31	-0.31	-0.31	-0.31	-0.31
Imports	-0.64	-0.07	-0.64	-0.07	-0.15	-0.02	0.06
Employment	-0.59	-0.13	-0.58	0.75	0.20	0.24	-0.14
Impact on prices (deflators):							
GDP	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Private Consumption	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Public Consumption	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Investment (GFCF)	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Exports	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Impact on the Balance of Goods and Services (deviation in percentage points of GDP):							
	0.27	0.08	0.27	0.16	0.17	0.09	0.01
IMPACT ON PUBLIC ACCOUNTS (deviation in million euros):							
Revenue:							
Total Tax revenue	791	44	205	1158	1157	1149	964
of which:							
Fossil fuel taxes	1048	1094	1049	1093	1089	1117	1073
Outher indirect taxes	-167	-5	-166	2	-11	15	-75
Direct taxes on households	-46	-1040	-45	60	34	13	-16
Company taxes	-45	-5	-633	3	46	3	-18
Social security Contributions	-118	-28	-117	268	58	55	-35
Other revenue	-35	-4	-35	3	36	3	-14
Expenditure:							
Exogenous expenditure (c)	0	0	0	1504	1274	1233	905
Unemployment benefits	58	13	58	-75	-20	-24	14
Subsidies to products	-5	-1	-5	-2	-2	-3	-4
Interest on public debt	-26	0	0	0	0	0	0
Global Balance	611	0	0	0	0	0	0
IMPACT ON CO_2 EMISSIONS (percent deviation):							
	-0.80	-0.16	-0.79	-0.13	-0.19	0.34	-0.38

(a) imposing a public deficit equal to the reference scenario.

(b) before deduction of fiscal benefits.

(c) including fiscal benefits.

(d) R&D is still treated in this table according to ESA95 conventions.

Source: Dias (2015), table 7

For the "No revenue recycling" option we used the standard version of MODEM 7 for simulation while for the other options we used the version with a fiscal policy rule (see last paragraph of section 2.2.4) which consisted in fixing the value of public deficit equal to the observed/simulated value from the reference scenario (*i.e.*, SGG, in equation 74, becoming an exogenous variable) and calculating residually (endogenizing) the adjustment (tax or expenditure) variable.

The option of revenue recycling through the "increase in fiscal incentives to projects promoting energy efficiency" (referred in the green fiscal law) was tested in the model assuming that these incentives would generate additional investment (GFCF) in equipment, buildings and computer programming services (products 23 to 28, 31, 36 and 53 of MODEM 7 nomenclature – see appendix 1) in the same proportion as observed for GFCF in these products for Portugal in 2008. The idea is that projects of energy efficiency may concern investment in any of the abovementioned products.

The introduction of a new carbon tax without recycling the additional public revenue implies a negative effect on the economy as the new tax boosts prices, reducing the purchasing power of economic agents which implies a reduction in final real demand and, therefore, in domestic output. CO_2 emissions decrease, but mainly due to the decrease in the level of global activity and of private consumption. The only positive effects of this option are (besides the reduction of CO2 emissions) a reduction in public deficit and an improvement in the balance of goods and services (imports decrease more than exports due to the reduction in total demand).

The best options of revenue recycling are, from an economic point of view, among those that were tested (in both price elasticity assumptions), the expenditure with education services (investment in human capital), followed by Research and Development and by investment in infrastructures, with positive impacts on GDP. Concerning public accounts, it should be stressed that, in terms of their level in euros, all options of revenue recycling have a zero impact on public deficit, as we impose a zero impact on public global balance in the model programming (model version with a fiscal policy rule) as a way to ensure the revenue recycling (see sections 4.1 and last paragraph of 2.2.4).

The other options tested for revenue recycling do not succeed in totally compensating the negative effects of this new tax on GDP (except for the reduction in personal income tax, in the negative price elasticity assumption), resulting in a negative effect on this variable.

Concerning a reduction in personal income tax rates, its impact on the level of economic activity is not direct, resulting only from the additional private consumption induced by the increase in households' disposable income.

The worst option for revenue recycling is, according to MODEM simulations, the reduction in company taxes. In fact, the impacts on the economy and on CO2 emissions are similar to those obtained with the "no revenue recycling" option, but in the first case there is no reduction in public debt as it happens in the second case. The explanation is that the reduction in companies' tax burden does not, in itself, necessarily generate an increase in final demand, which is (according to MODEM's logic) the driver of economic activity.

Table 2

Impact of a Carbon Tax - Portugal

H2: relative price elasticity of households consumption = -1

(35€/tCO2, applied to non-ETS, not exempt from tax on oil products)

(Evaluation with MODEM 7, combined with an I-O price model)

deviation from the reference scenario

	Revenue recycling options (a)						
	Reduction in public deficit (no revenue recycling)	Tax reduction (b)		Increase in public expenditure (c)			
		Personal Income Tax	Company tax	Education (investment in human capital)	R&D (d)	Investment in Infrastructures	Fiscal incentives to investment in energy efficiency
ECONOMIC IMPACT (percent deviation):							
Real Impact (volumes):							
GDP	-0.51	0.08	-0.50	0.87	0.59	0.36	-0.07
Private Consumption	-0.89	0.35	-0.88	0.19	-0.08	-0.29	-0.59
Public Consumption	-0.17	-0.17	-0.17	4.34	3.65	-0.17	-0.17
Investment (GFCF)	-0.39	-0.39	-0.39	-0.39	-0.39	2.90	2.04
Exports	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
Imports	-0.73	-0.14	-0.72	-0.14	-0.22	-0.09	0.00
Employment	-0.42	0.05	-0.42	0.97	0.40	0.44	0.04
Impact on prices (deflators):							
GDP	0.61	0.62	0.61	0.61	0.61	0.62	0.61
Private Consumption	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Public Consumption	0.17	0.17	0.17	0.17	0.18	0.17	0.17
Investment (GFCF)	0.39	0.39	0.39	0.39	0.39	0.40	0.39
Exports	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Impact on the Balance of Goods and Services (deviation in percentage points of GDP):							
	0.32	0.13	0.32	0.21	0.21	0.13	0.05
IMPACT ON PUBLIC ACCOUNTS (deviation in million euros):							
Revenue:							
Total Tax revenue	755	-22	147	1135	1134	1126	934
of which:							
Fossil fuel taxes	873	918	874	918	914	943	898
Outher indirect taxes	-59	111	-57	118	104	132	37
Direct taxes on households	-31	-1063	-30	78	51	29	0
Company taxes	-28	13	-639	21	65	21	0
Social security Contributions	-86	8	-85	315	98	94	1
Other revenue	-22	10	-22	17	51	17	0
Expenditure:							
Exogenous expenditure (c)	0	0	0	1561	1322	1280	938
Unemployment benefits	42	-5	42	-96	-40	-44	-4
Subsidies to products	-2	2	-2	2	1	1	0
Interest on public debt	-27	0	0	0	0	0	0
Global Balance	634	0	0	0	0	0	0
IMPACT ON CO_2 EMISSIONS (percent deviation):							
	-2.55	-1.91	-2.54	-1.88	-1.94	-1.38	-2.12

(a) imposing a public deficit equal to the reference scenario.

(b) before deduction of fiscal benefits.

(c) including fiscal benefits.

(d) R&D is still treated in this table according to ESA95 conventions.

Table 3

Impact of a Carbon Tax - Portugal

(35€/tCO2, applied to non-ETS, not exempt from tax on oil products)

Difference between H2 and H1 results

deviation from the reference scenario

	Revenue recycling options (a)						
	Reduction in public deficit (no revenue recycling)	Tax reduction (b)		Increase in public expenditure (c)			
		Personal Income Tax	Company tax	Education (investment in human capital)	R&D (d)	Investment in Infrastructures	Fiscal incentives to investment in energy efficiency
ECONOMIC IMPACT (percent deviation):							
Real Impact (volumes):							
GDP	0.16	0.18	0.16	0.21	0.20	0.18	0.17
Private Consumption	0.17	0.22	0.17	0.22	0.21	0.20	0.19
Public Consumption	0.00	0.00	0.00	0.17	0.14	0.00	0.00
Investment (GFCF)	0.00	0.00	0.00	0.00	0.00	0.10	0.09
Exports	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Imports	-0.09	-0.07	-0.09	-0.07	-0.07	-0.06	-0.06
Employment	0.16	0.18	0.16	0.22	0.20	0.20	0.18
Impact on prices (deflators):							
GDP	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.03
Private Consumption	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Public Consumption	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
Investment (GFCF)	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Exports	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Impact on the Balance of Goods and Services (deviation in percentage points of GDP):							
	0.05	0.04	0.05	0.05	0.05	0.04	0.04
IMPACT ON PUBLIC ACCOUNTS (deviation in million euros):							
Revenue:							
Total Tax revenue	-36	-65	-58	-23	-23	-23	-30
of which:	0	0	0	0	0	0	0
Fossil fuel taxes	-175	-175	-175	-175	-175	-174	-175
Outher indirect taxes	108	116	108	116	115	116	112
Direct taxes on households	14	-23	14	18	17	16	15
Company taxes	16	18	-6	18	20	18	17
Social security Contributions	32	36	32	47	39	39	36
Other revenue	13	14	13	14	16	14	14
Expenditure:	0	0	0	0	0	0	0
Exogenous expenditure (c)	0	0	0	57	48	47	34
Unemployment benefits	-16	-18	-16	-22	-19	-20	-18
Subsidies to products	3	3	3	3	3	3	3
Interest on public debt	-1	0	0	0	0	0	0
Global Balance	23	0	0	0	0	0	0
IMPACT ON CO_2 EMISSIONS (percent deviation):							
	-1.75	-1.75	-1.75	-1.75	-1.74	-1.72	-1.74

(a) imposing a public deficit equal to the reference scenario.

(b) before deduction of fiscal benefits.

(c) including fiscal benefits.

(d) R&D is still treated in this table according to ESA95 conventions.

The ranking of the impacts of the carbon tax on GDP for the various ways of revenue recycling is inversely related to the unit import content of the final demand (almost) directly generated by each option, as it is shown in table 4. This is the reason (considering the logic of MODEM) for the lower impact of revenue recycling through incentives to investment in energy efficiency projects (with an estimated import content of 46%) compared to expenditure in Education (with only 3% of import content), in R&D (7% import content) and in infrastructures (21% import content).

Table 4

Type of final expenditure	Unit imports content (a)	impact of a 35€/tCO2 carbon tax (applied to ISP payers) on GDP: ranking of revenue recycing options with impact on final expenditure		
		revenue recycling option:	H1	H2
Public consumption - Education services	0.03	Public consumption - Education services	0.67	0.87
Public consumption - R&D	0.07	Public consumption - R&D	0.39	0.59
Investment in infrastructures	0.21	Investment in infrastructures	0.17	0.36
Private consumption	0.28	reduction in personal income tax	-0.10	0.08
Investment in energy efficiency projects	0.46	incentives to Investment in energy efficiency projects	-0.24	-0.07

(a) source: Dias (2016) and additional calculations, based on I-O tables for Portugal, 2008.

Comparing the results presented in tables 1 and 2 (table 3 presents the differences between the impacts shown in tables 2 and 1) we conclude that if households react to relative price changes through the adjustment of their real demand shares (with a negative relative price elasticity of demand of, for example = -1) then the economic and environmental impact of a carbon tax is generally better (or less bad) than when they do not react to prices. The greater improvement in the results concerns CO_2 emissions reduction because fossil fuels are the products facing a greater price increase derived from the carbon tax, implying higher reductions in fossil fuel consumption in the negative price elasticity assumption compared to the zero price elasticity and, therefore, a greater reduction in CO_2 emissions.

The better economic results when price elasticity of consumers demand is negative (instead of zero) results from a higher total volume of consumption (for a given nominal disposable income or total nominal consumption) because the global price consumption deflator is lower when the consumption share of products facing a higher price increase is reduced. The other reason is related to the above average import content of fossil fuels (compared to total final consumption), implying a reduction in the global import content of final demand, and therefore an increase in its GDP content.

Concerning public accounts, the revenue from fossil fuel taxes is, naturally, lower when households react to fossil fuel price increases through the reduction of their consumption than when they don't, but, on the other hand, and because the global economic performance is better (when there is a consumer reaction to prices) there is more revenue collected from other taxes (except for those which are object of revenue recycling) and lower public expenditure with unemployment benefits.

We also verify that the ranking of alternative ways of revenue recycling of the carbon tax revenue, remains the same (in terms of economic and environmental benefits) for both price elasticity assumptions (see tables 1, 2 and 4) for the abovementioned reasons of the implied final demand boost and the respective import content.

5. CONCLUDING REMARKS

In this paper we made the comparison of the evaluation of the macroeconomic, fiscal and environmental impact of a carbon tax in Portugal, using a multi-sector macroeconomic model (MODEM 7) combined with an I-O price model, considering two alternative assumptions for relative price elasticity of households' real consumption shares (zero and -1).

The zero price elasticity assumption for households' final consumption was implicit in the study presented in Dias (2015). However, considering that this assumption might be somehow unrealistic, we tested now the -1 price elasticity alternative. The reason for considering only these two specific assumptions was a matter of algebraic relative easiness to deal with the issue of model recalibration, given the characteristics of the model used, in an input-output methodological context.

The -1 assumption was econometrically tested (and not rejected) for the specific case of the consumption share of refined petroleum products (with data from national accounts for the period from 1995 to 2011 – equation presented in Appendix 8). However, it was not tested for the other 84 products that are included in MODEM 7, not only because we did not have enough long time series with such a big disaggregation but also because there are many other factors affecting the evolution of macroeconomic consumption shares such as technological and cultural changes, business cycles, per capita income, income distribution, etc., besides the need to deal with the adding-up constraint.

It is the view of the author that reality is, maybe, somewhere, in between the two assumptions considered in this paper, with a price elasticity of demand closer to zero for "necessities" and more negative for "luxuries".

We only presented, in this paper, the results for one particular level of carbon tax (35€/tCO_2) because the purpose here was to compare results with two different price elasticity assumption and not to estimate the exact impact of this tax on the Portuguese economy.

However, we also tested the 5€/tCO2 rate (for the "no revenue recycling" option, under the -1 price elasticity assumption) and verified that the impacts (under the same price elasticity and revenue recycling assumptions) are almost proportional to the level of the tax rate: In fact, the ratio of the impacts simulated for the 35€ to the 5€ rate (under the -1 price elasticity assumption and the "no revenue recycling" option) ranged between 6.4 and 6.9 for the various endogenous variables.

The results presented for a given level of the carbon tax rate represent the deviations from a scenario without this tax.

The current level of this specific tax in Portugal is quite low (6.85€/tCO_2 for 2017), since it is indexed to EU ETS prices (which have been also low in the last few years), but the total amount of fossil fuel taxes charged in Portugal (ISP) is much higher, the "carbon tax slice" representing only probably less than 5% of that total.

The conclusions from the comparison of the two price elasticity assumptions are that, if consumers react to relative price changes through the adjustment of their real consumption shares (with a negative price elasticity of demand), the economic and environmental impacts of a carbon tax are better (or less bad) than when they do not react to price changes because they can increase their total real consumption level (for the same nominal disposable income), reduce CO_2 emissions (through the reduction of fossil fuels use, which become more expensive with this tax) and also reduce the total import content of the economy (as fossil fuels have an above average import content).

The ranking of the macroeconomic impacts of the various options tested to recycle the additional revenue originated from the carbon tax is the same for both price elasticity assumptions, with a better impact coming from the recycling options which have an implicit lower import content of the respective induced final demand.

Therefore, the best options of revenue recycling are, among those tested, the expenditure in Education services and in Research and Development, rather than, for example, the reduction in direct taxes.

Concerning revenue recycling through expenditure in Education or in R&D it should be stressed that these types of expenditure have not only a positive (demand-pull) short-term effect on the economy but also positive long-term effects (through the increase in total factor productivity), which are not considered in MODEM 7, but have been treated in other models for the Portuguese economy, such as HERPOR (Dias and Lopes, 2010a), as already mentioned in Dias (2015).

Some directions for future work may include efforts to improve model recalibration methodology in order to cover more generalized price elasticity assumptions (different elasticities for each product and type of demand), as well as the estimation of price elasticities of demand by products and types of demand.

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APPENDIX 1 – Products/industries considered in MODEM 7 and in the I-O price model

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 w ater; w ater treatment and supply services
35	37+38+39	Sew erage and w aste services; materials recovery
36	41	Buildings and building construction w orks
37	42	Constructions and construction w orks for civil engineering
38	43	Specialised construction w orks
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 ow ner-occupied dew llings)
59	6803	Imputed rents of ow ner-occupied dew llings
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 w ork services w ithout 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 7A – NATIONAL BLOCK

Note: Unless otherwise specified, indexes *i* and *j* (identifying products/industries) assume the values 1 to 85 (corresponding to MODEM 7A products/industries nomenclature, listed in column 1 of 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) $X_i = \sum_j an_{ij} \times X_j + CTN_i + GN_i + CS15N_i + IN_i + VEN_i + ACOVN_i + EXN_i$ (i =4,..,85)

Private Consumption (households) of domestic goods and services:

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

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

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

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

Public Consumption of domestic goods and services :

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

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

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

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

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

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

Change in Inventories of domestic goods:

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

Net Acquisition of Valuables of domestic goods:

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

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

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

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

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

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) $OT_j = aot_j \times X_j$ (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) $VAB = \Sigma VAB_j$ **Total Gross Value Added**

(36) $N = \Sigma N_j$ **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) $OT = \Sigma OT_j$ **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) $CT = CONS – CPE – \mathbf{CS15} + \mathbf{CEP}$ **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) $Y = CONS+G+IT+\mathbf{VE}+\mathbf{ACOV}+ EX–MF$ **GDP (obtained from Expenditure)**

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

(51) YDSOC = ryds $\times$ 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$\times$JURG **Balance of factor income with the RoW**

3.2 Labor Market

(55) PA = **PA0** + cpand$\times$ND **Labor Supply**

(56) ND = ndn$\times$N **Employment (number of individuals)**

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

3.3. Public Finances

(58) TD = rtdyd $\times$ YD **Direct Taxes on Households + NPISH**

(59) TDSC = rtdsy $\times$ 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 $\times$REM **Social Contribuitions received by the Government**

(69) REPG = repge $\times$ 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**$\times$DESEMP **Unemployment Benefits**

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

(73) JURG = **RG** $\times$ DIV **Interest on public debt**

Government Total Balance:

(74) $SGG = TD + TDSC + \mathbf{TD2S} + CSOCG + TIG \mathbf{-} SUBG + REPG – \mathbf{G} – TRIG + \mathbf{TREG} – JURG + \mathbf{TK} + \mathbf{TRKG} – \mathbf{IG}$

4. ENVIRONMENTAL EQUATIONS

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

(75) $ECO2_j = cco2_j \times X_j$ (j= 1,…,85)

CO_2 emissions resulting directly from households' comsumption:

(76) $ECO2_{ic} = cco2_{ic} \times (a_{ic} \times CT)$ for i =17 (refined petroleum products) and 33 (natural gas)

Total CO_2 emissions, associated to combustion processes:

(77) $ECO2 = \sum_j ECO2_j + ECO2_{17c} + ECO2_{33c}$

APPENDIX 3

LIST OF MODEM 7 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.

$ECO2_{ic}$ – Carbon dioxide emissions, associated to combustion processes, directly associated to households' final consumption of product i.

$ECO2_j$ – Carbon dioxide emissions, associated to combustion processes, directly associated to domestic production of product *j*.

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 and the CIF/FOB adjustment)

$EXZP_i$ – 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:

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

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

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

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).

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

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

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).

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).

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).

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).

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

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

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

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

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

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

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

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

$\mathbf{av_j}$ - Product transformation coefficient for industry j (share of GVA in the value of domestic output of industry j, at basic prices).

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

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

$\mathbf{cco2_j}$ - CO2 emission coefficient (combustion) of industry j (kgCO2 per euro of output at basic prices).

$\mathbf{cco2_{ic}}$ - CO2 emission coefficient of households' final consumption of product i (kgCO2 per euro of households' consumption at purchasers prices), for i =17 (refined petroleum products) and 33 (natural gas distributed).

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.

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

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

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

$\mathbf{qzp_{iF}}$ – 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).

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

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

$\mathbf{tmci}_i^k$ – 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).

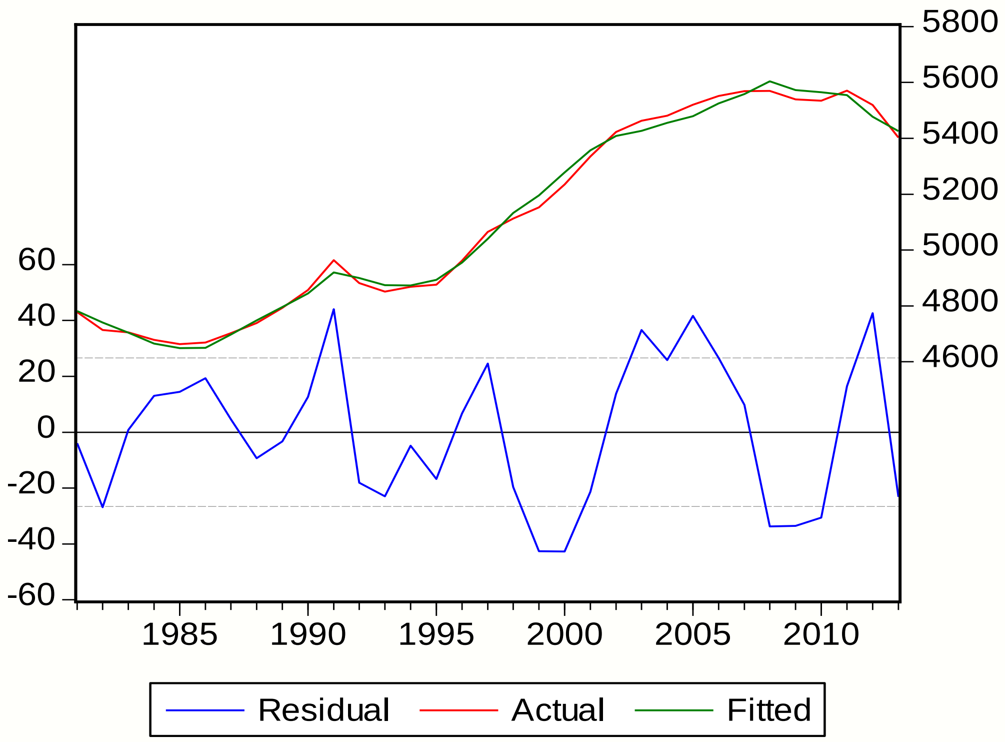
β – Average propensity to consume.

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 Value Added 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:

$cco2_i = ECO2_i / X_i$

$cco2_{ic} = ECO2_{ic} / FT_{iC}$

The values for X_i and FT_{iC} 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 $ECO2_{ic}$) were estimated by the process described on section 3 of Dias (2015).

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 input prices that have changes are those for taxes on inputs. Therefore, pm, pz and pv are, in this case, null matrices and equation (6) becomes:

(6a) $p' = i'(pt\circ AT)(I-AN)^{-1}$

The element of order (i,j) of matrix $(pt\circ AT)$ is $(pt_{ij}\times at_{ij})$, where pt_{ij} is the percent increase in the "price" of taxes over the input i used by industry j. Considering a fixed volume of output by industry j (X_j) and a fixed coefficient at_{ij} (in real terms), pt_{ij} is the percent increase in the value of taxes charged over the input i used by industry j, i.e., $pt_{ij} = \Delta T_{ij}/T_{ij}$.

As $at_{ij} = T_{ij}/X_j$, $pt_{ij}\times at_{ij}$ is equal to $\Delta T_{ij}/X_j$, which is the additional tax charged on input i, used by industry j, per unit of output of product j. It should be noted that, in the matter of taxes on products, it is very convenient to calculate directly $pt_{ij}\times at_{ij}$, instead of starting with the calculation of pt_{ij} because, when we consider a new tax, or a tax which incidence is enlarged to more products or industries than in the basic (reference) scenario, we have some initial values of T_{ij} that are equal to zero and so we cannot calculate pt_{ij} (because its denominator is zero), but we can calculate $pt_{ij}\times at_{ij} = \Delta T_{ij}/X_j$.

Therefore, we can rewrite equation (6a) as:

(6b) $p' = [i'\Delta T\, diag(X)^{-1}]\,(I-AN)^{-1}$

where ΔT is a (n×n) matrix for all ΔT_{ij}, and $diag(X)^{-1}$ is a (n×n) diagonal matrix which element of order (i,i) is $(1/X_i)$.

The matrix resulting from the operations $[i'\Delta T\, diag(X)^{-1}]$, in the second member of equation (6b), is a row-vector representing unit fiscal shocks (UFS'), which element of order j (UFS_j) represents the total increase in taxes on inputs per unit of output of industry j:

(7) $UFS_j = (\sum_i \Delta T_{ij})/X_j$

Therefore, equation (6b) can be rewritten as:

$$(8)\quad p' = UFS'(I–AN)^{-1}$$

For each product j, equation (8) becomes (designating the element of order (i,j) of $(I–AN)^{-1}$ by b_{ij}):

$$(8a)\quad p_j = \sum_i (UFS_i \times b_{ij})$$

Equation (8a) means that the percent increase in the basic price of product j, resulting from a given increase in taxes on products, is equal to the sum, across all products i, of the unit fiscal shock observed in each industry i (additional tax paid on all inputs per unit of output of product i) multiplied by the quantity of this industry's output necessary to satisfy one unit of final demand for product j (domestically produced).

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, for the case of a **zero price elasticity of final demand**, using the following formula:

$$(9)\ pft = p'\times ANF + pmf'\times AMF + ptf'\times ATF + pzf'\times AZF$$

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 pmf and pzf are null vectors and so equation (9) simplifies to:

$$(9a)\ pft = p'\times ANF + ptf'\times ATF$$

On the other hand, ptf'×ATF is, in fact, total additional tax paid per unit of final demand of type F and so we can rewrite equation (9a) as:

$$(9b)\ pft = p'\times ANF+ (\sum_i \Delta T_{iF})/Ftot$$

where ΔT_{iF} is additional tax on final demand of type F for product i and Ftot is total final demand of type F in the reference scenario (before the tax increase), at purchasers' prices.

The percent increase in the deflator of a given component of final demand (ptf) derived from an increase in taxes on products includes, therefore, a direct effect (ptf'×ATF), resulting from additional tax on final demand and an indirect effect (p'×ANF) associated to production price increases resulting from taxes on inputs.

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

$$(10)\ py = \{\sum_F(pft\times Ftot) - \sum_i[\sum_j(pm_{ij}\times M_{ij})]\}/Y$$

for F = all components of final demand and Ftot, M_{ij} and Y the values of final demand, imports of inputs and GDP in the reference scenario.

In the case of the present study, we assume that all pm_{ij} are zero and so, equation (10) simplifies to:

(10a) $py = [\sum_{F}(pft \times Ftot)]/Y$

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:

(11) $pf' = p' \times QNF + pmf' \times QMF + ptf' \times QTF + pzf' \times QZF$

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, using MODEM 7 code numbers for products – 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 described in Dias (2016)[4] and it 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);

[4] Note that in Dias (2016) we used NPCN06 code numbers while in the present paper we use MODEM 7 code numbers, for product/industry identification.

$qzf_{ii} \equiv qzp_{iF}$ (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, 2016 and 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[5])

$qnf_{ij} =MCi_{jF}/FT_{jF}$ (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[6])

$qnf_{ij} =MTNi_{jF}/FT_{jF}$ (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 [7])

$qmf_{ij} =MTMi_{jF}/FT_{jF}$ (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, **pmf** and **pzf** are null vectors and so equation (11) simplifies to:

(11a) $pf' = p'\times QNF + ptf'\times QTF$

[5] 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.

[6] *Vide* previous note.

[7] 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.

QTF is a diagonal matrix which element of order (i,i) is:

(12) $qtf_{ii} = T_{i,F} / F_i$ (share of taxes, $T_{i,F,}$ on the value, at purchasers' prices, of final demand of type F for product i, F_i, in the reference scenario, before the tax increase)

Therefore, the i^{th} element of the row-vector obtained from the operation ptf'×QTF is:

(13) $ptf_i \times qtf_{ii} = \Delta T_{iF} / F_i$

APPENDIX 7

METHODOLOGY FOR MODEM 7 RECALIBRATION AFTER A PRICE SHOCK

After the calculation of the impact of an increase in the price of primary inputs on production and purchaser prices (using the I-O price model), we must revise MODEM 7 nominal input-output coefficients (at current prices) accordingly, before using this model for the economic, fiscal and environmental evaluation of the impact of the price shock. The formulas used for this recalibration depend on the assumptions considered for price elasticity of demand.

In any recalibration of I-O coefficients it is necessary to respect a number of intra and inter-matrix identities, namely that the column sum of vertical coefficients must remain equal to 1 for all columns (industries and types of final demand) - equation (1) presented below; and also that the sum of all types of flows (domestic at basic prices, imports CIF, taxes, net of subsidies, on products, trade and transport margins) of product i to industry (or type of final demand) j must add up to the respective total flow at purchaser prices - equation (2):

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

(2) $a_{ij\,(1)} = an_{ij(1)} + am_{ij(1)} + at_{ij(1)} + az_{ij(1)} + amc_{ij(1)} + amt_{ij(1)}$ for each (i,j)

with j= 1,…,85, F with F= the seven final demand components considered in the model; and using the index (1) for revised coefficients (see appendixes 3 and 5 for coefficients definition/description and for the method of their calculation for the reference simulation, as well as for the list of final demand components).

Two specific assumptions were considered regarding price elasticity of demand (relative real demand response to relative price changes), which allow a relatively simple mathematical treatment for model recalibration, observing the abovementioned restrictions: zero and -1 price elasticity. The indexes $_{(0)}$ and $_{(1)}$ will be used for, respectively, the original and revised values (before and after the price shock).

H.1: Price elasticity of demand = 0

If we assume that real demand is not affected by price changes, then I-O vertical coefficients should remain unchanged in real terms (after a price shock) and nominal coefficients should be revised through the multiplication of the real coefficients by the respective price indexes (calculated in the I-O price model).

Therefore, we used the following formulas for model recalibration when this assumption was considered:

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

$am_{ij(1)} = am_{ij(0)} \times (PM_{ij}/P_j)$ (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);

$amc_{ij(1)} + amt_{ij(1)} = amc_{ij(0)} + amt_{ij(0)}$ (coefficients of trade and transport margins for product i, used by industry (or final demand) j;

$a_{ij(1)} = an_{ij(1)} + am_{ij(1)} + at_{ij(1)} + az_{ij(1)} + amc_{ij(1)} + amt_{ij(1)}$ (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)

$tmcF_{i\ (1)}^{k} = tmcF_{i\ (0)}^{k} \times [a_{iF(0)}/a_{iF(1)}]$ (trade margin rate of type k on final demand of type F for product *i*)

with 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.

Since total technical coefficients [$a_{ij(1)}$] were calculated through the sum of the revised coefficients for each type of flow, the abovementioned identity (2) was respected.

On the other hand, 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, therefore respecting the abovementioned equation (1).

In the case of a shock in taxes on products all price indexes for primary inputs are equal to 1 except for taxes (PT_{ij}) and so the above formulas simplify accordingly.

Recalibration of carbon dioxide emission coefficients was made using the following formulas:

$cco2_{j(1)} = cco2_{j(0)} / P_j$
$cco2_{ic(1)} = cco2_{ic(0)} / PC_i$

where PC_i is the purchaser price index of product i after the price shock (=1 before the price shock).

H.2: Price elasticity of demand = -1

If we assume that price elasticity of demand (relative real demand response to relative price changes) is equal to -1, then nominal vertical coefficients should remain unchanged. We considered this assumption only for final demand components, as, for intermediate demand, we assumed a certain inertia in production technology response to price changes (at least in the short term).

The total nominal coefficient a_{iF} represents the share of product i in total final demand of type F (FT) (value at purchaser prices):

$a_{iF} = F_i/FT$.

After a price shock, assuming a relative price elasticity of real demand share = -1 and excluding any other factors of coefficients change, the new real coefficient (that we will distinguish from the nominal coefficient by adding the letter r: ar_{iF}) has the following **behavioral equation**:

(3) $ar_{iF(1)} = a_{iF(0)} \times (PF_i/PFT)^{-1} = a_{iF(0)} \times (PFT/PF_i)$

where PF_i and PFT are, respectively, the price indexes for product i in final demand of type F and for total final demand of type F.

Note that for the reference scenario (before the price shock) the real and nominal coefficients coincide ($ar_{iF0)} = a_{iF(0)}$) because price indexes are, by definition, equal to 1 in this scenario.

On the other hand, the **definition equation** for ar_{iF} is:

(4) $ar_{iF(1)} \equiv [F_{i(1)}/PF_i]/ [FT_{(1)}/PFT] = [F_{i(1)} /FT_{(1)}] /(PF_i\times/ PFT) = a_{iF(1)}\times (PFT/PF_i)$

Equating the right hand side members of equations (4) and (4) we obtain:

(5) $a_{iF(1)}\times (PFT/PF_i) = a_{iF(0)} \times (PFT/PF_i)$

Multiplying both members of equation (5) by (PF_i/PFT) we obtain:

(6) $a_{iF(1)} = a_{iF(0)}$

Equations (3) to (6) prove that nominal coefficients a_{iF} remain unchanged after a price shock when we assume a relative price elasticity of demand = -1 (of ar_{iF} towards PF_i/PFT), as we mentioned in the first paragraph of this section.

The following **formulas** were used to **recalibrate final demand** MODEM 7 **nominal coefficients** when this assumption was considered, **after a price shock** resulting from a **carbon tax**:

$a_{iF(1)} = a_{iF(0)}$ (total coefficients: demand shares by products)

$az_{iF(1)} = az_{iF(0)}$ (coefficients for subsidies on products);

$at_{iF(1)} = [at_{iF(0)}+\Delta T_{iF}/FT_{(0)}]\times(PFT/PF_i)$ (coefficients for taxes on products, for i = 17, 33 and F= C, *ie*, for final consumption of fossil fuels by households);

$an_{iF(1)} = an_{iF(0)} – [at_{iF(1)} - at_{iF(0)}]\times\{an_{iF(0)} /[(an_{iF(0)+}am_{iF(0)}]\}$ (coefficients for domestic inputs, for i = 17, 33 and F= C);

$am_{iF(1)} = am_{iF(0)} - [at_{iF(1)} - at_{iF(0)}]\times\{am_{iF(0)}/[(an_{iF(0)+}am_{iF(0)}]\}$ (coefficients for imported inputs , for i = 17, 33 and F= C);

$at_{iF(1)}=at_{iF(0)}$ (coefficients for taxes on products, for i ≠ 17, 33 or F≠ C, *ie*, for final demand of all products except consumption of fossil fuels);

$an_{iF(1)} = an_{iF(0)}$ (coefficients for domestic inputs, for i ≠ 17, 33 or F≠ C);

$am_{iF(1)} = am_{iF(0)}$ (coefficients for imported inputs , for $i \neq 17, 33$ or $F \neq C$);

$amc_{iF(1)}+amt_{iF(1)} = amc_{iF(0)}+amt_{iF(0)}$ (coefficients of trade and transport margins for final demand of type F on product i);

The reason for the above specific formula for $at_{iF(1)}$ regarding fossil fuels is because the total amount of carbon tax paid for each fuel by households should be proportional to the volume of fossil fuels consumed (and not to its nominal value).

These formulas ensure that identity (2), mentioned at the beginning of this Appendix, is respected because $at_{iF(1)}+an_{iF(1)}+am_{iF(1)}= at_{iF(0)}+an_{iF(0)}+am_{iF(0)}$. Identity (1) is also respected because total coefficients (demand shares) remain unchanged.

The method for recalibration of CO2 coefficients is the same as described in H.1 because it is independent of the price elasticity assumption.

APPENDIX 8

EQUATION ESTIMATED FOR THE REFINED PETROLEUM PRODCTS SHARE ON HOUSEHOLDS FINAL CONSUMPTION (at constant, 2008 prices)

Dependent Variable: LOG(C17_08/CT08)
Method: Least Squares
Date: 05/27/14 Time: 12:32
Sample: 1995 2011
Included observations: 17

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3.060101	0.020789	-147.1961	0.0000
LOG(P17_08/PCT08)	-1.067290	0.081065	-13.16585	0.0000

R-squared	0.920357	Mean dependent var	-2.835889
Adjusted R-squared	0.915047	S.D. dependent var	0.168676
S.E. of regression	0.049163	Akaike info criterion	-3.077201
Sum squared resid	0.036256	Schwarz criterion	-2.979176
Log likelihood	28.15621	F-statistic	173.3395
Durbin-Watson stat	1.436789	Prob(F-statistic)	0.000000