Supplementary Table 1. Model equations in reduced form

I. Producers:

Output ($Y_{j,t}$) by industry 'j' **in time period 't'** is a Leontief function of a value added and energy composite ($VAE_{j,t}$) and non energy intermediate inputs ($X_{i,j,t}$).

$$Y_{j,t} = \text{Leontief}\,[VAE_{j,t}, X_{1,j,t}.....X_{n,j,t}]$$

Non energy intermediate input demands in industry 'j' are a CES function of intermediate input choices between sources of origin 'r' (domestic; EU import; non-EU import) and an elasticity of substitution for the nest (σ). The value added-energy nest is a CES function of labour by occupation 'o' ($LAB_{o,j,t}$), capital ($CAP_{j,t}$), land ($LND_{j,t}$), energy type 'e' ($EGY_{e,j,t}$) and σ.

$$X_{i,j,t} = \text{CES}\,[\Sigma_r X_{i,r,j,t}, \sigma];\ VAE_{j,t} = \text{CES}\,[LAB_{o,j,t}, CAP_{j,t}, LND_{j,t}, EGY_{e,j,t}, \sigma]$$

Assuming perfect competition, constant returns to scale and zero profits in all industries 'j', implies:

$$P_{j,t}(1+T_{j,t}^{P})Y_{j,t} = rent_{j,t}(1+T_{j,t}^{K})CAP_{j,t} + \Sigma_o\, wage_{o,j,t}(1+T_{o,j,t}^{L})LAB_{o,j,t} + rentl_{j,t}(1+T_{j,t}^{La})LND_{j,t} + P_{i,j,t}^{II}(1+T_{i,j,t}^{II})X_{i,j,t} + \Sigma_g P_{g,j,t}^{E} E_{g,j,t}$$

where the market value of production (left hand side) is equal to the tax inclusive price of the production factors, intermediate inputs and the emissions of each greenhouse gas (GHG) 'g' in each sector ($E_{g,j,t}$) multiplied by the marginal abatement cost ($P_{g,j,t}^{E}$).

II. Consumers:

Consumers in household 'h' in time period 't' maximise LES utility from the consumption of commodities 'i' (=1..n) from source of origin 'r' in time period 't' ($C_{i,h,r,t}$)

$$U_{h,t} = \text{LES}[C_{i,h,r,t} \ldots C_{i,h,r,t}]$$

Where total household expenditures (over all 'h') post consumer taxes ($T_{i,r,h,t}^{C}$) and savings are assumed equal to factor incomes on total capital stock (K_t), labour (L_t) and land (LA_t), multiplied by capital rent (r_t), the wage rate (w_t) and the land rent (rl_t), plus total quota rents ($RENT_t$):

$$\Sigma_i \Sigma_h \Sigma_r P_{i,h,r,t}.[1 + T_{i,r,h,t}^{C}].C_{i,h,r,t} + S_t = r_t K_t + w_t L_t + rl_t LA_t + RENT_t$$

III. Factor markets:

The total stock of endogenous capital, labour and land must be equal to the CES demands for each factor of production

$$K_t = \Sigma_j CAP_{j,t}\ ;\ L_t = \Sigma_o \Sigma_j LAB_{o,j,t}\ ;\ LA_t = \Sigma_j LND_{j,t}$$

IV Investment:

Endogenous capital accumulation in the current period 't', consists of the capital stock in the previous period 't-1', net of (an exogenous rate of) depreciation (DEPR), plus new investment in the previous period:

$$CAP_{j,t} = CAP_{j,t-1}.[1 - DEPR] + INV_{j,t-1}$$

where new investment in sector 'j' is a weighted average (determined by parameter δ) of investor expectations in the previous period ($EROR_{j,t-1}$) and the rate of return in the current period ($ROR_{j,t}$):

$$INV_{j,t} = [1 - \delta]EROR_{j,t-1} + \delta ROR_{j,t}$$

Total investment in period 't' is therefore:

$$I_t = \Sigma_j INV_{j,t}$$

V. Government:

Government demands are a Leontief function of total government expenditure (exogenous):

$$G_t = \text{Leontief}\,[G_{1,t} \ldots . G_{n,t}]$$

where total government expenditure inclusive of net transfers is equal to taxes on factors, intermediate inputs, output, final consumption and carbon tax revenues.

$$\Sigma_j P_{j,t} G_{j,t} + TRAN_{j,t} = rent_{j,t}(T_{j,t}^{K})CAP_{j,t} + \Sigma_o wage_{o,j,t}(T_{o,j,t}^{L})LAB_{o,j,t} + rentl_{j,t}(T_{j,t}^{La})LND_{j,t} + \Sigma_i \Sigma_j P_{i,j,t}^{II}(T_{i,j,t}^{II})X_{i,j,t} + P_{j,t}(T_{j,t}^{Y})Y_{j,t} + \Sigma_i \Sigma_h \Sigma_r P_{i,h,r,t}.[T_{i,r,h,t}^{C}].C_{i,h,r,t} + P_{j,t}^{E} E_{j,t}^{P}$$

VI. Emissions market

Emissions by sector 'j' of each GHG 'g' are fixed coefficients (γ, ς, φ) of intermediate energy usage ('e'), output and land use drivers

$$E_{j,t} = \Sigma_g \Sigma_e \Sigma_r \Sigma_j \gamma_{g,e,r,j,t} X_{g,e,r,j,t} + \Sigma_g \varsigma_{g,j,t} Y_{g,j,t} + \Sigma_g \varphi_{g,j,t} LND_{g,j,t}$$

Whilst total emissions in Spain cover all industrial emissions ($E_{j,t}$) and a fixed coefficient ($\square$) of the change in final demand driven usage of energy ('e'):

$$E_t^{ESP} = \Sigma_j E_{j,t} + \Sigma_g \Sigma_e \Sigma_h \Sigma_r \alpha_{g,e,h,r} C_{g,e,h,r,t}$$

Diffuse emissions (which are subject to sector specific quota limits) account for each relevant sector's emissions plus (in the case of transport) consumer demands for transport services and (in the case of dwellings) consumer demands for coal and gas energy. In the emissions trading scheme (ETS), total demand for ETS permits is the sum over all ETS sectors 'j'.

$$E_t^{ETS} = \Sigma_j E_{j,t}$$

The demand for ETS permits (E_t^{ETS}) in Spain must be equal to the (exogenous) domestic supply of permits (E_t^{DOM}) plus imported permits (E_t^{IMP}) at the exogenous permit price (P_t^{ETS})

$$E_t^{ETS} = E_t^{DOM} + E_t^{IMP}$$

VII. External market

External demands for Spanish exports of commodity 'i' from industry 'j' to foreign destination 'd' ($EX_{i,j,d,t}$) are a CET function of the exogenous exchange rate (ER), exogenous f.o.b. world prices (PFOB), the domestic price and the transformation elasticity:

$$EX_{i,j,d,t} = \text{CET}[ER, PFOB_{i,d,t}, P_{i,j,d,t}, \sigma]$$

where total exports and imports in time period 't' are given as:

$$EXPORT_t = \Sigma_i \Sigma_j \Sigma_d EX_{i,j,d,t};\quad IMPORT_t = \Sigma_i \Sigma_r \Sigma_j X_{i,r,j,t} + \Sigma_i \Sigma_h \Sigma_r C_{i,h,r,t} \qquad (r=EU, ROW)$$

Given that domestic markets clear, the neoclassical macro closure implies that exports minus imports minus emissions imports (or negative emissions imports are exports), are equal to saving less investment:

$$EXPORT_t - IMPORT_t - E_t^{IMP}.\, P_t^{ETS} = S_t - I_t$$