Chapter 17
FIT and Global Data Assembly

A FIT

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The 'FIT' procedure is one of the many components of the overall 'build' of the GTAP Data Base. During 'FIT', individual country input-output tables (IOTs) are updated using an assortment of global data such as bilateral trade flows from the COMTRADE database provided by the United Nations Conference on Trade and Development (UNCTAD), tariff measures from the International Trade Centre (ITC/Geneva) and energy data from the International Energy Agency (IEA) among others.

A.1 Overview

This chapter describes the updated GTAP 'FIT' procedure, which has never been fully documented since its earliest version developed for the SALTER model (James and McDougall 1993), including importantly the energy balancing module.[1]

The 'FIT' procedure has also been thoroughly recoded, with two main innovations: (1) the nomenclature has been completely revised to more carefully hone to the nomenclature of the GTAP model, version 7 (Corong et al. 2017); and the coding has been streamlined to remove duplication of functional relationships—in essence, this means that treatment of all columns of the input Input-Output Table (IOT) is generic and not differentiated across agents, except where needed.

The aim of the 'FIT' procedure is to adjust the contributed IOT subject to a series of exogenous assumptions listed here:

[1]This updated version of the 'FIT' procedure is still undergoing testing. The current build uses the former code—though the underlying methodology is largely identical. Testing suggests that the results are very close and can be attributed to minor changes in specification such as the price index relations and the treatment of stock-building.

1. Value of aggregate expenditures by households, government and investment
2. Value of export and import vectors at border prices and import vectors at basic prices (i.e., tariff inclusive)
3. Value of stock-building for both domestic and imported goods[2]
4. Tax rates for purchases of domestic and imported goods across all agents
5. Export and output tax rates
6. IEA energy balances, which are imposed for energy activities, with some allowance for adjustment across non-energy activities (including households).

The adjustment process is based on maximum entropy principles, which in its simplest form is essentially a RAS procedure. In the case of the 'FIT' procedure, the maximum entropy has three objectives: (1) keep the top-level budget shares (i.e., domestic+imported) as close as possible to the original top-level budget shares; (2) keep the agent-specific import shares as close as possible to the original shares; and (3) keep the resulting energy balances as close as possible to the IEA energy balances—subject to an overall constraint on energy use by carrier.

A.2 The core methodology

The core methodology is based on an information theoretic approach that minimizes the 'information' function subject to a series of constraints including the new 'information' such as the national accounts, new trade constraints, energy balances, etc. In the original formulation adapted for the SALTER model (James and McDougall 1993) the objective function was based on two separate information objectives: (1) the upper level constraints on the cost coefficients, which is standard practice; and (2) the second level constraint on sourcing shares. The current version includes a third element in the total information function, which is meant to allow for targeting of the energy balances to an external source, such as that from the IEA.

Top level budget shares

We define the first information function as:

$$I^t = \sum_a E_a I_a^t = \sum_a E_a \sum_c S_{c,a}^t(1) \log \frac{S_{c,a}^t(1)}{S_{c,a}^t(0)} \tag{17.1}$$

were $S_{c,a}^t$ is the expenditure share of commodity c by agent a, and E_a represents total expenditures. Here we take the definition of agents to include all activities, and private, public and investment expenditures.[3] Note that $S_{c,a}$ is the expenditure share on the Armington good, i.e., the sum of

[2]Changes in stock is eliminated during the FIT process.
[3]Stock-building activities are treated separately.

expenditures on domestic and imported goods. Also note the in the case of activities, c also includes expenditures on the factors of production, of which there are three: labor, capital and land. Index '0' refers to the original cost shares and index '1' refers to the 'estimated' shares as a result of the minimization process. Finally, the information specification uses expenditures as weights.

Sourcing shares

The second information function refers to the sourcing shares:

$$I^s = \sum_a \sum_c E_{c,a} I^s_{c,a} = \sum_a E_a \sum_c S^t_{c,a}(1) \sum_s S^s_{s,c,a}(1) \log \frac{S^s_{s,c,a}(1)}{S^s_{s,c,a}(0)} \tag{17.2}$$

where $S^s_{s,c,a}$ represents the source share of the purchase of commodity c by agent a. In the 'FIT' procedure s takes the value of d for domestic goods and m for imported goods. The information function uses weights $E_{c,a}$ which represents total expenditures on commodity c by agent a, where $E_{c,a} = E_a S^t_{c,a}$.

Energy balances

The third information component relates to the external energy balances. We currently use the IEA's energy balances, which are defined over ae agents and ce energy commodities. In the current configuration, there are 23 IEA agents—22 are production activities and the final agent is the household.[4] The 65 GTAP sectors are mapped to the 22 IEA production activities and the 6 GTAP energy commodities are mapped to the 5 IEA energy commodities.[5] Note that the IEA targets are provided at the 'Armington' level, i.e., there is no sourcing information, and the values are assumed to be represented at basic prices, i.e., before user taxes.The information component for energy is then defined as:

$$I^e = \sum_{ci} \sum_{ai} NRG_{ci,ai}(1) \log \left(\frac{NRG_{ci,ai}(1)}{NRG_{ci,ai}(0)} \right) \tag{17.3}$$

In other words, the objective is to remain as close as possible to the original IEA balances. In fact, the procedure will fix the value of energy use in the five IEA energy activities and allow for (minimal) re-allocation of energy use across the other users, including households. Two constraints are included with the energy targeting, as described below.

[4]Energy use by government and investment will be eliminated in the 'FIT' procedure, but are considered to be part of the set of IEA agents by the code.

[5]For energy, the mapping is one-to-one with the exception of gas where GTAP's 2 gas commodities, `'GAS'` and `'GDT'` are mapped to IEA's single gas commodity.

Total information

We define the total information content of the revision to the input-output structure as a weighted sum of the information content of the revisions to the top and lower levels and the energy targeting:[6]

$$I = \omega^t I^t + \omega^s I^s + \omega^e I^e \tag{17.4}$$

where ω^t, ω^s and ω^e are weights for the three components of the total information function.

Constraints

There are two constraints for the top-level and sourcing shares:

$$\sum_c S^t_{c,a}(1) = 1 \qquad \forall a \Longrightarrow \mu^t_a \tag{17.5}$$

$$\sum_s S^s_{s,c,a}(1) = 1 \qquad \forall a \forall c \Longrightarrow \mu^a_{c,a} \tag{17.6}$$

The first constraint will be associated with the shadow price given by μ^t, defined for all agents. Note as well that in the case of activities, there is an additional share for aggregate value added, which is subject to the same shadow price. The second constraint will be associated with the shadow price given by μ^a, defined for all commodities and agents.

In addition to the adding up constraints of the expenditure shares, we add an additional constraint that import expenditures aggregated across all agents are fixed:

$$M_c = \sum_a E_a S^t_{c,a}(1) S^s_{m,c,a}(1) \qquad \forall c \Longrightarrow \mu^m_c \tag{17.7}$$

The energy use targeting has two constraints. First, total energy use per carrier must equal an exogenous level, currently set to the initial level provided by the IEA. Second, the energy values from the full IO table must add up to the corresponding values for the IEA-based aggregation. These two constraints are defined by:

$$\sum_{ai \in \{ait\}} NRG_{ci,ai}(1) = NRG^t_{ci,ait} \qquad \forall ci \forall ait \Longrightarrow \mu^{ce}_{ci,ait} \tag{17.8}$$

$$\sum_{c \in \{ci\}} \sum_{a \in \{ai\}} S^t_{c,a}(1) E_a = NRG_{ci,ai}(1) \qquad \forall ci \forall ai \Longrightarrow \mu^{iea}_{ci,ai} \tag{17.9}$$

[6] The GEMPACK code does not include the weights for I^t and I^s, i.e., they are implicitly set to 1.

In equation (17.8), the set ait represents an aggregation of IEA agents of which there are 8: `coa`, `oil`, `gas`, `p_c`, `ely`, `xnr`, `gov`, and `inv`. All but `xnr` map one-to-one to the original IEA agents. Thus `xnr` represents all non-energy IEA activities and private households.[7] The constraint generates a shadow price for each aggregate target, `ait`, and each IEA energy commodity, `ci`. The second constraint links energy use in the full IOT to energy use defined at the IEA level and generates the shadow price μ^{iea}.

Minimization

The mathematical problem is thus to minimize total information, I, subject to the five constraints. To solve this we begin by defining the Lagrangian:

$$\begin{aligned}
\mathcal{L} &= I + \sum_a \mu_a^t E_a \left(1 - \sum_c S_{c,a}^t(1)\right) + \sum_a \sum_c \mu_{c,a}^a E_a S_{c,a}^t(1) \left(1 - \sum_s S_{s,c,a}^s(1)\right) \\
&+ \sum_c \mu_c^m \left(M_c - \sum_a E_a S_{c,a}^t(1) S_{m,c,a}^s(1)\right) \\
&+ \sum_{ci} \sum_{ait} \mu_{ci,ait}^{ce} \left(\sum_{ai \in \{ait\}} NRG_{ci,ai}(1) - NRG_{ci,ait}^t\right) \\
&+ \sum_{ci} \sum_{ai} \gamma_{ci,ai}^{iea} \left(\sum_{c \in \{ci\}} \sum_{a \in \{ai\}} S_{c,a}^t(1) E_a - NRG_{ci,ai}(1)\right)
\end{aligned} \tag{17.10}$$

Taking the derivative of the Lagrangian with respect to $S_{c,a}^t$, $S_{m,c,a}^s$, NRG, and the five shadow prices leads to the following 8 equations:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial S_{c,a}^t} = 0 \iff \omega^t \left(1 + \log \frac{S_{c,a}^t(1)}{S_{c,a}^t(0)}\right) + \omega^s \delta_c^c \sum_s S_{s,c,a}^s(1) \log \frac{S_{s,c,a}^s(1)}{S_{s,c,a}^s(0)} \\
= \begin{cases} \delta_c^c \mu_c^m S_{m,c,a}^s(1) + \mu_a^t & \forall a \forall c \notin \{nrg\} \\ \delta_c^c \mu_c^m S_{m,c,a}^s(1) + \mu_a^t + \mu_{ci,ai}^{iea} & \forall a \forall c \in \{nrg\}, \text{ for } c \in \{ci\} \text{ and } a \in \{ai\} \end{cases}
\end{aligned} \tag{17.11}$$

$$\frac{\partial \mathcal{L}}{\partial S_{m,c,a}^m} = 0 \iff \omega^s \left(1 + \log \frac{S_{s,c,a}^s(1)}{S_{s,c,a}^s(0)}\right) = \begin{cases} \mu_{c,a}^a + \mu_c^m & \forall c \forall a, \text{ for } s = m \\ \mu_{c,a}^a & \forall c \forall a, \text{ for } s = d \end{cases} \tag{17.12}$$

[7] This is somewhat different from the original ‘FIT’ code that in essence only modeled ’xnr’ as energy use by all of the other agents is fixed to IEA levels (or in the case of government and investment expenditures is fixed at zero). The new formulation is more general and more readily adaptable to alternative aggregations.

$$\frac{\partial \mathcal{L}}{\partial NRG_{ci,ai}} = 0 \iff \omega^e \left(1 + \log \frac{NRG_{ci,ai}(1)}{NRG_{ci,ai}(0)}\right) = \mu^{ce}_{ci,ait} - \mu^{iea}_{ci,ai} \qquad \forall ci \forall ai \in \{ait\} \quad (17.13)$$

$$\frac{\partial \mathcal{L}}{\partial \mu^t_a} = 0 \iff \sum_c S^t_{c,a}(1) = 1 \quad \forall a \qquad (17.14)$$

$$\frac{\partial \mathcal{L}}{\partial \mu^a_{c,a}} = 0 \iff \sum_s S^s_{s,c,a}(1) = 1 \quad \forall c \forall a \qquad (17.15)$$

$$\frac{\partial \mathcal{L}}{\partial \mu^m_c} = 0 \iff \sum_a E_a S^t_{c,a}(1) S^s_{m,c,a}(1) = M_c \quad \forall c \qquad (17.16)$$

$$\frac{\partial \mathcal{L}}{\partial \mu^{ce}_{ci,ait}} = 0 \iff \sum_{ai \in \{ait\}} NRG_{ci,ai}(1) = NRG^t_{ci,ait} \qquad \forall ci \forall ait \qquad (17.17)$$

$$\frac{\partial \mathcal{L}}{\partial \mu^{iea}_{ci,ai}} = 0 \iff \sum_{c \in \{ci\}} \sum_{a \in \{ai\}} S^t_{c,a}(1) E_a = NRG_{ci,ai}(1) \qquad \forall ci \forall ai \qquad (17.18)$$

In equation (17.11), the flag δ^c_c takes the value of 1 for commodities and 0 for aggregate value added.[8] Equations (17.11), (17.12) and (17.13) determine respectively $S^t_{c,a}$, $S^s_{s,c,a}$, and $NRG_{ce,ae}$. Equations (17.14), (17.15), (17.16), (17.17), and (17.18) determine respectively μ^t_a, $\mu^a_{c,a}$, μ^m_c, $\mu^{ce}_{ci,ait}$ and $\mu^{iea}_{ci,ai}$.

A.3 The full model

Prices

The following equations define some of the key price relations. Equations (17.19) and (17.20) represent respectively the agents' prices for domestic and imported commodities, where PDS and PMS are respectively the basic prices for domestic and imported goods and T^d and T^m are respectively the power of the sales tax on domestic and imported goods.[9] Most factor prices are fixed at base levels (typically 1). The FIT procedure allows the return to capital to adjust to changes in the price of investment, equation (17.21), where RR^i is exogenous.

[8]The adjustment for the aggregate value added share takes the simple form:

$$\omega^t \left(1 + \log \frac{S^t_{va,a}(1)}{S^t_{va,a}(0)}\right) = \mu^t_a \qquad \forall a \in \{ACTS\}$$

[9]The power of a tax rate is 1 + the tax rate.

$$PD_{c,a} = T^d_{c,a} PDS_c \tag{17.19}$$

$$PM_{c,a} = T^m_{c,a} PMS_c \tag{17.20}$$

$$PFE_{cap,a} = RR^i_a PO_{inv} \tag{17.21}$$

Equation (17.22) is the zero profit condition and determines the 'output' price. In the case of activities it includes the cost of the production factors where PFE and QFE represent the price and demand for production factors, and e is an index for the factors. The flag δ^f takes the value 1 for activities and 0 for all other agents. The next two equations determine the basic prices. For domestic goods, it is equal to the unit cost of output times the power of the production tax, T^p. For imported goods, it is the landed, or CIF price, times the power of the import tariff. Note that the original GEMPACK code does not have PO as a separate variable for activities as the zero profit condition directly includes the production tax. Also note that the GEMPACK code has strict separation of activities and commodities. The code for equation (17.23) maps from activities to commodities using a diagonal transition matrix.

$$PO_a QO_a = \sum_c \left\{ PD_{c,a} QD_{c,a} + PM_{c,a} QM_{c,a} \right\} + \delta^f_a \sum_e PFE_{e,a} QFE_{e,a} \tag{17.22}$$

$$PDS_c = T^p_c PO_c \tag{17.23}$$

$$PMS_c = T^i_c PCIF_c \tag{17.24}$$

Demand for goods and factors

Domestic and imported demand for goods and services are given respectively by equations (17.25) and (17.26), where the nested share coefficients—total cost share and source share—are multiplied together and multiplied by output. Stock changes (index dst) are handled separately and will be eliminated. held fixed and the volume is derived by dividing the value by the relevant price. The GEMPACK code treats stock-building somewhat differently [TBD] as the levels can be negative and hence the variable is defined as a 'change' variable.

$$QD_{ca} = \begin{cases} S^t_{ca} S^s_{dca} QO_a & \text{if } a \neq dst \\ YD_{c,dst}/PD_{c,dst} & \text{if } a = dst \end{cases} \tag{17.25}$$

$$QM_{ca} = \begin{cases} S^t_{ca} S^s_{mca} QO_a & \text{if } a \neq dst \\ YM_{c,dst}/PM_{c,dst} & \text{if } a = dst \end{cases} \tag{17.26}$$

Demand for factors, equation (17.27), is similar. The coefficient S^t_{fa} represents the share for aggregate factors and will be updated in the information minimization procedure. The coefficients S^e represent the second level shares and allocate total factor demand across the factor components, indexed by e. The latter shares are calibrated using the base data and held fixed.

$$QFE_{ea} = S^t_{fa} S^e_{ea} QO_a \tag{17.27}$$

Market equilibrium

Equations (17.28) and (17.29) represent respectively the goods market equilibrium for domestic production and aggregate import demand. In both cases, the demand across all agents for commodity c is summed, and in the case of domestic supply, it includes export demand QEX. The border price of exports, $PFOB$, is equal to the basic supply price multiplied by the power of the export tax, equation (17.30). Equation (17.31) calculates the value of exports at the border. In most cases, $YQEX$ will be exogenous and this equation therefore determines the volume of exports, QEX.

$$QO_c = \sum_a QD_{c,a} + QEX_c \tag{17.28}$$

$$QIM_c = \sum_a QM_{ca} \tag{17.29}$$

$$PFOB_c = T^e_c PDS_c \tag{17.30}$$

$$YQEX_c = PFOB_c QEX_c \tag{17.31}$$

Stock-building in GEMPACK requires some care as it is introduced as an ordinary change variable since in can be negative and/or take the value 0.

The following formula (without the commodity index) must hold from above:

$$PDS \cdot QO = \sum_a PDS \cdot QD_a + PDS \cdot QEX$$

Taking the first difference leads to:

$$\Delta PDS \cdot QO + PDS \cdot \Delta QO = \Delta PDS \sum_{a \notin \{stb\}} QD_a + PDS \sum_{a \notin \{stb\}} \Delta QD_a + \Delta PDS \cdot QEX + PDS \cdot \Delta QEX + \Delta YD_{stb}$$

where the stock-building has been isolated from the other demand agents. Dividing by YO and re-arranging, we get:

$$\dot{pds} + \dot{qo} = \dot{pds} \sum_{a \notin \{stb\}} S_a^q + \sum_{a \notin \{stb\}} S_a^q \dot{qd}_a + \dot{pds} \cdot S_x^q + S_x^q \dot{qex} + \frac{\Delta YD_{stb}}{YO}$$

where the shares represent the value shares of the respective components as a share of the total value of output. The demand shares must add up to 1, and hence $S_{stb}^q = 1 - \sum_{a \notin \{stb\}} S_a^q - S_x^q$. The final formula (adjusting by 100 to convert to percentage change) is:

$$\dot{qo} = \sum_{a \notin \{stb\}} S_a^q \dot{qd}_a + S_x^q \dot{qex} - S_{stb}^q \dot{pds} + 100 \frac{\Delta YD_{stb}}{YO}$$

Similar reasoning holds for aggregate import demand, which takes the following form in the GEMPACK code:

$$\dot{qim} = \sum_{a \notin \{stb\}} S_a^m \dot{qim}_a - S_{stb}^m \dot{pms} + 100 \frac{\Delta YM_{stb}}{YQIM}$$

Imports

Equation (17.16) replaces the original equation (17.16), i.e., in the FIT procedure we are targeting the border value of imports, $YQIM^{cif}$, and thus this equation determines the shadow price of the import constraint, μ^m. Equation (17.32) effectively determines the power of the import tariff, which is endogenous in the FIT procedure. Equation (17.33) effectively determines the border price, $PCIF$, as the FIT procedure assumes that the 'real' border price is fixed relative to the GDP deflator.

$$YQIM_c^{cif} = PCIF_c QIM_c \tag{17.16}$$

$$YQIM_c = PMS_c QIM_c \tag{17.32}$$

$$PCIF_c^r = PCIF_c / PGDP \tag{17.33}$$

Macroeconomic closure and identities

Equation (17.34) defines the volume of aggregate expenditures for three final demand agents indexed by fd: households, government and investment expenditures. In the FIT procedure, the relevant values, YO are fixed and the price deflators are defined by equation (17.22).

$$QO_{fd}PO_{fd} = YO_{fd} \tag{17.34}$$

The following set of equations determines the aggregate volume of imports, the aggregate import price index, the aggregate volume of exports and the aggregate export price index. Imports and exports are measured at border prices.[10]

$$TIMP = \sum_c PCIF_{c,0} QIM_c \tag{17.35}$$

$$PIMP \cdot TIMP = \sum_c PCIF_c QIM_c \tag{17.36}$$

$$TEXP = \sum_c PFOB_{c,0} QEX_c \tag{17.37}$$

$$PEXP \cdot TEXP = \sum_c PFOB_c QEX_c \tag{17.38}$$

The following equations define total GDP and the GDP price deflator. The latter is used to determine real import prices.

$$GDP = \sum_{fd} PO_{fd,0} QO_{fd} + PEXP_0 TEXP - PIMP_0 TIMP \tag{17.39}$$

$$PGDP \cdot GDP = \sum_{fd} PO_{fd} QO_{fd} + PEXP \cdot TEXP - PIMP \cdot TIMP \tag{17.40}$$

A.4 Cost share adjustment

Top level cost shares

Equation (17.41) is similar to the cost share constraint above, equation (17.14). The two differences are that the aggregate value added cost share, $S^t_{f,a}$, is separately identified and is only needed for

[10]The original GEMPACK code did not have variables for aggregate imports, exports or GDP.

activities This equation determines the Lagrangian multiplier μ^t, defined over all agents except for stock-building. Equation (17.42) provides the adjustment for the top-level cost coefficient for commodities, $S^t_{c,a}$—similar to equation (17.11) from above. Equation (17.43) provides the adjustment for the aggregate value added cost shares, which is only valid for activities.

$$\sum_c S^t_{c,a}(1) + S^t_{f,a}(1) = 1 \quad \forall a \tag{17.41}$$

$$\begin{aligned} &\omega^t \left(1 + \log \frac{S^t_{c,a}(1)}{S^t_{c,a}(0)}\right) + \omega^s \sum_s S^s_{s,c,a}(1) \log \frac{S^s_{s,c,a}(1)}{S^s_{s,c,a}(0)} \\ &= \begin{cases} \mu^m_c S^s_{m,c,a}(1) + \mu^t_a & \forall a \forall c \notin \{nrg\} \\ \mu^m_c S^s_{m,c,a}(1) + \mu^t_a + \mu^{iea}_{ci,ai} & \forall a \forall c \in \{nrg\}, \text{for } c \in \{ci\} \text{ and } a \in \{ai\} \end{cases} \end{aligned} \tag{17.42}$$

$$\omega^t \left(1 + \log \frac{S^t_{f,a}(1)}{S^t_{f,a}(0)}\right) = \mu^t_a \qquad \forall a \in \{acts\} \tag{17.43}$$

Sourcing shares

This section describes the adjustments to the sourcing share, S^s. Equation (17.44) replicates equation (17.15) and determines the shadow price μ^a. Equation (17.12) is split into two equations—one for the domestic share and the other for the import share.

$$\sum_s S^s_{s,c,a}(1) = 1 \quad \forall c \forall a \tag{17.44}$$

$$\omega^s \left(1 + \log \frac{S^s_{d,c,a}(1)}{S^s_{d,c,a}(0)}\right) = \mu^a_{c,a} \qquad \forall c \forall a \tag{17.45}$$

$$\omega^s \left(1 + \log \frac{S^s_{m,c,a}(1)}{S^s_{m,c,a}(0)}\right) = \mu^a_{c,a} + \mu^m_c \qquad \forall c \forall a \tag{17.46}$$

Energy targets

The biggest change methodologically with the original ‘FIT’ code is the treatment of the constraints. The IEA agents (including government and investment) are partitioned into a set labeled ait. In the current configuration, there is a one-to-one mapping between the energy activities plus the government and investment agents and all non-energy activities and households form the residual aggregate account. This is a generalization of the initial code, which can be readily amended in the future. The energy target equations replicate those from the first section.

$$\omega^e \left(1 + \log \frac{NRG_{ci,ai}(1)}{NRG^{iea}_{ci,ai}}\right) = \mu^{ce}_{ci,ait} - \mu^{iea}_{ci,ai} \qquad \forall ci \forall ai \in \{ait\} \tag{17.47}$$

$$\sum_{ai \in \{ait\}} NRG_{ci,ai}(1) = NRG^t_{ci} \qquad \forall ci \forall ait \tag{17.48}$$

$$\sum_{c \in ce} \sum_{a \in ae} S^t_{c,a}(1) E_a = NRG_{ce,ae}(1) \qquad \forall ce \forall ae \tag{17.49}$$

The GEMPACK solution method requires that all equations be at an equilibrium before the shock.[11] In the case of equation (17.47) this can only hold if the denominator equals the numerator, i.e., the starting point for the algorithm must have the initial IOT-based energy targets in the denominator and not the desired IEA-based energy targets. This implies that the denominator is a *variable* in the GEMPACK code, whose initial level is equal to the initial IOT-based energy use and which will be shocked (exogenously) to match the IEA-based targets. Taking the first differences of this equation leads to the following formulation:

$$n\dot{r}g_{ci,ai} = n\dot{r}g^{iea}_{ci,ai} + \frac{1}{\omega^e}\left(\Delta\mu^{ce}_{ci,ait} - \Delta\mu^{iea}_{ci,ai}\right)$$

This expression highlights that the conversion of the information-based first order conditions for GEMPACK leads to hybrid equations with percentage change variables on the one side and ordinary change variables on the other side.

A.5 Exogenous variables

Table 17.1 provides a list of the *shocked* exogenous variables and their correspondence with their counterparts from the original code, the relevant header in the HAR-based shock file and the original text-based shock file. Many of the shocked variables are only partially shocked and/or shocked using more than one shock file. The new code has merged all of the shocks into a single HAR file, with no explicit distinguishing between energy and non-energy targets, or any other partition of the shocks. The only exception is the stock-building shock which applies only to the `'STB'` element of the YD and YM variables. The energy shocks are contained in a separate HAR file. In the original code, the energy shocks were embedded in the code using a 'homotopy' variable that takes the value of '0' initially and shocked to '1'. A future version may revert back to this way of introducing the energy targets.

[11] The GAMS version does not require this, but in fact the target is initialized to the values in the original IOT and there is a smoothing process that converts the original target to the desired IEA target.

Table 17.1: Shocked exogenous variables

New	Old	Description	HAR	Old shock file
$YQEX$	`expboc`	Border value of exports	`XFOB`	sxef.txt, shk2.txt
$YQIM^{cif}$	`empboc`	Border value of exports	`MCIF`	smef.txt, shk3.txt
$YQIM$	`empbac`	Border value of exports	`MBAS`	smem.txt, sh7.txt
YO	`ech`, `ecg`, `eiv`	Aggregate domestic absorption	`NIPA`	shk1.txt
YD	`estbadc`	Value of domestic stock-building	`DSTB`	shk4.txt
YM	`estbamc`	Border value of exports	`MSTB`	shk5.txt
T^d	`wtcimdc`, `wtcchdc`	Power of tax rates on use of domestic products	`TD`	sdit.txt, shk9.txt, sdct.txt
T^m	`wtcimmc`, `wtcchmc`	Power of tax rates on use of imported products	`TM`	siit.txt, shk0.txt, sict.txt
T^e	`wtcxpc`	Power of tariff on exports	`ETAX`	shk6.txt
T^p	`wtpi`	Power of output tax	`PTAX`	sptw.txt, shk8.txt
NRG^t	`etge0c`	Aggregate IEA energy targets	`ATGT`	
NRG^{iea}	`eimtgci`, `echtgc`	Target IEA energy balances	`IEAT`	

Table 17.2 lists the other exogenous variables—none of which are shocked. There are some additional exogenous variables compared with the original version due to the merging of final demand agents with activities.

Table 17.2: Other exogenous variables

New	Old	Description	Notes
$PCIF^r$	`premc`	'Real' border price of imports	
RR^i	`rri`	Rental price of capital	
PFE	`vl`, `vn`	Factor prices	Fixed for labor, land and final demand agents
QFE^r	NA	Factor demand	Fixed for final demand agents
$S^t_{f,a}$	NA	Aggregate factor coefficient	Fixed for final demand agents
$QO_{c,STB}$	NA	Aggregate volume of stock-building	
$\mu^t_{c,STB}$	NA	Top-level shadow price for stock-building	
$S^t_{c,STB}$	NA	Stock-building top-level cost coefficient	
$S^s_{d,c,STB}$	NA	Stock-building domestic cost share	
$S^s_{m,c,STB}$	NA	Stock-building import cost share	

Appendix

IEA agents and concordance with GTAP

Table 17.3: IEA sectors

	IEA Code	Description
1	AGR	Agriculture
2	COA	Coal extraction
3	OIL	Crude oil extraction
4	GAS	Natural gas extraction
5	OMN	Other mining
6	FPR	Food processing
7	TWL	Textile and leather
8	LUM	Wood and wood products
9	PPP	Paper, pulp and printing
10	P_C	Refined oil
11	CHM	Chemicals
12	NMM	Non-metallic minerals
13	I_S	Iron and steel
14	NFM	Non-ferrous metals
15	TEQ	Transport equipment
16	OME	Other machinery and equipment
17	OMF	Other manufacturing
18	ELY	Electricity
19	CNS	Construction
20	TPT	Transport services
21	SER	Other services
22	DWE	Dwellings

Table 17.4: Mapping of GTAP sectors to IEA sectors

	IEA	GTAP		IEA	GTAP
1	AGR	pdr	34	CHM	bph
2	AGR	wht	35	CHM	rpp
3	AGR	gro	36	NMM	nmm
4	AGR	v_f	37	I_S	i_s
5	AGR	osd	38	NFM	nfm
6	AGR	c_b	39	OME	fmp
7	AGR	pfb	40	OME	ele
8	AGR	ocr	41	OME	eeq
9	AGR	ctl	42	OME	ome
10	AGR	oap	43	TEQ	mvh
11	AGR	rmk	44	TEQ	otn
12	AGR	wol	45	OMF	omf
13	AGR	frs	46	ELY	ely
14	AGR	fsh	47	GAS	gdt
15	COA	coa	48	SER	wtr
16	OIL	oil	49	CNS	cns
17	GAS	gas	50	SER	trd
18	OMN	oxt	51	SER	afs
19	FPR	cmt	52	TPT	otp
20	FPR	omt	53	TPT	wtp
21	FPR	vol	54	TPT	atp
22	FPR	mil	55	SER	whs
23	FPR	pcr	56	SER	cmn
24	FPR	sgr	57	SER	ofi
25	FPR	ofd	58	SER	ins
26	FPR	b_t	59	SER	rsa
27	TWL	tex	60	SER	obs
28	TWL	wap	61	SER	ros
29	TWL	lea	62	SER	osg
30	LUM	lum	63	SER	edu
31	PPP	ppp	64	SER	hht
32	P_C	p_c	65	DWE	dwe
33	CHM	chm			