IAJ The Integrated Assessment Journal
Bridging Sciences & Policy
Vol. 6, Iss. 3 (2006), Pp. 45–49

An integrated assessment of economy, energy and climate. The model WIAGEM—A reply to Commment by Roson and Tol

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1 Reply to comment

This paper replies to the comments by Roberto Roson and Richard S. J. Tol (2006). Roson and Tol discuss in a very profound way the model results by Kemfert (2002*b*) and illustrate very comprehensively the differences between modelling approaches. Roson & Tol (2006) provide a extensive discussion and comparison of model methodologies and compare important results of the model. This paper explains the model findings and discusses which model specifications play a major role in determining the observed results. Furthermore, this study shows some general model explanations and reactions to the major critiques.

WIAGEM, as other CGE models and approaches, follow the general equilibrium model rules of market closure and zero profit conditions. Appendix A shows the basic market closure conditions that are relevant to understanding the different market behaviour. CGE models are simulation models that determine a baseline growth path to calibrated steady state growth path. Intertemporal optimisation models like the Nordhaus DICE model determine the optimal growth path.

Crucial model parameters in CGE models do indeed cover the income elasticity of consumption. Even more crucial, however, are substitution elasticities between input factors in the production function, and Armington elasticities. Kemfert (2001) performs sensitivity analysis of Armington elasticities and studies their impacts on trade. As model results confirm, interregional and intersectoral trade plays a major role. As Kemfert (2002*a*) illustrates, a decomposition of welfare effects into trade and spill-over effects due to climate change shows that trade effects always dominate. Figure 5 of Kemfert (2002*a*) shows sectoral impacts of climate policy strategies. Due to climate policy, sectoral productivities change, which leads to production changes. As Roson and Tol mention, this effect shows that some sectors are more vulnerable than others. These effects are however not shown in Kemfert (2002*b*).

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It is very challenging to compare different model results as modelling approaches differ substantially; see Weyant & Hill (1999) for a model comparison. The main aim of developing an integrated assessment model that combines a dynamic multi regional, multisectoral economic-energy model with a climate model and impacts of ecology changes was indeed to compare the existent model results with an innovative modelling concept. Tol (2002*a*,*b*) estimates in a very detailed way the damage costs of climate change due to specific vulnerability indicators.

WIAGEM covers a growth engine that distinguishes between three investment categories: production investment, investment in protection and investment in R&D. In contrast to investment in R&D, investment in protection is stranded investment that crowds out other investment, as can be seen by equation (1.2) in Kemfert (2002*b*). This induces production losses. Protection cost estimates are taken from Tol (2002*a*,*b*). As Kemfert (2002*a*) illustrates, the share of protection costs is much higher in developing countries than in developed nations, so the impact of climate change is substantial (Table 4 in Kemfert (2002*a*)). Nordhaus (1994) does not cover these effects. He simply uses one damage factor in order to assess potential impacts. The inclusion of protection costs is a more advanced approach but certainly does not take all effects of climate change into account.

Because of that, WIAGEM covers the impacts of climate change assessed by Tol (2002*a*): impacts of ecosystem changes, vector borne diseases, mortality changes and demand for space heating and cooling. This is of course not taken into account as energy consumption or pure welfare changes, as Roson and Tol indicate. All those impacts are measured endogenously due to temperature changes and per capita income (see Kemfert (2002*b*)). The results exceed those by Tol considerably. The reason is that Tol does not cover endogenous feedback effects of production and temperature changes. WIAGEM determines production and temperature changes for each time period. Due to the above described production losses of climate change, regional impacts are significant. However, both modelling approaches by Tol and Kemfert are hardly comparable. Comparable results to Kemfert would need to be based on similar CGE model approaches or intertemporal growth models. Previous studies of IPCC did not take these effects into account. It might be discussed whether it is suitable or not to adapt the approaches taken by Tol into a CGE model approach, as Tol simulates much lower impacts. It might also be discussed whether Tol underestimates the effects as he did not take into account dynamic feedback effects. Nevertheless, climate change impacts cannot be reduced to pure productivity changes that are studied in a static CGE model. Such an approach neglects important dynamic feedback effects.

2 Acknowledgement

We thank the Volkswagen Foundation for supporting the ECOBICE project to develop an integrated assessment modelling approach. We thank Carlo Carraro, Hans Kremers, Roberto Roson and Richard Tol for their very helpful comments.

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A Appendix

The following overview shows the basic market closure conditions. It is assumed that all factor markets behave perfectly competitively—supply and demand are cleared by market prices. The output of domestically produced goods of sector j is an input to the Armington production sector. Armington goods are produced by the Armington sector and are used for energy, consumption, investment and public production.

$$\frac{\delta \prod_j^Y(p)}{\delta p_j} Y_j = -\frac{\delta \prod_j^A(p)}{\delta p_j} A_j \qquad \perp p_j \quad \forall \quad j = 1 \ldots J \tag{1}$$

and

$$\frac{\delta \prod_j^A(p)}{\delta p_j^A} A_j = -\sum_i \frac{\delta \prod_i^M(p)}{\delta p_j^A} M_i - \sum_j \frac{\delta \prod_i^E(p)}{\delta p_j^A} E_i - \frac{\delta \prod_{HH}^E(p)}{\delta p_j^A} E_{HH} \quad (2)$$
$$-\frac{\delta \prod^{CG}(p)}{\delta(p_j^A(1+\lambda t_j^c))} CG - \frac{\delta \prod^I(p)}{\delta(p_j^A(1+t_j^I))} I - \frac{\delta \prod^Z(p)}{\delta p_j^A}$$
$$\perp p_j^A \quad \forall \quad j = 1 \ldots J$$

The market clearance of the sector specific energy aggregate can be formulated:

$$\frac{\delta \prod_j^E(p)}{\delta p_j^E} E_j = -\sum_i \frac{\delta \prod_i^Y(p)}{\delta p_j^E} Y_j \quad (3)$$
$$\perp p_j^E \quad \forall \quad j = 1 \ldots J$$

The aggregated energy of households for consumption production is determined by the following market clearance condition:

$$\frac{\delta \prod_{HH}^E(p)}{\delta p_{HH}^E} E_{HH} = -\sum_i \frac{\delta \prod_i^Y(p)}{\delta p_{HH}^E} CG \quad (4)$$
$$\perp p_{HH}^E \quad \forall \quad j = 1 \ldots J$$

The equilibrium condition of labor requires that the sum of all sectoral demand for labor equals supply:

$$\frac{\delta \prod^L(p)}{\delta p^L} L = -\sum_i \frac{\delta \prod_i^Y(p)}{\delta p^L} Y_j \quad (5)$$
$$\forall \quad p^L$$

Capital is traded with a price p^{RK}, which is produced in the capital sector and demanded by the production sectors.

$$\frac{\delta \prod^{RK}(p)}{\delta p^{RK}} K = -\sum_i \frac{\delta \prod_i^Y(p)}{\delta p^{RK}} Y_j \quad (6)$$
$$\forall \quad p^{RK}$$

The capital stock of one period is determined by the depreciated capital stock and the investment of the previous period.[1]

$$\frac{\delta \prod_{t-1}^K(p)}{\delta p_t^K} K_{t-1} + \frac{\delta \prod_{t-1}^I(p)}{\delta p_t^K} = -\sum_i \frac{\delta \prod_t^K(p)}{\delta p_t^K} K_t \quad (7)$$
$$\perp p_t^K \quad \forall \quad t = 1 \ldots T$$

[1]The investment is additionally composed by investment in production, R&D and protection to climate change.

The public good is determined by the total available income of the government Inc^Z that is determined by the tax incomes and the public deficit:

$$\frac{\delta \prod^T(p)}{\delta p^Z} Z = \frac{Inc^Z}{p^Z} \quad \perp p^Z \tag{8}$$

The foreign trade balance assumes that in each period the sum of exports and the balance of payment deficit or surplus must be equal to the sum of imports:

$$\frac{\delta \prod_j^Y(p)}{\delta p^{FX}} Y_j + \sum_{j=1}^{T} BOP_j = -\sum_j \frac{\delta \prod_j^A(p)}{\delta p^{FX}} A_j \quad \forall \quad p^{FX} \tag{9}$$

The intertemporal balance of payment condition determines the equivalence of the sum of exports and balance of payments and the sum of imports. This means that potential trade deficits or surpluses must be equalized over the entire time period. This condition represents the basic closure of the model:

$$\sum_i \sum_j \frac{\delta \prod_{t,j}^Y(p)}{\delta p_t^{FX}} Y_{t,j} + \sum_t \sum_{j=1}^{T} BOP_{t,j} = -\sum_t \sum_j \frac{\delta \prod_{t,j}^A(p)}{\delta p_t^{FX}} A_{t,j} \quad \forall \quad p_t^{FX} \tag{10}$$

The total income of the representative agent Inc^r is the sum of factor incomes minus tax payments minus the balance of payment.

$$\begin{aligned} Inc^r = \; & p^L \left(-\sum_i \frac{\delta \prod_i^Y(p)}{\delta p^L} Y_j \right) + p^{RK} \left(-\sum_i \frac{\delta \prod_i^Y(p)}{\delta p^L} Y_j \right) \\ & + p^E \left(-\sum_i \frac{\delta \prod_i^Y(p)}{\delta p^E} Y_j \right) + Inc^Z - \sum_t \sum_{j=1}^{T} BOP_{t,j} \end{aligned} \tag{11}$$

Among the entire model horizon, we assume that from the consumer budget constraint that there is no net change in indebtedness. The sum of all regional trade imbalances must be zero.

$$\sum_t \sum_{j=1}^{T} BOP_{t,j} = 0 \tag{12}$$

$$\sum_i \sum_j \frac{\delta \prod_{t,j}^Y(p)}{\delta p_t^{FX}} Y_{t,j} + \sum_t \sum_{j=1}^{T} BOP_{t,j} = -\sum_t \sum_j \frac{\delta \prod_{t,j}^A(p)}{\delta p_t^{FX}} A_{t,j} \quad \forall \quad p_t^{FX} \tag{13}$$