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A MULTI-REGION SOCIAL ACCOUNTING MATRIX (1995) AND REGIONAL ENVIRONMENTAL GENERAL EQUILIBRIUM MODEL FOR INDIA (REGEMI)

by

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Research programme on:
Responding to Global and Local Environmental Challenges



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RÉSUMÉ

Ce document technique présente l'ensemble des données techniques de la version actuelle du modèle d'équilibre général régional et environnemental (RE-GEM — *Regional and Environmental General Equilibrium Model*) utilisé pour l'Inde. Toutes les équations structurelles et comportementales clés y sont répertoriées et viennent justifier les caractéristiques retenues. Ce document propose en outre une description complète des méthodes d'estimation et des sources utilisées pour les données indiennes ; une version agrégée de la matrice régionale de comptabilité sociale construite pour l'Inde est fournie en annexe. Les auteurs souhaitent ainsi donner un maximum d'informations aux chercheurs désireux de poursuivre les travaux de modélisation de l'OCDE ; ils espèrent aussi contribuer, avec cet instrument, au débat sur l'économie des politiques d'environnement dans les pays en développement.

SUMMARY

This technical paper presents the complete technical specification of the current version of the RE-GEM (*Regional and Environmental General Equilibrium Model*) for India. The document lists all the key structural and behavioural equations, providing a justification for the chosen model specification. In addition, a complete description is provided of the estimation methods and the sources of the Indian data used in the model; an aggregated version of the Indian regional Social Accounting Matrix we constructed is appended to this document. The object is to inform in the most detailed way possible researchers interested in building on the OECD's modelling effort, and to provide a useful tool for informing the debate on the economics of environmental policy in developing countries.

I. INTRODUCTION

The economic costs of climate protection measures, juxtaposed with the significant scientific uncertainties about the extent and impacts of climate change, have generally favoured a “wait-and-see” attitude on the part of policy makers. Although the awareness of the problem is raising and governments are committed to action, progress in global climate policy negotiations has been slow. In all countries, policy makers find themselves under strong pressure to enhance domestic competitiveness rather than curtail it by adopting costly energy taxes. The situation is compounded in developing countries by a rightful preoccupation with meeting basic human needs.

Motivated by these considerations, the OECD Development Centre has undertaken a series of studies on the potential ancillary benefits from climate policy in terms of local pollution abatement. Three case studies for Chile, India and China are part of the Centre’s research programme on “Responding to the Global and Local Environmental Challenges” and they show that — up to a point — near-term, tangible benefits, in the form of improved human health and agricultural productivity, can counter-balance the costs of environmental taxes.

The actual measurement of these costs and benefits is a highly technical effort that stands on two essential pillars: reliable and updated databases and careful economy-wide model analyses. This paper aims at providing a detailed reference for both the Social Accounting Matrix (SAM) and the Computable General Equilibrium (CGE) model, which constitute the two pillars used in this sort of analyses. Although specifically applied to India in this paper, the data and the analytical framework developed here have a general validity and provide useful quantitative tools that can now be applied to a large set of issues to better elucidate the economic consequences of policy before it is implemented.

Properties and advantages of SAMs are well established in the recent literature on policy simulation modelling: they provide a comprehensive and consistent data foundation, as well as ensure that the share parameters in behavioural functions reflect observed facts. SAMs usefulness has also recently been reflected in the United Nations and joint agency new edition of the manual on national accounts, which dedicates an entire chapter to them. In the past, the OECD Development Centre has produced SAMs for various other countries and these that have been the empirical base in numerous studies; the particular SAM presented here is used to inform our Indian case study on climate policy and additional studies on poverty in South Asia.

General equilibrium models also have obvious advantages in the analyses of complex policy reforms. It is obvious from the complexity of influences giving rise to our results that policy makers relying on economic theory, intuition, or rules of thumb alone

are unlikely to adequately foresee the consequences of their actions. Not only are the magnitudes of induced adjustments difficult to ascertain because of the scope of indirect effects, but qualitative outcomes often directly contradict intuition or the predictions of highly simplified models, leading to the opposite results from the intended ones.

Additionally, its geographical dimensions complicate the particular case of environmental policy. On the one hand, climate policy is normally made by national policymakers interested principally in the economy-wide costs while, on the other, the ancillary health benefits are experienced locally and the size of those benefits depends on a variety of local characteristics — e.g. the concentration of energy-intensive industries and activities, meteorological conditions that affect the atmospheric dispersion of pollutants, and population density and distribution in relation to pollutant concentrations. The spatial modelling of emissions and concentrations for all of India would have been too data demanding, not to mention the disaggregation of our economic model to the level of detail required for such an analysis. So, we have implemented a second-best solution, *viz.* to divide India into a number of major regions, calculating emissions at the regional level and linking them to pollutant concentrations in the major regional population centres. This necessarily involves a simpler air dispersion model than would be used in a more geographically focused analysis. At the same time, it allows the introduction of a degree of geographic differentiation into the analysis that would be impossible with a single India-wide model.

In sum, our research method consists of a combination of local characteristics with aggregate features and by constructing a multi-region model we provide a good compromise between a bottom-up and a top-down approach while maintaining tractability and manageable data requirements.

This paper is organised in two parts: in the first, sources and methodology for the construction of the regional Social Accounting Matrices for India are described; in the second, the full algebraic structure of the model is presented.

II. THE SAM

A SAM is a square matrix that describes quantitatively the economic transactions taking place in an economy during a specified period of time, generally one year. It consists of row and column accounts that represent the different productive activities, economic agents, institutions, and policy instruments of an economy at a chosen level of disaggregation. By convention, each cell of the matrix represents a payment from the column account to the row account. The underlying principle of double-entry accounting requires that row totals equal column totals for each account in the SAM. In practice, a SAM is the natural extension of the Input-Output (IO) accounting system devised by Leontief more than 50 years ago, and it includes not only inter-industry transactions but also payments to factors of production, expenditures of households, transfers to and expenditures by government, and transactions with the rest of the world. A quite large literature on IO and SAMs now exists and readers interested in more detailed description should start from Pyatt and Round (1985) and the recent CEC, IMF, OECD, UN and WB (1993) revised manual on the System of National Accounts. A schematic representation of a generic SAM and the macroeconomic account identities derived from the equality of the row and column totals is shown in Figure 1.

Figure 1. **A Schematic SAM and its Basic Macroeconomic Accounts**

	Suppl. 1	Househ. 2	Gov. 3	CapAcc. 4	ROW 5	
1 Suppliers	IC	C	G	I	E	Demand
2 Households	Y					Income
3 Government		T				Receipts
4 Capital Account		Sh	Sg		Sf	Savings
5 Rest of the World	M					Imports
	Supply	Expend.	Expend.	Investment	ForExchg.	
1) $Y+M = C+G+I+E$	<i>GNP: Value added + Imports</i> <i>= Consumption + Gov Expenditure + Investment + Exports</i>					
2) $C+T+Sh = Y$	<i>Domestic Income: C + Direct taxes + Hh Savings = Income</i>					
3) $G+Sg = T$	<i>Government Budget: G + Gov. Savings = Taxes</i>					
4) $I = Sh+Sg+Sf$	<i>Investment = Savings (private + public + foreign)</i>					
5) $E + Sf = M$	<i>Foreign Balance</i>					

The data used to construct the national India SAM, from which four inter-connected regional SAMs are derived, has been drawn from various sources including input-output tables, national accounts, government budgets, household surveys, industrial surveys, and agriculture production statistics. The following list presents some of the key data sources used in the construction of the regional SAMs for India.

- 1) 1989/1990 Central Statistical Organisation's (CSO) Input Output Table for India, New Delhi, India.
- 2) 1994/1995 Household Expenditure Survey. CSO, New Delhi, India.
- 3) 1995/1996 Annual Survey of Industries, Volumes I, II and III. CSO, New Delhi, India.
- 4) 1997/98 Annual Survey of Industries: Provisional Results for Factory Sector. CSO, New Delhi, India.
- 5) 1998 National Accounts Statistics, CSO, New Delhi, India.
- 6) 1998 Agriculture. Centre for Monitoring Indian Economy, Bombay, India.
- 7) A technical note to the Eighth Plan of India (1992/97). Planning Commission of the Government of India, New Delhi.
- 8) Pradhan *et al.* (1999) A Social Accounting Matrix for India, 1994-95.

The methodology for estimation of the regional SAM cell entries is documented in the next sections as follows: section II.1 briefly describes the national Indian SAM and section II.2 illustrates the methodology and data sources used to estimate the regional SAMs.

II.1. National SAM

The original national SAM for India assembled by Pradhan *et al.* (1999) contains 60 productive sectors, 2 factors of production, and 12 household occupational categories (in our SAM, however, there is only a single representative household). This SAM is an updated and expanded version of the 1989-90 IO table prepared by the Indian Central Statistical Organisation. This SAM had been re-estimated by transforming its basic prices into purchaser's prices, i.e. by adding to the initial values indirect taxes and transportation and commercial margins. Given the energy policy focus of this study, an important change we introduced has been the split of the initial merged sector of "Crude Oil and Gas" into its two separate Oil and Gas components. The other general sources, methods, and assumptions made for estimating the inputs, outputs and final demand components for various sectors of the economy are detailed in Pradhan *et al.* (1999). Table 1 presents the main dimensions of the India multi-region SAM.

Table 1. Dimensions of the 1994/1995 India Multi-Region Social Accounting Matrix

60 Sector classification		35 Sector classification and bridge				Regions	States
1 Food crops	36 Other basic metal industry	1 Agriculture	1 -	4	1 North	Haryana	
2 Cash crops	37 Metal products except mach	2 Livestock	5			Himachal Pradesh	
3 Plantation crops	38 Agricultural machinery	3 Forestry	6			Jammu & Kashmir	
4 Other crops	39 Industrial machinery for food and textiles	4 Fishing	7			Punjab	
5 Animal husbandry	40 Other machinery	5 Coal Lignite	8			Rajasthan	
6 Forestry & logging	41 Electrical,electronic,machinery & appliances	6 Crude Oil	9			Uttar Pradesh	
7 Fishing	42 Railway transport equipment	7 Crude Gas	9			Chandigarh	
8 Coal and lignite	43 Other transport equipment	8 Iron Mining	10			Delhi	
9 Crude petroleum & natural gas	44 Miscellaneous manufacturing industries	9 Other Mining	11			2 West	Gujarat
10 Iron ore	45 Construction	10 Food	12 -	15			Madhya Pradesh
11 Other minerals	46 Electricity	11 Textiles	16	17 18	Maharashtra		
12 Sugar	47 Gas and water supply	12 Apparel	19		Goa		
13 Food products excluding sugar	48 Railway transport services	13 Wood Products	20	21	Daman & Diu		
14 Beverages	49 Other transport services	14 Paper And Printing	22	23	D. & N. Haveil		
15 Tobacco products	50 Storage and warehousing	15 Leather	24		3 South	Andhra Pradesh	
16 Cotton textiles	51 Communication	16 Plastic	25			Karnataka	
17 Wool, silk & synthetic fibre textiles	52 Trade	17 Oil Products	26			Kerala	
18 Jute, hemp and mesta textiles	53 Hotels and restaurants	18 Coal Products	27			Tamil Nadu	
19 Textiles products including wearing apparel	54 Banking	19 Fertilizer	30			Pondicherry	
20 Wood and wood products except furniture	55 Insurance	20 Pesticide Drugs	32	28 29 31	Lakshadweep		
21 Furniture and fixture	56 Ownership of dwellings	21 Cement	33		4 East and Northeast	Bihar	
22 Paper and paper products	57 Education and research	22 Non Metal Products	34			Orissa	
23 Printing, publishing and allied activities	58 Medical and health	23 Iron Steel	35			West Bengal	
24 Leather and leather products	59 Other services	24 Other Metals	36			A. & N. Islands	
25 Plastic and rubber products	60 Public administration and defense	25 Industrial Machinery	38			Sikkim	
26 Petroleum products		26 Other Machinery	40	39		Assam	
27 Coal tar products		27 Electric Equipment	41			Manipur	
28 Inorganic heavy chemicals		28 Transp. Equipment	42	43		Meghalaya	
29 Organic heavy chemicals		29 Other Manufacturing	44	37		Nagaland	
30 Fertilizers		30 Construction	45			Tripura	
31 Paints, varnishes and lacquers		31 Electricity	46	47	Arunachal Pradesh		
32 Pesticides, drugs and other chemicals		32 Gas and Water			Mizoram		
33 Cement		33 Transp. Services	48	49			
34 Non metallic mineral products		34 Communication	51				
35 Iron & steel industries and foundries		35 Other Services	52 -	60 50			

II.2. Regional SAMs

The national SAM serves as a benchmark for the estimation of its regional components, which, when aggregated together, reproduce the national SAM. As clearly shown in Figure 2, the construction of a regional SAM entails the estimation of various components: regional input output tables (IC , using the figure symbols), regional final demands (C , G , I and E) and supply (Y which represents factor payments plus M), regional household savings and direct tax payments (Sh and Tx), and, finally, inter-regional trade flows (T)¹. Apart from some aggregates, namely savings and direct taxes, all the remaining regional variables have to be estimated at sectoral levels (i.e. at the 35-sector level shown in the third column of Table 1). We used different sources and methods for the various regional variables and, in some cases, even for the same variable, estimation techniques differed across groups of sectors. The following subsections briefly describe the estimation procedures.

Figure 2. A Schematic Two-Region SAM

	Suppl. ₁	Househ. ₁	CapAcc. ₁	Suppl. ₂	Househ. ₂	CapAcc. ₂	Gov	ROW	
	1	2	3	4	5	6	7	8	
1 Suppliers ₁	IC ₁	C ₁	I ₁	T ₁₂			G ₁	E ₁	Demand ₁
2 Households ₁	Y ₁								Income ₁
3 Capital Account ₁		Sh ₁						Sf ₁	Savings ₁
4 Suppliers ₂	T ₂₁			IC ₂	C ₂	I ₂	G ₂	E ₂	Demand ₂
5 Households ₂				Y ₂					Income ₂
6 Capital Account ₂					Sh ₂		Sg	Sf ₂	Savings ₂
7 Government		Tx ₁			Tx ₂				GRceipts
8 Rest of the World	M ₁			M ₂					Imports
	Supply ₁	Expend. ₁	Invest. ₁	Supply ₂	Expend. ₂	Invest. ₂	GExpend	ForExchg.	

Note. Symbols in the cells are the same as those of figure 1 except for the following differences:
 - The subscripts indicate the two regions, so that, for example, C₁ is private consumption of region 1
 - T₂₁ is the trade flow from region 2 to region 1, and Tx represents direct tax

Gross Output

Agricultural and other primary sectors (sectors 1 to 9 in column 3 of Table 1), manufacturing (sectors 10 to 29 plus 31 and 32), and services (sectors 30, and 33 to 35) are considered separately. For gross production in primary sectors, basic data for quantities and producer prices were obtained from the study conducted by the Centre for Monitoring Indian Economy (1999) on agriculture production and also from other sectoral studies conducted by the Indian Agricultural Statistics Research Institute. For

1. Here, E and M refer to exports to and imports from the rest of the world (ROW) by a particular region of India.

manufacturing sectors, production value data were taken from the 1995/1996 Industry Survey. This survey provides production figures for each manufacturing sector at a two-digit level of detail and classified by Indian states. For services sectors, the main source for regional data is the States Accounts Yearbook compiled by the Central Statistical Office of India. The use of different sources created some consistency problem in the sense that we had to adjust some of the data so that the regional aggregation could reproduce the India-wide figures from the IO table.

Intermediate Demands

Unfortunately information on production structures, defined as the mix of intermediate inputs and value added, does not exist at regional level for all sectors. In particular, we have had to assume that primary and tertiary regional production structures are the same as the India-wide one, and that regional differences are only in the scale of production. More specifically, this means that each region is assumed to produce rice, for example, with the identical input and value added structures — i.e. with identical technology.

In contrast, the 1995/1996 Annual Survey of Industries of India provides regional (actually, state-by-state) production structures for all manufacturing sectors. This survey reports the intermediate input demands and labour and capital value added at a very detailed level. A first step in the construction of regional manufacturing input-output tables has been to devise a common classification mapping the Industry Survey sectoral and intermediate input categories into those of the SAM. It should be noted that the Survey distinguishes between material inputs and fuel inputs, a quite useful distinction given our climate policy focus. A second, simpler step consists of aggregating the States into our four regions. From these three steps we obtain for each of the four regions a set of 22 tables showing intermediate purchases by sector for each manufacturing sector. Finally, we adjust this set of regional estimates to make it consistent with the value of the national intermediates demand as reported in the national SAM.

Labour and Capital Value Added

For primaries and services we have again to assume that the shares of labour and capital VA at the regional level are the same as those at the national level. For manufacturing industries the aforementioned Annual Survey supplies the necessary regional data.

Final Demand

This consists of private consumption, government expenditures, investment and variation of stocks, and international exports. Basic data on household consumption by product and region are obtained from the 1994/1995 Household Expenditure Survey. This survey distinguishes rural and urban households' expenditure patterns for all Indian states. The derivation of the four-region by thirty-five sector household consumption matrix consists of the following steps. First, a concordance between the 819 items considered in the household survey and the 35-sector classification of our SAM is

established. Second, from the resulting sectoral consumption values we calculate sectoral shares that we then multiply by the aggregate regional consumption figures. Finally, consumption values are further adjusted so that the sum over all regions and households for a given product equals the total for each commodity as shown in the national SAM for India. It should be noted that the Household Survey also provides the basic data used in estimating regional direct taxes and household savings.

Government expenditures statistics are not available at a regional level. To estimate consumption by product and by regional government, we assume that the sectoral composition of public expenditure and its total value as a share of regional GDP are the same across all regions. Thus we estimate GDP for each region from the States Accounts figures, calculate the India-wide ratio of public expenditure to GDP and use it to calculate regional aggregate public expenditure; finally we estimate sectoral values by using the national sectoral shares.

Gross fixed capital formation and variation of stocks are not available at regional level, so we used the same procedure employed for public expenditure to disaggregate the national values. In practice, we assume that regional ratios of investment over GDP and variation of stocks over GDP as well as their sectoral compositions are the same as those at the national level.

Export demand is treated together with import supply in the next subsection.

International trade

The original source for Indian international trade is the 1994/1995 national SAM. To estimate regional exports for each product and service considered in the SAM, we assume that export ratios do not differ across regions. More explicitly, exports from region r of product i ($E_{r,i}$) are determined by the following relationship: $E_{r,i} = (E_{India,i} / GDP_{India,i}) \times GDP_{r,i}$.

Similarly for regional imports we assume that they depend only on total domestic demand defined as absorption (ABS_{ri}), i.e. the sum of intermediate consumption and final consumption. In this way imports by region r of product i are calculated using the following equation:

$$M_{r,i} = (M_{India,i} / ABS_{India,i}) \times ABS_{r,i}$$

Inter-Regional Trade

Once intermediate demands, final demands, value added and international trade have been estimated for each region, the only remaining variable to be calculated is inter-regional trade. Unfortunately we were not able to find any reliable statistics on Indian internal trade: apart from some shipment values for bulk goods gathered from the railway or coastal water transportation yearbooks, no other figures on inter-regional commerce were available. For example, no statistics could be found on road transport. While various sub-national governments impose levies on trade with other parts of India (known as *octroi*), it was not possible to locate a source of data on *octroi* revenue by commodity (or even in aggregate). Due to these data limitations, we had to rely on the

residual values calculated as regional supply minus regional demand to estimate net trade flows. A cross-check of some of these estimated trade flows against measures reported by the railway system indicated broad consistency. The main limitation of this residual approach consists of the impossibility of estimating gross inter-regional trade flows, since each region has either an excess supply or excess demand of a particular commodity, which gives rise to an offsetting *net* export or *net* import.

An aggregated version of the regional SAM for India is found in appendix.

III. THE TECHNICAL SPECIFICATION OF THE INDIAN REGIONAL AND ENVIRONMENTAL – GENERAL EQUILIBRIUM MODEL (RE-GEM)

A brief description of the main characteristics of the RE-GEM model is followed by a fuller description of the model's algebraic structure.

One of the key features of this model is its regional dimension. There are as many sub-models as there are regions and these are connected by inter-regional trade flows to form an India-wide economic unit. Regional savings as well as regional tax revenues, transfers and other government expenditures are aggregated to generate the India-wide macro balances for the investment-savings relation and central government budget. Although goods can freely move across regions, the current version does not include inter-regional factor mobility.

For each region, production is modelled with a nested Constant Elasticity of Substitution (CES), constant returns to scale production function. Output results from two composite goods: non-energy intermediates and energy plus value added. The intermediate aggregate is obtained combining all products in fixed proportions (Leontief structure). The value added and energy components are decomposed into two parts: aggregate labour and capital, which includes energy. The capital-energy bundle is further disaggregated into its basic components². As in a vintage capital model, the capital existing at the beginning of each period, or already installed, is distinguished from that resulting from contemporaneous investment (putty/semi-putty production function). Finally, the energy aggregate is decomposed into different types of fuels or energy sources. Adjustment possibilities in the demand for factors of production originating from variations in their relative prices are reflected in values of the substitution elasticities, which will usually be higher for new than for old capital vintages. Specific elasticity values used in the India study include³ 0.00 between intermediates and value added with *old* capital plus energy; 0.50 between intermediates and value added with *new* capital plus energy; 0.12 between aggregate labour and the *old* capital-energy bundle; 1.00 between aggregate labour and the *new* capital-energy bundle; 0.00 between *old* capital and

-
2. The particular production function of this model treats energy as a separate factor of production rather than an intermediate input. Energy use is typically highly polluting and the specific nesting structure adopted here allows monitoring more closely energy-related emissions. Moreover bundling energy together with capital is motivated by the fact that new technologies, embodied in new capital goods, are usually energy saving (i.e. energy substituting).
 3. These elasticities are derived from the most recent relevant literature. In fact, they are mostly derived from background studies done for the construction of the OECD GREEN model. See for instance Burniaux *et al.* (1992).

energy; 0.80 between *new* capital and energy; 0.25 among different sources of energy associated with *old* capital; 2.00 among those associated with *new* capital.

Labour and capital income is allocated to a single household group. Private consumption demand is obtained through maximisation of a household utility function following the Extended Linear Expenditure System (ELES). Household utility, a function of consumption of different goods and saving, is not influenced by environment quality. Once their total India-wide value is determined, government and investment demands are disaggregated into regional aggregates and then sectoral demands according to fixed coefficient functions.

Imperfect substitution among goods originating in different geographical areas is a central feature of the model. Producers decide to allocate their output to different markets responding to relative prices. In the same way consumers demand goods originating from different markets to minimise the aggregate cost function that is sensitive to relative price changes. The model implements a two-stage procedure for determining import and export flows and domestic regional supplies and demands. At the first stage, demand for a certain good is decomposed into a domestic bundle and an import component. At the second stage, aggregate domestic demand is allocated across the various regions of the model. The supply side is treated in a symmetric fashion: producers allocate production between domestic and foreign markets. At the second stage, aggregate domestic sales are distributed to the various regions based on the relative price the producer can receive in each market. International import and export prices are treated as exogenous. The balance of payments equilibrium is determined by the equality of capital flows (which are exogenous) to the value for the current account. With fixed world prices and capital flows, all adjustments are accommodated by changes in the real exchange rate. A real exchange rate depreciation, for example, would be reflected in price decreases in importables and a shift of resources towards export sectors — in short, a fall in domestic resource costs.

The dynamic structure of the model results from the equilibrium condition between savings and investment. A change in the savings volume influences capital accumulation in the following period. Exogenously determined growth rates are assumed for various other factors that affect the growth path of the economy, such as: population and labour supply, labour and capital productivity, and energy efficiency. Agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. The model dynamics are therefore recursive, generating a sequence of static equilibria.

Emissions are determined by either intermediate or final consumption of polluting products, mostly fossil fuels in the case of air pollution. In addition, certain industries have a process emission component linked directly to their output levels. It is assumed that labour and capital do not pollute.

Once emissions are calculated, a dispersion equation determines concentrations of pollutants in the air at monitoring stations in major Indian cities. This equation discriminates among emissions released at different stack heights, attributing larger contributions to overall concentration levels the lower the height of the stack. A dose-response function is finally used to estimate health impacts on the exposed population. Valuation of these damages is based on willingness to pay estimates for India contained

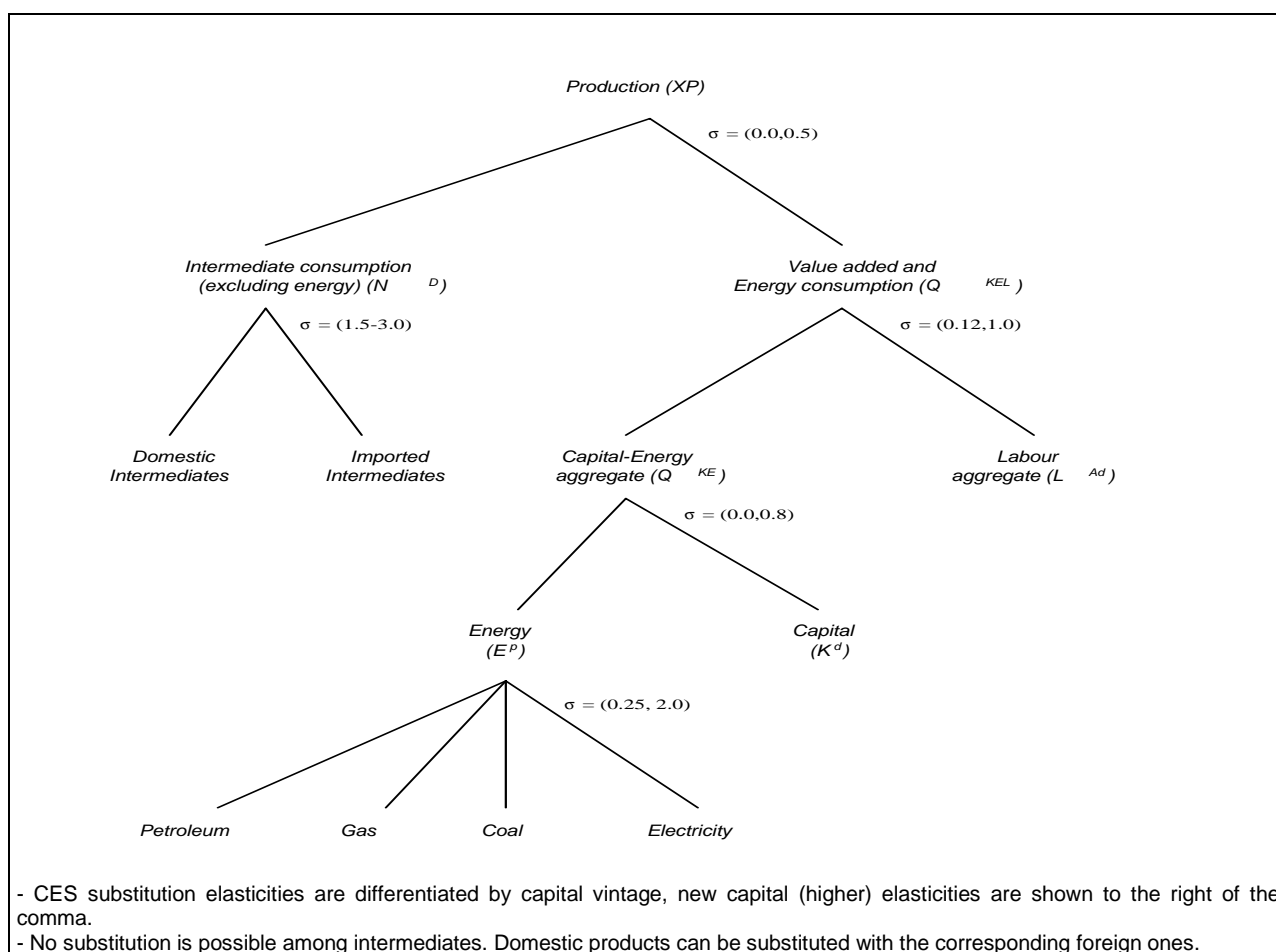
in the literature (see Bussolo and O'Connor, 2001, for more details). Reductions in these damages as a result of climate policy constitute the model evaluation of ancillary benefits.

III.1. Model blocks

III.1.1. Production

For each sector of the regional economy, production is modelled as a nested structure of different inputs. For each level of the nest, producers choose an optimal mix depending on the relative prices of the inputs and the substitution elasticities. A graphical description of the production structure is given in Figure 3.

Figure 3. Nested Production Function



At the top level, the producer chooses a mix of value added plus energy⁴ aggregate (Q^{KEL}) and an intermediate demand aggregate (N^D). The optimisation problem takes the following form:

$$\min P_j^{KEL} Q_j^{KEL} + P_j^N N_j^D$$

subject to the production function:

$$XP_j = \left[a_j^{KEL} Q_j^{KEL \rho_{i,p}} + a_j^N N_j^D \right]^{1/\rho_{i,p}}$$

where P_j^{KEL} is the aggregate price of value added plus energy, P_j^N is the price of the intermediate aggregate, α_j^{KEL} and α_j^N are the CES share parameters, and ρ is the CES exponent. The exponent and the CES elasticity are related via this relationship:

$$\sigma = \frac{1}{1-\rho} \Leftrightarrow \rho = \frac{\sigma-1}{\sigma}.$$

Note that in the model, the share parameters incorporate the substitution elasticity using the following relationships:

$$\alpha_j^{KEL} = (a_j^{KEL})^\sigma \quad \text{and} \quad \alpha_j^N = (a_j^N)^\sigma$$

The solution to this minimisation problem yields Equations (2.1) and (2.3) in Table 2. Notice that because of the existence of vintage capital, each producing sector is modelled as comprising two distinct technologies, producing a homogeneous good, but with different production parameters. Hence, intermediate and value added plus energy aggregate demands are indexed by vintage (using the index v). For each production sector, Equation (2.1) determines the demanded volume of a bundle of non-energy intermediates Nv^D , by vintage. Equation (2.2) determines the sum across vintages for non-energy intermediates, N^D . Equation (2.3) determines the demand for the composite bundle of value added and energy, Q^{KEL} .

Table 2. Top Level Production Nest

$$(2.1) \quad N_{jv}^D = \alpha_{jv}^N \left(\frac{PXv_{jv}}{P_j^N} \right)^{\sigma_{jv}^p} XPv_{jv}$$

$$(2.2) \quad N_j^D = \sum_v Nv_{jv}^D$$

$$(2.3) \quad Q_{jv}^{KEL} = \alpha_{jv}^{KEL} \left(\frac{PXv_{jv}}{P_{jv}^{KEL}} \right)^{\sigma_{jv}^p} XPv_{jv}$$

4. Due to the crucial importance of energy in terms of pollution, the demand for energy has been separated from the rest of intermediate demand, and incorporated in the value added nest.

The next level of the production nest, shown in Table 3, concerns the demand for the single components of the N^P and Q^{KEL} bundles. In Equation (3.1), N^P is split into its individual input components (at the Armington level⁵) assuming a Leontief technology. The index nf (for *non-fuels*) identifies elements pertaining to the set of non-energy commodities. Notice that in Equation (3.1) aggregate non-energy intermediate demand is not dependent on the vintage. The matrix α is the matrix of input-output coefficients for non-energy intermediate inputs.

At the same level, the Q^{KEL} bundle is split into aggregate labour demand on the one hand L^A , and the Q^{KE} bundle on the other. This is done using a CES function with the substitution elasticity σ^{kel} , which is assumed to be vintage specific. Equations (3.2) and (3.3) provide the reduced form first-order conditions for this level of the nest. Aggregate labour demand is independent of vintage therefore it is summed directly in Equation (3.2) where L^{Ad} represents aggregate sectoral labour demand. P^{KEL} is the aggregate (or CES dual) price of the Q^{KEL} bundle, W^A is the price of aggregate labour in each sector, and P^{KE} is the price of the Q^{KE} bundle. The share parameters are α^l for labour, and α^{KE} for the Q^{KE} bundle. It should be noticed that Labour is assumed to be perfectly mobile across sectors, which implies a uniform economy-wide wage rate. However, we allow for the possibility of differential sectoral wages to take into account observed data that reflect specific institutional features: the parameter ω is fixed and determines the relative wage across sectors.

Table 3. **Second Level CES Production Equations**

$$(3.1) X_{nf,j}^{AP} = a_{nf,j} N_j^D$$

$$(3.2) L_j^{Ad} = \sum_v \alpha_{jv}^L \left(\frac{P_{jv}^{KEL}}{\omega_j W^A} \right)^{\sigma_{jv}^{KEL}} Q_{jv}^{KEL}$$

$$(3.3) Q_{jv}^{KE} = \alpha_{jv}^{KE} \left(\frac{P_{jv}^{KEL}}{P_{jv}^{KE}} \right)^{\sigma_{jv}^{KEL}} Q_{jv}^{KEL}$$

The next level of the CES nesting disaggregates the Q^{KE} bundle into the energy bundle on one side, and capital demand on the other side. The equations in Table 4 provide the reduced form first-order conditions for demand for E^P and K_v .

5. Armington goods are composites of domestically produced and imported goods. A formal definition is given below, see page 33.

Table 4. Demand for the Energy Bundle and Capital

$$(4.1) E_{jv}^P = \alpha_{jv}^E \left(\frac{P_{jv}^{KE}}{P_{jv}^{EP}} \right)^{\sigma_{jv}^{KE}} Q_{jv}^{KE}$$

$$(4.2) Kv_{jv}^d = \alpha_{jv}^K \left(\frac{\lambda_{jv}^K P_{jv}^{KE}}{R_{jv}} \right)^{\sigma_{jv}^{KE}} \frac{Q_{jv}^{KE}}{\lambda_{jv}^K}$$

$$(4.3) K_j^d = \sum_v Kv_{jv}^d$$

E^P is demand for the energy bundle (by vintage), P^{EP} is the price of the energy bundle, Kv^d represents capital demand by vintage, and R is the vintage specific rental rate of capital. The share parameters are α^E for the energy bundle, and α^K for capital. Capital demand incorporates changes in capital factor efficiency. Equation (4.3) determines aggregate sectoral capital demand.

The energy bundle is the last one to be decomposed: Table 5 lists the equations for determining energy demand by fuel type.

Table 5. Demand for Energy by Fuel Type

$$(5.1) X_{e,j}^{AP} = \sum \alpha_{e,j,v}^{EP} \left(\frac{\lambda_{jv}^{EP} P_{j,v}^{EP}}{PA_e} \right)^{\sigma_{jv}^{EP}} \frac{E_{jv}^P}{\lambda_{jv}^{EP}}$$

Energy demand is vintage specific, and the substitution possibilities across fuels are generally lower for old capital than for new capital. The current version of the model uses a single energy nesting, i.e. the decomposition of the energy bundle into the fuel components requires only one CES function. The index e represents the fuel commodities in the sectoral disaggregation. Equation (5.1) determines the demand for each fuel and incorporates energy efficiency improvement that is both sector and vintage specific (but not fuel specific).

This completes the description of the production structure. Starting from output, XP_v , the nested CES tree structure of production unfolds until at the end of each branch a basic commodity (at the Armington level) or factor of production is specified. The next section will describe the formulation of prices in the production sector. The description of prices proceeds in the opposite direction. It starts at the bottom of the tree, using the equilibrium prices, and moves up the tree to define the price of the different CES aggregate bundles.

III.1.2. Production Prices

Table 6 describes the (CES) price of the energy bundle. It is an aggregation of the Armington price of the individual fuels.

Table 6. Price of the Energy Bundle in Production

$$(6.1) P_{jv}^{EP} = \left[\sum_v \alpha_{e,j,v}^{EP} \left(\frac{PA_e}{\lambda_{jv}^{EP}} \right)^{1-\sigma_{jv}^{EP}} \right]^{1/(1-\sigma_{jv}^{EP})}$$

Table 7 provides the equations describing the remaining prices in production. The price of aggregate non-energy intermediate demand, specified in Equation (7.1), is given by adding up the unit price of non-energy input goods. Equation (7.2) determines the CES dual price of the capital-energy bundle, PKE . The price of the Q^{KEL} bundle is provided by the formula in Equation (7.3). Equation (7.4) determines the CES dual price of production by capital vintage, PXv . Equation (7.5) determines the average unit cost of production, PX , averaged over both types of capital. Finally, Equation (7.6) provides the producer price, PP , which is equal to the cost of production plus an indirect tax.

Table 7. Price of the Q^{KE} and Q^{KEL} Bundles, and Unit Production Cost

$$(7.1) P_j^N = \sum_{nf} a_{nf,j}^N PA_{nf}$$

$$(7.2) P_{jv}^{KE} = \left[\alpha_{jv}^E (P_{jv}^{EP})^{1-\sigma_{jv}^{KE}} + \alpha_{jv}^K \left(\frac{R_{jv}}{\lambda_{jv}^K} \right)^{1-\sigma_{jv}^{KE}} \right]^{1/(1-\sigma_{jv}^{KE})}$$

$$(7.3) P_{jv}^{KEL} = \left[\alpha_{jv}^L (W_j^A)^{1-\sigma_{jv}^{KEL}} + \alpha_{jv}^{KE} (P_{jv}^{KE})^{1-\sigma_{jv}^{KEL}} \right]^{1/(1-\sigma_{jv}^{KEL})}$$

$$(7.4) PXv_{jv} = \left[\alpha_{jv}^N (P_j^N)^{1-\sigma_{jv}^P} + \alpha_{jv}^{KEL} (P_{jv}^{KEL})^{1-\sigma_{jv}^P} \right]^{1/(1-\sigma_{jv}^P)}$$

$$(7.5) PX_j XP_j = \sum_v PXv_{jv} XPv_{jv}$$

$$(7.6) PP_i XP_i = PX_i (1 + \tau_i^P) XP_i$$

1. Equilibrium in Factor Markets

This section describes the determination of factor market equilibria. There are two parts to this section: the labour markets, and the capital markets.

Consider first labour markets. Labour supply in the RE-GEM model can be determined in two ways: either excess supply is assumed (i.e. real wage is fixed, which is equivalent to imposing an infinite elasticity to the supply curve) or employment is sensitive to real wage (labour supply wage elasticity is a value close to 1).

Table 8. **Equilibrium on the Labour Market**

$$(8.1) W^A = P^{CPI} W_0^A$$

$$(8.2) L^S = \alpha^{LS} \left(\frac{W^A}{P^{INDEX}} \right)$$

$$(8.3) L^S = L_g^d + \sum_i L_{i,t}^d$$

The two possible closures are alternatively determined by Equation (8.1) or Equation (8.2). The former simply sets the fixed real wage, and employment will be determined via demand. Equation (8.2) determines labour supply as a positively sloped function of real wages. Finally Equation (8.3) is the market clearing condition setting labour demand equal to labour supply.

For the capital market it is necessary to distinguish between comparative statics and recursive dynamics. In comparative static mode, all the dynamic transition equations are left out of the model definition. The putty/semi-putty structure of production is also irrelevant, and only *old* capital exists (i.e. only the *old* production elasticities are used). The sectoral supply of capital is determined using a CET supply function. An elasticity of substitution of zero implies sector-specific capital, and an elasticity of infinity implies perfectly mobile capital.

Table 9. **Equilibrium on the Capital Market (comparative static)**

$$(9.1) \begin{cases} R^A = \left[\sum_i \alpha_i^k (R_i^{Old})^{1+\omega^k} \right]^{1/(1+\omega^k)} & \text{if } \omega^k < \infty \\ K^s = \sum_i K_i^d & \text{if } \omega^k = \infty \end{cases}$$

$$(9.2) \begin{cases} K_i^{s,Old} = \alpha_i^k \left(\frac{R_i^{Old}}{R^A} \right)^{\omega^k} K^s & \text{if } \omega^k < \infty \\ R_i^{Old} = R^A & \text{if } \omega^k = \infty \end{cases}$$

$$(9.3) K_i^{s,Old} = K_i^d$$

The equations in Table 9 determine sectoral capital supply in *comparative static* mode. In the case of finite elasticities, Equation (9.1) determines the aggregate (or average) rental rate using the definition of the CET dual price function. Equation (9.2) determines the sector-specific capital supply as a function of the sector specific rental rate relative to the average rate of return. Equation (9.3) determines the sector-specific rental rate through a market equilibrium equation. If the CET elasticity is zero, it is easy to see through Equation (9.2) that capital supply then becomes sector-specific. If capital is perfectly mobile, i.e. the CET elasticity is infinite, Equation (9.1) determines the economy-wide (i.e. uniform) rate of return on capital, in other words, this equation is a market equilibrium equation. Equation (9.2) sets the sectoral rental rate to the uniform rate, and Equation (9.3) equates sector supply to sector demand.

Consider now the *dynamic* version of the model. In the long run, profit rates across sectors should be equal and therefore capital should usually assumed to be perfectly sectorally mobile. In the short-term, the opposite is observed: sectors register different rates of profitability and capital is sector specific. The recursive dynamic framework used in the model allows to have an intermediate situation between these two extremes by combining short term capital immobility (or low degree of mobility) for the old (or installed) vintage of capital and long-term perfect mobility for new capital.

In order to do that it is first necessary to determine the supply of old capital. At the beginning of a period if a sector is expanding, its supply of old capital, KO^s , is insufficient to produce its expanding output and therefore it will demand new capital. In this case it is assumed that the rental price of the old capital is the same as the rental price of the new capital. There is a unique economy-wide rental rate on new capital. If, however, a sector is declining, it will want to disinvest part of its beginning-of-period-capital-stock. In the case of a declining sector, the rental rate on old capital is sector specific. The disinvestment function is based on the relative rates of return of old capital versus new capital. The following equation determines the supply of old capital to a sector in decline:

$$KOld_{i,t}^s = KO_{i,t}^s \left[\frac{r_{i,t}^{Old} / r_{i,t}^{New}}{r_{i,t-1}^{Old} / r_{i,t-1}^{New}} \right]^{\eta_i^k}$$

Supply of old capital⁶ will increase with the rental rate of old capital, with an absolute limit when the rental ratio of old and new capital is equal to 1. The equilibrium condition for old capital is that supply must equal demand; therefore, in the equation above, we replace directly the supply for old capital by demand for old capital. Finally, the above equation is inverted and solved for the rental ratio. This leads to Equation (10.1) in Table 10, where R^r is the ratio of the rental rate of old capital to the rental rate of new capital, and η_i^k is the disinvestment elasticity. The rental rate ratio is bounded above by 1.

6. It is possible by simply subtracting $KO_{i,t}^s$ from both sides of the above equation, to represent the

supply of disinvested capital as: $KO_{i,t}^s - KOld_{i,t}^s = KO_{i,t}^s \left[1 - \left(\frac{r_{i,t}^{Old} / r_{i,t}^{New}}{r_{i,t-1}^{Old} / r_{i,t-1}^{New}} \right)^{\eta_i^k} \right]$

Table 10. **Supply of Old Capital in Declining Sectors**

$$(10.1) R_{i,t}^R = \min \left(R_{i,t-1}^R \left[\frac{Kv_{i,old,t}^d}{KO_{i,t}^s} \right]^{1/\eta_i^k}, 1 \right)$$

The single rental rate on all capital, which is not part of a declining sector, remains to be calculated. In other words, the single rental rate which applies to all new capital, plus old capital in expanding sectors, plus old capital being disinvested by declining sectors has not yet been determined. Equation (11.1) determines the rental rate of new capital, R^A , which is a single economy-wide rental rate. Equation (11.2) determines the sector specific rental rate of old capital. This could be determined as well by an equilibrium condition, but this was already integrated into Equation (11.1). Therefore the rental rate of old capital is simply determined by multiplying the rental rate ratio, by the rental rate of new capital. Finally, Equation (11.3) sets the rental rate of new capital.

Table 11. **Equilibrium on the Capital Market (recursive dynamics)**

$$(11.1) \sum_i K_{i,t}^d + K_{g,t}^d = K_t^s$$

$$(11.2) R_i^{Old} = R^A R_i^R$$

$$(11.3) R_i^{New} = R^A$$

2. Determination of Vintage Output

In each period, producers are faced with the decision to optimally allocate production across vintages. The model implements a simple rule. First, producers will use all the capital installed at the beginning of the period, i.e. old capital. If demand for output is greater than what can be produced with the installed capital, producers will demand new capital to produce the residual amount. If demand is less than what producers desire to produce with the installed capital, i.e. if a sector is in decline, producers will market the surplus capital on the second-hand market. The production allocation decision of the producer can be derived from the optimal capital/output ratio for each type of capital. The optimal capital/output ratio can be derived from Equations (2.3), (3.3), and (4.2). Equation (12.1) provides the capital/output ratio for each vintage type. The optimal capital/output ratio will depend on all the prices in the nested CES structure and will only be constant if the entire production structure is a Leontief technology. Equation (12.2) determines output produced by old capital. It uses the capital/output ratio to determine the optimal production with installed capital. If the latter is less than production, than that quantity is assigned to "old" production. If the quantity is greater than total demand, than the quantity produced with old capital will be set equal to total demand, and the residual capital will be disinvested. Finally, Equation (12.3) determines the quantity of output produced with new capital. It will simply be the difference between total production and the amount produced with old capital.

Table 12. Allocation of Domestic Production across Vintages

$$(12.1) \quad \chi_i^v = \alpha_{jv}^{KEL} \left(\frac{PX_{jv}}{P^{KEL}} \right)^{\sigma_{jv}^P} \alpha_{jv}^{KE} \left(\frac{P_{jv}^{KEL}}{P_{jv}^{KE}} \right)^{\sigma_{jv}^{kel}} \frac{\alpha_{jv}^k}{\lambda_{jv}^k} \left(\frac{\lambda_{jv}^k P_{jv}^{KE}}{R_{jv}} \right)^{\sigma_{jv}^{ke}}$$

$$(12.2) \quad \begin{cases} XP_{v_i}^{Old} = \frac{KO_i^s}{\chi_i^{Old}} & \text{if } \frac{KO_i^s}{\chi_i^{Old}} \leq XP_i \\ XP_{v_i}^{Old} = XP_i & \text{if } \frac{KO_i^s}{\chi_i^{Old}} > XP_i \end{cases}$$

$$(12.3) \quad XP_{v_i}^{New} = XP_i - XP_{v_i}^{Old}$$

III.1.3. Household Consumption

In many CGE models household expenditure behaviour functions are derived from the maximisation of Cobb-Douglas or Constant Elasticity of Substitution (CES) utility. The limitation of using these functional forms for consumption is that they imply unitary income elasticity of demand. This fails to account for the way changes in income affect the structural adjustment of the economy to exogenous shocks. In order to avoid such drawbacks, consumption demand in the current model is determined by using the utility function associated with the extended linear expenditure system (ELES). The ELES is similar to the LES or Stone-Geary system⁷, but incorporates household saving into the utility function.

Consumers under the ELES are assumed to maximise the following utility function:

$$\max U = \sum_i \mu_i \ln(C_i - \theta_i) + \mu_s \ln\left(\frac{S}{P}\right)$$

subject to the budget constraint:

$$\sum_i P_i^C C_i + S = Y^d$$

C is consumer spending, S is saving (in value), Y^d is disposable income, P^C are consumer prices, and μ and θ are the ELES parameters.⁸ The Engel aggregation condition⁹ requires the following constraints on the parameters μ :

7. See Stone (1954).

8. In the utility function, S needs to be deflated by an appropriate price, which would represent the consumer spot price of future consumption. This price does not need to be specified for the model since household saving can be derived as a residual from the budget constraint. For welfare

$$\sum_i \mu_i + \mu_s = 1$$

The following demand functions can be derived:

$$C_i = \theta_i + \frac{\mu_i}{P_i^C} \left(Y^d - \sum_j P_j^C \theta_j \right)$$

The usual interpretation of this demand function is that consumption is composed of two parts. The first part has been referred to as the subsistence minima (or floor consumption), θ . The term in parenthesis represents residual income, or *supernumerary* income, i.e. it is the residual income after subtracting expenditures on the subsistence minima. Therefore the second part of consumption is a share of supernumerary income. Note that there is no minimal consumption of savings, i.e. θ_s is 0. Saving can be determined via the budget constraint:

$$S = Y^d - \sum_i P_i^C C_i$$

The income and price elasticities are given by the following formulae:

$$\eta_i = \frac{\mu_i Y^d}{P_i^C C_i} = \frac{\mu_i}{\chi_i}$$

$$\varepsilon_i = \frac{\theta_i (1 - \mu_i)}{C_i} - 1$$

The income elasticity is equal to the ratio of the marginal propensity to consume good i out of supernumerary income, θ , over the average propensity to consume good i out of income.

The relevant model equations are exactly the same as those derived above and the only difference is given by the fact that energy goods are initially grouped in one basket and then disaggregated by fuel type; in other words, in a first stage, consumers maximise over all non-energy goods and a single energy bundle. This allows introducing an energy efficiency parameter. Table 13 presents the quantity equations (for the first stage): Equation (13.1) defines supernumerary income. The subsistence minima are calibrated in the base year on a per capita basis; in each subsequent period, they are multiplied by the total population (pop) in order to grow with it. Equation (13.2) defines consumer demand; equations (13.3) and (13.4) define region-specific (S_h) and India-wide (S_h^{Tot}) household savings.

calculations, the consumer price index, *cpi*, has been chosen as the saving deflator since there is no forward-looking behaviour in RE-GEM.

9. See Deaton and Muellbauer (1980), page 16.

Table 13. Household Consumption

$$(13.1) Y^* = Y^d - Pop \sum_{k'} P_k^C \theta_k,$$

$$(13.2) C_k = \theta_k Pop + \frac{\mu_k}{P_k^C} Y^*$$

$$(13.3) S_h = Y^d - \sum_k P_k^C C_k$$

$$(13.4) S_h^{Tot} = \sum_r S_h$$

The next stage maps household demand in terms of consumer commodities into demand for produced commodities, this is trivially determined for the non-energy commodities. Equation (14.1) in Table 14 determines the Armington consumer demand for non-energy commodities. The matrix ac is simply a matrix of 0's and 1's, mapping the non-energy goods indexed by k to the same non-energy good mapped by nf .

Table 14. Transformation of Consumption into Produced Goods

$$(14.1) X_{nf}^{AC} = a_{nf,k}^C C_k$$

$$(14.2) X_e^{AC} = a_e^{EC} \frac{C_{Energy}}{\lambda^{EC}} \left(\frac{\lambda^{EC} P^{EC}}{PA_e} \right)^{\sigma^{EC}}$$

Equation (14.2) determines the demand for the fuel components of the energy aggregate. The formula includes an energy efficiency factor for consumption.

3. Consumer Prices

Consumer prices are determined starting from the most disaggregated level. Table 15 describes the prices of the consumer goods that are determined from the Armington prices.

Table 15. Consumer Prices

$$(15.1) P^{EC} = \left[\sum_e a_e^{EC} \left(\frac{PA_e}{\lambda^{EC}} \right)^{1-\sigma^{EC}} \right]^{\frac{1}{1-\sigma^{EC}}}$$

$$(15.2) P_k^C = \sum_{nf} a_{nf,k}^C PA_{nf}$$

$$(15.3) P_{Energy}^C = P^{EC}$$

$$(15.4) P^{CPI} = \frac{\sum_k P_k^C C_k}{\sum_k P_{k0}^C C_k}$$

Equation (15.1) in Table 15 defines the CES dual price, P^{EC} , for the energy bundle in consumption. Equation (15.2) maps the Armington price to the consumer price for non-energy goods, where the index k runs over the non-energy commodities. Equation (15.3) simply transfers the price of the energy bundle into the consumer price vector. Finally, Equation (15.4) defines the consumer price index.

III.1.4. Other Final Demands: Investment, Stock Building and Government Demands

Apart from household consumption, final demand includes private capital expenditures (private investment and stock building), and government current and capital expenditures.

III.1.4.1. Investment and Stock Building: Quantity and Price Equations

Total savings determine aggregate investment¹⁰ and this is disaggregated into final demand for goods and services using a fixed coefficient Leontief function. The energy bundle is further disaggregated using the same nested structure as that of consumption. Table 16 presents the equations for investment final demand for goods and services.

10. Notice that final demand for regional investment goods is determined in three steps: in the first step, total India-wide investment, ITOT, is set equal to India-wide aggregate savings, see equation (25.1) below. Secondly, total investment is distributed to regions according to some fixed shares (see equation (25.2)). Finally, the regional aggregate investment, I_r^{TOT} , is allocated to demand for specific investment goods according to the fixed shares rule of equation (16.1).

Table 16. Final Demand for Investment Intermediate Inputs

$$(16.1) X_{nf}^{AI} = a_{nf}^I I_r^{TOT}$$

$$(16.2) E^I = a^{EI} I_r^{TOT}$$

Equation (16.1) specifies the (Armington) demand for non-energy investment goods and services, where X_{nf}^{AI} represents demanded quantity, and a_{nf}^I are the Leontief fixed input coefficients. Equation (16.2) determines demand for the energy bundle, E^I , where a^{EI} is the input coefficient for aggregate energy investment.

Table 17 lists the equations describing the disaggregation of the energy bundle into the fuel composites.

Table 17. Demand for the Fuel Components in Investment

$$(17.1) X_e^{AI} = a_e^I \frac{E^I}{\lambda^{EI}} \left(\frac{\lambda^{EI} P^{EI}}{PA_e} \right)^{\sigma^{EI}}$$

Equation (17.1) decomposes the energy bundle into the fuel components. The CES share parameters are given by a_e^I , and the substitution elasticity is σ^{EI} . The energy efficiency factor enters at this level of the energy nest.

The aggregate volume of stock building, I^{STOCK} , is exogenous in each period, and normally set to zero in some future year. Final demand for stock building is determined via a fixed coefficient function, including demand for the fuel composites, i.e. the substitution elasticity for splitting the energy bundle into fuel composites is equal to zero. Table 18 lists the equations of intermediate demand derived from stock building.

Table 18. Demand for Intermediate Goods and Services, and Fuels

Derived from Stock Building

$$(18.1) X_{nf}^{ASTOCK} = a_{nf}^{STOCK} I^{STOCK}$$

$$(18.2) X_e^{ASTOCK} = \frac{a_e^{STOCK}}{\lambda^{ESTOCK}} I^{STOCK}$$

Equation (18.1) determines (Armington) demand for non-energy goods and services, X_{nf}^{ASTOCK} , derived from stock building, and Equation (18.2) defines demand for the fuel composites.

Prices in investment and stock building are determined going from the bottom up. Table 19 describes the prices in the demand for investment goods.

Table 19. **Prices in Investment and Stock Building**

$$(19.1) P^{EI} = \left[\sum_e a_e^I \left(\frac{PA_e}{\lambda^{EI}} \right)^{1-\sigma^{EI}} \right]^{\frac{1}{1-\sigma^{EI}}}$$

$$(19.2) P_r^I = \sum_{nf} a_{nf}^I PA_{nf} + a^{EI} P^{EI}$$

$$(19.3) P^I I^{TOT} = \sum_r P_r^I I_r^{Tot}$$

$$(19.4) P^{STOCK} = \sum_{nf} a_{nf}^{STOCK} PA_{nf} + \sum_e a_e^{STOCK} \frac{PA_e}{\lambda^{ESTOCK}}$$

Equation (19.1) in Table 19 defines the CES dual price, P^{EI} , for the energy bundle. Equation (19.2) determines the aggregate region-specific price index of investment and equation (19.3) the same index at India-wide level, with P^I and I^{TOT} representing the India-wide investment price index and India-wide investment in physical units respectively. Finally, Equation (19.4) defines the aggregate price of stock building, P^{STOCK} . It is the weighted sum of the intermediate input prices, with λ^{ESTOCK} being the energy efficiency factor in the stock building sector.

III.1.4.2. Government Expenditures: Quantity and price Equations

This section determines government expenditures on purchases of goods and services, as well as on labour and capital. Contrary to the other final demand sectors, government is assumed to demand factor services¹¹. The top-level government expenditure function is a CES function in capital, labour, and aggregate intermediate inputs. Final demand by the government is assumed to derive from the minimisation of the following cost function:

$$\min P^{Cg} C_g + R_g K_g^d + W_g^A L_g^A$$

subject to the production function:

$$X^{TotG} = \left[a^{GC} C_g^{\rho^g} + a^{GK} K_g^d{}^{\rho^g} + a^{GL} L_g^A{}^{\rho^g} \right]^{1/\rho^g}$$

11. Note, however, that due to lack of data in the current data-set on labour and capital use in the government sector, government expenditures are only on goods and services. This simply means that, during the calibration of the model, the labour and capital shares of total expenditure are set to zero.

Equations in Table 20 provide the derived reduced form first order conditions for government demand for the three components of the CES expenditure function. Notice that X^{TotG} , the volume of government expenditure, is exogenous in each period and grows at the same rate of growth of India-wide real gross product.

Table 20. **Government Demand for Goods, Services, Labour, and Capital**

$$(20.1) C_g = a^{GC} X^{TotG} \left(\frac{P^G}{P^{Cg}} \right)^{\rho^g}$$

$$(20.2) K_g^d = a^{GK} X^{TotG} \left(\frac{P^G}{R_g} \right)^{\rho^g}$$

$$(20.3) L_g^{Ad} = a^{GL} X^{TotG} \left(\frac{P^G}{W_g^A} \right)^{\rho^g}$$

Equation (20.1) determines aggregate demand for goods and services by the government, C_g ; with P^G representing the aggregate price of government purchases, P^{Cg} the aggregate purchase price of goods and services, a^{GC} the CES share parameter for goods and services, and ρ^g is the CES substitution elasticity. Equation (20.2) determines government demand for capital, K_g^d , where R_g is the rental rate on government capital. Equation (20.3) determines government's aggregate demand for labour, L_g^{Ad} .

The next level of demand disaggregates the C_g bundle into sectoral demand for non-energy goods, and the energy bundle. The energy bundle is further decomposed into demand for the fuel components.

Table 21. **Government Demand for Goods, Services, Energy, and Fuels**

$$(21.1) X_{nf}^{AG} = a^{GCnf} C_g$$

$$(21.2) E_g = a^{GE} C_g$$

$$(21.3) X_e^{AG} = a_e^{GE} \frac{E^G}{\lambda^{EG}} \left(\frac{\lambda^{EG} P^{EG}}{PA_e} \right)^{\sigma^{EG}}$$

Equation (21.1) determines (Armington) demand for non-energy goods and services, X_{nf}^{AG} , using the fixed coefficients α^{GCnf} . Equation (21.2) determines demand for

the energy bundle, E_g . Equation (21.3) determines the demand for the fuel components, by disaggregating the CES energy bundle¹².

As in all other economic sectors, prices in government demand start at the bottom with basic prices.

Table 22. Prices in Government Consumption

$$(22.1) P^{EG} = \left[\sum_e a_e^{GE} \left(\frac{PA_e}{\lambda^{EG}} \right)^{1-\sigma^{EG}} \right]^{\frac{1}{1-\sigma^{EG}}}$$

$$(22.2) P^{Cg} = \sum_{nf} a^{GCnf} PA_{nf} + a^{GE} P^{EG}$$

$$(22.3) P^G = \left[a^{GC} P^{Cg}^{(1-\rho^g)} + a^{GK} R_g^{(1-\rho^g)} + a^{GL} W_g^A^{(1-\rho^g)} \right]^{\frac{1}{1-\rho^g}}$$

Equation (22.1) in Table 22 determines the price of the energy bundle, P^{EG} . The aggregate price of expenditures on goods and services, P^{Cg} , is given by Equation (22.2). The CES dual price of output, P^G , is given by Equation (22.3).

III.1.5. Income Distribution, Government and Investment Equilibrium Conditions

RE-GEM has only one representative household that receives most of its income from value added. Other sources of income include transfers from the government. Table 23 lists the equations determining household income.

Table 23. Household Income and GDP Statistics

$$(23.1) Y = \sum_l W_l \left[\omega_{lg} L_{lg}^d + \sum_l \omega_{li} L_{li}^d \right] + R_g K_g^d + \sum_v \sum_i R_{iv} K_{iv}^d$$

$$(23.2) Y^D = Y - H^{TAX} + P^{CPI} G^{TRA}$$

$$(23.3) X^{RGDP} = \sum_l W_{l,0} \left[\omega_{lg} \lambda_{lg}^L L_{lg}^d + \sum_l \omega_{li} \lambda_{li}^L L_{li}^d \right] + R_{g,0} K_g^d + \sum_v \sum_i R_{iv,0} \lambda_{iv}^K K_{iv}^d$$

$$(23.4) P_t^{GDP} = \frac{Y_t}{\sum_l W_{l,0} L_{li}^s + K_t^s}$$

12. Aggregate government labour demand should still be disaggregated by skill type. This is easily derived with a CES conditional demand but it is not shown here since not used in the current model.

Equation (23.1) defines total household income, Y : it is the sum of payments to production factors (including payments by the government). Equation (23.2) determines household disposable income, Y^d . Y^d is equal to aggregate income, less direct taxes, H^{TAX} , plus transfers from government to households, G^{TRA} . G^{TRA} needs to be multiplied by a price in order to preserve the homogeneity of the model. The consumer price index, P^{CPI} , was chosen as the appropriate deflator. Equation (23.3) defines real GDP, X^{RGDP} ¹³. It is the sum of factor demand in efficiency units. Equation (23.4) defines the GDP deflator, P^{GDP} ¹⁴. The GDP deflator is defined as the value of factor payments, divided by the sum of factor volumes.

Table 24 presents the government closure rules. Equations (24.1) and (24.2) determine respectively the government's tax revenues from the production tax and the import tax. Note that in Equation (24.2) the regional indices are explicitly used: tariff rates may be region specific.

Table 24. **Government Receipts and Saving**

$$(24.1) Y_i^{INDTAX} = \tau_i^P P X_i X P_i$$

$$(24.2) Y_{ri}^{TARIF} = \tau_i^r W P M_i M_i^r$$

$$(24.3) S_g = P^{INDEX} \bar{S}_g$$

$$(24.4) S_g = H^{TAX} + \sum_i (Y_i^{INDTAX} + Y_i^{TARIFF}) - P^G X^{TotG} - P^{CPI} G^{TRA}$$

The government closure rule is specified in Equation (24.3): when this equation is active the government saving (defined as the difference between government revenue and government expenditure in Equation (24.4)) is fixed in real terms. The household direct tax rate – H^{TAX} in Equation (24.4) – is used as the instrument to get to the targeted government saving. If Equation (24.3) is not active, government saving is an endogenous variable determined by Equation (24.4) and households direct taxes will be fixed.

13. It is assumed that there is no change in the efficiency of capital in the government sector, though there is efficiency improvement in the use of labour.

14. All base year factor prices are equal to one, therefore, this implies that the denominator is evaluated in base year prices.

Table 25. **Determination of Aggregate Investment (Exogenous Foreign Saving)**

$$(25.1) P^I I^{TOT} = S_h^{TOT} + S_g + P^{SAVF} S_f + Y^{DEPR} - \sum_i P A_i X_i^{ASTOCK}$$

$$(25.2) P_r^I I_r^{TOT} = \alpha_r P^I I^{TOT}$$

$$(25.3) S_f = P^{SAVF} \bar{S}_f$$

Table 25 includes the equations for the closure of the saving and investment account. The domestic India-wide *value* of investment — the product of investment price index P^I , which was defined in equation (19.2)¹⁵, and the investment volume I^{TOT} — is equal to domestic saving (households and government savings) plus foreign saving, plus depreciation, less expenditure on stock building¹⁶. Regional aggregate investment *value* is a fixed share of the India-wide total value. Under this rule, regional investment does not react to regional changes in relative rates of return. Real foreign saving is exogenous in each time period and Equation (25.2) defines the value of foreign saving using P^{SAVF} as a price index.

III.1.6. International and Interregional Trade Equations

Import Structure

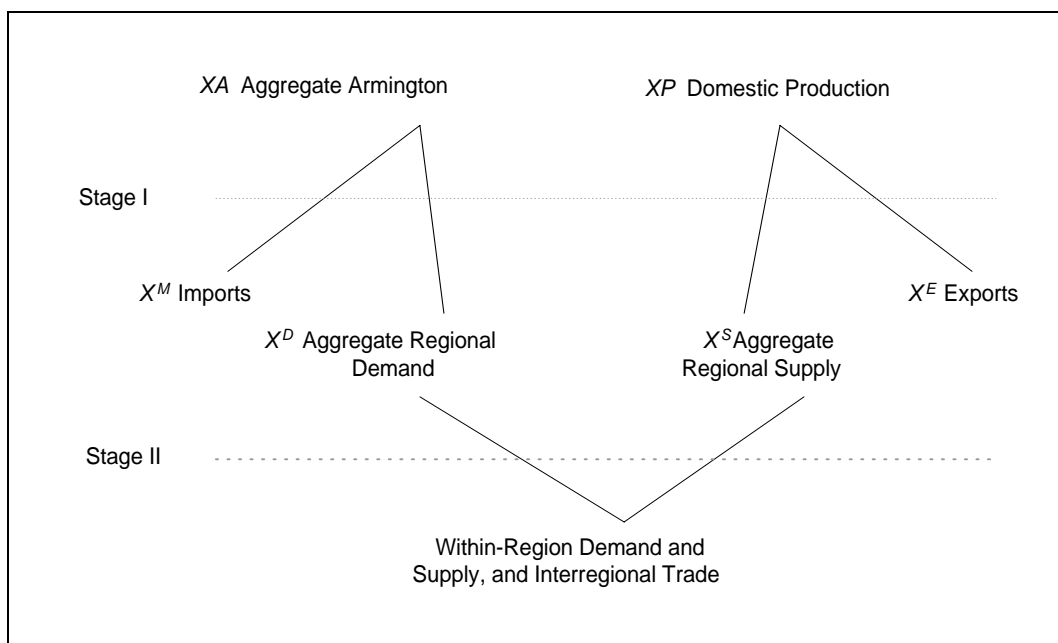
For each region in the model, demand by all economic agents has now been specified at the Armington level of aggregation. It is assumed that propensity to import will be equal across all agents in the economy and this implies that we can aggregate the Armington demand across all agents and then allocate the resulting total value between domestic and imported goods.

Recall that the Armington assumption simply posits that goods are differentiated with respect to region of origin. The model has implemented this assumption using a nested structure. At the top level, each domestic agent optimises some objective function (e.g. cost minimisation or utility maximisation). This leads to demand for a composite commodity that has been referred to as the Armington commodity. At the next level, agents minimise the cost of acquiring this Armington bundle, subject to a CES aggregation function between a bundle of domestic goods (produced within the region or in another Indian region) and imports. At the next and final level, agents minimise the cost of the aggregate domestic bundle, again subject to an aggregation function over regional supplies originating in each Indian region. This import structure, jointly with the export structure that is explained below, is depicted in Figure 4.

15. See note 10.

16. Notice that households' savings are regional specific variables but the regional indexes and summation across regions have been omitted for simplicity.

Figure 4. International and Interregional Trade Structure



The mathematical formulation for the CES minimization leads to:

$$\begin{aligned} \min P^D D + P^M M \\ \text{s. t.} \\ X = [a_d D^\rho + a_m M^\rho]^{1/\rho} \end{aligned}$$

where X is the demand for the Armington good, D is demand for domestic production, M is import demand, P^D is the price of domestic sales, and P^M is the domestic price of imports (tariff inclusive).

The first order conditions lead to the following demand functions:

$$\begin{aligned} D &= \alpha_d X \left(\frac{PA}{P^D} \right)^\sigma & \text{where } \alpha_d &= a_d^\sigma \\ M &= \alpha_m X \left(\frac{PA}{P^M} \right)^\sigma & \text{where } \alpha_m &= a_m^\sigma \end{aligned}$$

and the substitution elasticity is given by:

$$\sigma = \frac{1}{1-\rho} \Leftrightarrow \rho = \frac{\sigma-1}{\sigma}$$

PA is the (Armington) CES dual price determined using PD and PM :

$$PA = \left[\alpha_d P^{D^{1-\sigma}} + \alpha_m P^{M^{1-\sigma}} \right]^{\frac{1}{1-\sigma}}$$

Table 26 specifies the equations relative to the first level of the Armington nest. Equation (26.1) determines aggregate Armington demand, XA , i.e. the sum of Armington demand across all agents, with X^{AP} , X^{AC} , X^{AG} , X^{AI} representing intermediates, final private, government, and investment demands respectively. Equations (26.2) and (26.3) decompose the aggregate Armington demand into the domestic bundle component, X^D , and the import component, X^M .

Table 26. Armington Decomposition

$$(26.1) \quad XA_i = \sum_j X_{i,j}^{AP} + X_i^{AC} + X_i^{AG} + X_i^{AI}$$

$$(26.2) \quad X_i^D = \alpha_i^d XA_i \left(\frac{PA_i}{P_i^D} \right)^{\sigma_i^m}$$

$$(26.3) \quad X_i^M = \alpha_i^m XA_i \left(\frac{PA_i}{P_i^M} \right)^{\sigma_i^m}$$

Equation (27.1) in Table 27 determines the Armington price, PA , which is the CES dual price of the Armington component prices, i.e. P^D and P^M . Equation (27.2) determines the domestic price for international imports by adding import tariffs, τ_i , to the world price and converting it in local currency¹⁷.

Table 27. Armington Price

$$(27.1) \quad PA_i = \left[\alpha_i^d P_i^D (1-\sigma_i^m) + \alpha_i^m P_i^M (1-\sigma_i^m) \right]^{\frac{1}{1-\sigma_i^m}}$$

$$(27.2) \quad P_i^M = P^{SAVF} P_i^{World} (1 + \tau_i)$$

Stage II in Figure 4 consists of the decomposition of the domestic bundle into demand for regional products. Again, the CES functional form is used to implement the imperfect substitutability of commodity demand across regions.

Equation (28.1) in Table 28 determines interregional import volumes by sector and region of origin, $X_{r,i}^{MReg}$. Given that goods are differentiated by region of origin, each good has its own price, $P_{r,i}^{MReg}$, and the price for the aggregate domestic bundle, P_i^D , is determined as the CES dual price by equation (28.2).

17. P^{SAVF} is the same conversion coefficient used in equation (25.3).

Table 28. **Second-Level Armington Equations**

$$(28.1) X_{r,i}^{MReg} = \beta_{r,i}^{MReg} \left(\frac{P_i^D}{P_{r,i}^{MReg}} \right)^{\Lambda_i^r} X_i^D$$

$$(28.2) P_i^D = \left[\sum_r \beta_{r,i}^{MReg} (P_{r,i}^{MReg})^{1-\Lambda_i^r} \right]^{\frac{1}{1-\Lambda_i^r}}$$

Export Structure

Export supply is treated symmetrically to import demand, as shown in Figure 4. Producers are assumed to differentiate between the domestic market and the export market. Producers are modelled as maximising sales between the domestic and export markets subject to being on a production possibilities frontier. The model uses the Constant Elasticity of Transformation (CET) specification to implement the production possibilities frontier. The resulting equations are similar to the CES first order condition with reversals in signs to reflect that producers are maximising revenues, as opposed to the CES where agents are minimising costs. As for the Armington specification, there are two levels in the export supply structure. In the first, producers decide the allocation of their supply between domestic sales and exports. In the second level, domestic supply is differentiated across Indian regions, in response to changes in relative regional prices. It should be said that elasticities of substitution and transformation at this second (Indian-regional) level are much higher than at the first level, reflecting the fact that buyers, as well as suppliers, consider goods of different regions as being almost perfect substitutes. In addition the model does not discriminate between “within-region” and “outside-region” markets by differentiating elasticities across them; in other words, there is only one nest combining within region and outside region products.

Equation (29.1) and (29.2) provide the first order conditions for determining the producers supply decisions. Equation (29.1) determines the optimal supply of goods for the domestic market, X^S . Notice the change from the CES functional form: a rise in the domestic price (with respect to the producer price), leads to a rise in domestic supply. Equation (29.2) determines export supply, X^E . Equation (29.3) is the CET dual price function, which replaces the primal CET function.¹⁸ Finally Equation (29.4) determines the domestic price of exports.

18. The primal function is given by the following formula:

$$XP_i = \left[a_{t,i}^d X_i^D \rho_i^t + a_{t,i}^e E_i^S \rho_i^t \right]^{1/\rho_i^t}$$

where the following relations hold:

$$\rho_i^t = \frac{\sigma_i^t + 1}{\sigma_i^t} \Leftrightarrow \sigma_i^t = \frac{1}{\rho_i^t - 1} \quad \text{and} \quad a_{t,i}^d = (\alpha_{t,i}^d)^{1-\rho_i^t} \quad a_{t,i}^e = (\alpha_{t,i}^e)^{1-\rho_i^t}$$

Table 29. CET Top Nest Decomposition

$$(29.1) X_i^S = XP_i \left(\frac{P_i^S}{\alpha_i^d PP_i} \right)^\sigma$$

$$(29.2) X_i^E = XP_i \left(\frac{P_i^E}{\alpha_i^e PP_i} \right)^\sigma$$

$$(29.3) PP_i = \left[\alpha_i^d (P_i^S)^{\sigma+1} + \alpha_i^e (P_i^E)^{\sigma+1} \right]^{1/(\sigma+1)}$$

$$(29.4) P_i^E = P^{SAVF} P_i^{World}$$

The final trade equations determine the second nest of the CET decomposition of interregional exports. The regional disaggregation is given in Equation (30.1) and it should be noticed that this equation is symmetrical with respect to equation (28.1) and that the regional subscript r has a transpose sign ($'$) to designate a *destination* rather than *origin* for the corresponding trade flow. Equation (30.2) determines aggregate price for the domestic supply P^S .

Table 30. Second-Level CET Equations

$$(30.1) X_{r',i}^{MReg} = \beta_{r',i}^{EReg} \left(\frac{P_i^S}{P_{r',i}^{MReg}} \right)^{\Omega_i^r} X_i^S$$

$$(30.2) P_i^S = \left[\sum_r \beta_{r',i}^{EReg} (P_{r',i}^{MReg})^{1-\Omega_i^r} \right]^{\frac{1}{1-\Omega_i^r}}$$

It should be noticed that the interregional trade equilibrium, defined as the condition for which demand equal supply, is implicitly assumed in equations (28.1) and (30.1) by using the *same* variables, $X_{r',i}^{MReg}$ and $P_{r',i}^{MReg}$, in both sets of equations.

III.1.7. Walras Law and Numeraire

In the RE-GEM model, Walras' law has been defined at the India-wide level and is represented by equality of the trade balance to foreign saving. Equation (31.1) defines Walras' law.

Table 31. Trade Closure

$$(31.1) S_f + \sum_i P^{FSAV} P_i^{World} X_i^E = \sum_i P^{FSAV} P_i^{World} X_i^M$$

On one side of the balance sheet are exports, evaluated at world prices, and net foreign saving. On the other side of the balance sheet are imports evaluated at world prices (excluding tariffs). Due to Walras' law, one equation is redundant, and Equation (31.1) is dropped from the model.

Any price in the model can be chosen as the numéraire. In the current version of the model, the foreign saving price index, P^{SAVF} , has been designated as the numéraire, and its value is always set to 1.

It may be worthwhile to notice that regional balance, the sum of all regional exports plus government transfers and other inflows is equal to the sum of all regional imports, regional taxes, household savings and other outflows, so that there is no need for an explicit equation to target this balance. In fact, regional balance is implicitly included in the other macro-closures of the model from which it can be derived. More clearly and considering the symbols of Figure 2 we can write:

$$C_1 + I_1 + G_1 + E_1 = Y_1 + T_{21} + M_1 - T_{12} \text{ [demand = supply for region 1]}$$

from which we can calculate the (potential) excess of demand of region 1 as:

$$T_{12} - T_{21} = C_1 + I_1 + G_1 + E_1 - M_1 - Y_1 \text{ ;[excess demand for region 1]}$$

by symmetry the excess supply of region 2 can be written as:

$$T_{12} - T_{21} = -C_2 - I_2 - G_2 - E_2 + M_2 + Y_2 \text{ ;[excess supply for region 2]}$$

their explicit equality can thus be written as:

$$Y_1 - C_1 + Y_2 - C_2 - (I_1 + I_2) - (G_1 + G_2) - (E_1 + E_2 - M_1 - M_2) = 0$$

the three terms in parenthesis can be rearranged using the macro-balances that have to be always satisfied by the model closure rules: $I_1 + I_2 = Sh_1 + Sh_2 + Sg + Sf$, total investment is equal to total savings; $G_1 + G_2 = Tx1 + Tx2 - Sg$, the government budget constraint; and $E_1 + E_2 - M_1 - M_2 = -Sf$ the external account constraint; substituting these into the previous equation gives us:

$$Y_1 - C_1 - Sh_1 - Tx_1 + Y_2 - C_2 - Sh_2 - Tx_2 = 0$$

which is always respected (see equations of the 13.3 and 23.2).

III.1.8. Aggregate Capital Stock and Productivity Growth

This section and the next provide the key equations for describing the transition from one period to the next. The aggregate capital stock is not pre-determined because it depends on the current level of investment. The one-year gap transition equation is given by:

$$K_t = (1 - \delta)K_{t-1} + I_{t-1}$$

where K is the aggregate capital stock, δ is the annual rate of depreciation, and I_{t-1} is the level of real investment in the previous period. A problem appears when the gap between solution periods is greater than 1 year. Since investment in the intervening years is not calculated assumptions must be made in order to integrate the stream of investment. The transition equation for a multi-period gap expanded has this form:

$$\begin{aligned} K_t &= (1 - \delta)[(1 - \delta)K_{t-2} + I_{t-2}] + I_{t-1} \\ &\vdots \\ K_t &= (1 - \delta)^n K_{t-n} + \sum_{j=1}^n (1 - \delta)^{j-1} I_{t-j} \end{aligned}$$

The model does not calculate investment between periods. A linear growth model is assumed to explain investment in intermediate years, i.e.:

$$I_j = (1 + \gamma^j)I_{j-1}$$

where

$$\gamma^j = \left(\frac{I_t}{I_{t-n}} \right)^{\frac{1}{n}} - 1$$

where the annual growth rate of investment is derived from the annualised growth rate of investment in the current period compared to investment in the previous period. We can re-write the multi-year transition equation to be:

$$K_t = (1 - \delta)^n K_{t-n} + \sum_{j=1}^n (1 - \delta)^{j-1} (1 + \gamma^j)^{n-j} I_{t-n}$$

The transition equation is then derived and given by Equation (32.2) in Table 32, where the growth parameter γ^j is determined in Equation (32.1). The capital stock is only pre-determined in Equation (32.2) if the gap between periods is equal to one year. Due to base year normalisation rules (the rental rate is set to 1 in the base year), the aggregate stock of capital, K , is normalised to yield K^e (Equation (32.3)), which is the level of capital used in determining equilibrium on the capital market¹⁹.

19. The following numerical example may shed some light on the normalisation rule. Assume the value of capital in a region is 100. Assume, as well, that capital remuneration is 10. Capital remuneration is simply rK where r is the rental rate and K the demand for capital. In this example, rK is equal to 10, which implies a rental rate of 0.1. RE-GEM uses a different normalisation rule. It assumes that the base year rental rate is 1, and normalises the capital data to be consistent with this normalisation rule, in other words, the normalised capital demand is 10, and it is really an index of capital volume. The non-normalised level of capital is used only in the accumulation function (Equation (32.2)), and in determining the value of capital depreciation allowance (Equation (23.1)). All other capital stock equations use the normalised value of capital.

Table 32. **Aggregate Capital Stock**

$$(32.1) \gamma^i = \left(\frac{I_t}{I_{t-n}} \right)^{\frac{1}{n}} - 1$$

$$(32.2) K_t = (1 - \delta)^n K_{t-n} + \frac{(1 + \gamma^i)^n - (1 - \delta)^n}{\gamma^i + \delta} I_{t-n}$$

$$(32.3) K_t^s = \frac{K_{t-n}^s}{K_{t-n}} K_t$$

Productivity

The efficiency growth of labour and energy is always assumed to be exogenous. The efficiency growth of capital is normally exogenous, but in the reference scenario, the capital efficiency factor is calibrated in order to achieve a target growth rate for real GDP. Since there is only one target growth rate for real GDP per region, there can only be one instrument to achieve this target. In the current version of the model, it is assumed that capital efficiency is uniform across sectors and vintages. The capital efficiency parameter is only endogenous in the reference (or business-as-usual) scenario. In all shock simulations, the capital efficiency parameter is exogenous.

Equation (33.1) determines the real growth rate of GDP, γ^y , in most simulations. However, in the reference simulation, γ^y is exogenous, and Equation (33.1) is used to determine the capital efficiency growth parameter, γ^k . Equation (33.2) determines the cumulative capital efficiency factor.

Table 33. **Productivity Factors for Capital**

$$(33.1) X_t^{RGDP} = (1 + \gamma^y)^n X_{t-1}^{RGDP}$$

$$(33.2) \lambda_{jv,t}^k = (1 + \gamma_t^k)^n \lambda_{jv,t-n}^k$$

The remaining equations deal with the pre-determined variables, which are updated at the beginning of each period. These are transition equations do not rely on any contemporaneous variable, hence are not directly an endogenous result of the model.

Table 34. **Initial Supply of Old Capital**

$$(34.1) KO_{i,t}^s = (1 - \delta)^n K_{i,t-n}^d$$

In Table 34 KO^s represents the installed old capital at the beginning of each period by sector²⁰. It is simply equal to the sector's previous period's total (depreciated) capital stock. The end of period stock of old capital (in a given sector) may be less than the initial stock. If the sector is declining, old capital will be disinvested and the actual stock of old capital will be less than the initial stock.

Table 35. **Other Pre-Determined Exogenous Variables**

$$(35.1) \alpha_{i,t}^{LS} = (1 + \gamma_{i,t}^{LS})^n \alpha_{i,t-n}^{LS}$$

$$(35.2) Pop_t = (1 + \gamma_t^p)^n Pop_{t-n}$$

$$(35.3) D_{g,t}^{TFD} = (1 + \gamma_t^y)^n D_{g,t-n}^{TFD}$$

In Table 35, Pop_t is the population at time t. D_g^{TFD} is the level of total real government expenditures on goods and services is assumed to grow at the same rate as the economy. Equation (35.1) determines the labour supply shift factor that is equal to the previous period's labour supply shift factor multiplied by an exogenously specified labour supply growth rate.

The energy efficiency factors are also exogenous and pre-determined leading to the following set of transition equations:

Table 36. **Energy and Labour Efficiency Factors**

$$(36.1) \lambda_{i,t}^E = (1 + \gamma_{i,t}^E)^n \lambda_{i,t-n}^E$$

$$(36.2) \lambda_{l,t}^l = (1 + \gamma_t^l)^n \lambda_{l,t-n}^l$$

The annual autonomous energy efficiency factor is given by $\lambda^{e,p}$, representing the growth in energy efficiency in production. The energy efficiency factors in production are specific to both sector and vintage. The cumulative factor is given by the γ variable. Equation (36.2) determines the labour efficiency factor. The growth in labour efficiency is exogenous and is labour-type specific.

Vintage Re-Calibration

The model has a vintage structure of capital based on an assumption of a putty/semi-putty structure of production. It is further assumed that the substitutability of capital differs across vintage, with old capital typically less substitutable than new capital. There are only two vintages, *old* and *new*. New capital is generated by investment in the previous period. Old capital is the installed capital in the previous period. Over time, the structure of old capital changes as the previously new capital gets merged into the old capital. Rather than keep track of each vintage over time, we modify the structural

20. See page 22 where KO_i^s is defined.

parameters of the old capital to reflect its changing composition. The key rule that has been adopted is that the share parameters associated with old capital should be able to produce all of the previous period's production (with the substitution elasticities of the old capital). For example, assume we have a CES production function in capital (K), labour (L), and energy (E). Production then has the form:

$$X_v = [a_{k,v} K_v^{\rho_v} + a_{l,v} L_v^{\rho_v} + a_{e,v} E_v^{\rho_v}]^{1/\rho_v}$$

where

$$\sigma_v = \frac{1}{1 - \rho_v}$$

and X is output (by vintage), K_v is capital by vintage, L_v is labour, and E_v is energy. The share parameters are vintage specific as is the substitution elasticity. The first order conditions for cost minimisation lead to:

$$\begin{aligned} K_v &= \alpha_{k,v} X_v \left(\frac{P_v}{r_v} \right)^{\sigma_v} & \text{where } \alpha_{k,v} &= a_{k,v}^{\sigma_v} \\ L_v &= \alpha_{l,v} X_v \left(\frac{P_v}{w} \right)^{\sigma_v} & \text{where } \alpha_{l,v} &= a_{l,v}^{\sigma_v} \\ E_v &= \alpha_{e,v} X_v \left(\frac{P_v}{e_v} \right)^{\sigma_v} & \text{where } \alpha_{e,v} &= a_{e,v}^{\sigma_v} \end{aligned}$$

where r , w , and e are respectively the price of capital, labour, and energy. (Note that the model uses the modified share parameters, i.e. the share parameters of the CES function raised to the power of the substitution elasticity. The former share parameters are never formally employed in the model since only the first order conditions and the CES price function are used.) P is the CES dual price which is given by the following equation:

$$P_v = \left[\alpha_{k,v} r_v^{1-\sigma_v} + \alpha_{l,v} w^{1-\sigma_v} + \alpha_{e,v} e_v^{1-\sigma_v} \right]^{1/(1-\sigma_v)}$$

We assume that the production structure of output associated with new capital is constant over time, i.e. the share parameters and substitution elasticities are not time dependent (except for the efficiency factors). However, old capital changes over time as in each time period previously new capital is added to the old capital stock. In order to account for the change in old capital the share parameters for the production structure associated with old capital are modified in such a way that the total of the factors in the previous period could produce all of the previous period's output assuming the old substitution elasticities. To continue with the above notation, we re-calibrate the share parameters according to the following formula:

$$\bar{\alpha}_{k,o} = \frac{K_{t-1}}{X_{t-1}} \left(\frac{r_{t-1}}{P_{t-1}} \right)^{\sigma_o}$$

$$\bar{\alpha}_{l,o} = \frac{L_{t-1}}{X_{t-1}} \left(\frac{w_{t-1}}{P_{t-1}} \right)^{\sigma_o}$$

$$\bar{\alpha}_{e,o} = \frac{E_{t-1}}{X_{t-1}} \left(\frac{e_{t-1}}{P_{t-1}} \right)^{\sigma_o}$$

where the re-calibrated share parameters, α , are calibrated at the beginning of each period, and all the volumes are the sum of the old and new vintages from the previous period, and the prices are the average prices (N.B. the subscript o is used for old capital, and n for new capital):

$$X_{t-1} = X_{o,t-1} + X_{n,t-1}$$

$$K_{t-1} = K_{o,t-1} + K_{n,t-1}$$

$$E_{t-1} = E_{o,t-1} + E_{n,t-1}$$

$$P_{t-1} = [P_{o,t-1} X_{o,t-1} + P_{n,t-1} X_{n,t-1}] / X_{t-1}$$

$$r_{t-1} = [r_{o,t-1} K_{o,t-1} + r_{n,t-1} K_{n,t-1}] / K_{t-1}$$

$$e_{t-1} = [e_{o,t-1} E_{o,t-1} + e_{n,t-1} E_{n,t-1}] / E_{t-1}$$

With the above definitions of the aggregate factors and average factor prices, the production function associated with the α parameters is consistent with the aggregate output X_{t-1} .

For brevity, the above formulas are not repeated for all the nested CES production functions. As described in more detail below, the production structure can be represented by a nested tree structure of CES and Leontief functions. Within this structure, there are several CES aggregation functions whose old-vintage share parameters are re-calibrated in the manner described above.

III.1.9. Emissions and Disease-Damage Equations

Equation (37.1) defines the total level of emissions for each type of pollutant p . The bulk of pollution is accounted for by the direct consumption of polluting goods, which is the second term in the expression. The level of pollution is constant across buyers, i.e. the same coefficient π is used for all producing sectors, final private demand, government and investment demand²¹. The first term in Equation (37.1) represents *process* pollution and it represents the residual amount of pollution that is not explained by the consumption of inputs.

21. It should be noticed that variation of stocks do not generate pollution.

The remaining equations in Table 37 re-produce the corresponding equations in the text if a pollution tax is imposed. This is actually endogenously calculated as the shadow price of Equation (37.1), once a target on the level of emission has been exogenously specified. The tax is implemented as an excise tax, i.e. it is implemented as a tax per unit of emission. It is converted to a price wedge on the consumption of the commodity (as opposed to a tax on the emission), using the commodity specific emission coefficient. For example in Equation (7.6'), the tax adds an additional price wedge between the unit cost of production exclusive of the pollution tax and the final cost of production. Let production be equal to 100 million (in Local Currency Units, LCU), and let the amount of pollution be equal to 1 ton of emission per 10 million of output. Then the total emission in this case is 10 tons. If the tax rate is equal to 25 LCU per ton of emission, the total tax bill for this sector is 250 LCU. In the formula below, π_p^{Prod} is equal to 0.1 (tonnes per million), XP is equal to 100 (millions LCU), and τ_p is equal to 25 LCU.

Table 37. Emissions and Price Wedges

$$(37.1) \quad E_p = \sum_i \pi_{i,p}^{Prod} XP_i + \sum_i \pi_{i,p}^{Cons} \left(\sum_j X_{ij}^{AP} + \sum_h X_{ih}^{AC} + \sum_f X_{if}^{AF} \right)$$

$$(7.6') \quad PP_i \quad XP_i = PX_i(1 + \tau_i^p)XP_i + \sum_p \pi_{i,p}^{Prod} XP_i \tau^{Poll}$$

$$(27.1') \quad PA_i = \left[\alpha_i^d P_i^D^{(1-\sigma_i^m)} + \alpha_i^m P_i^M^{(1-\sigma_i^m)} \right] \frac{1}{1-\sigma_i^m} + \sum_p \pi_{i,p}^{Cons} \tau^{Poll}$$

$$(26.2') \quad X_i^D = \alpha_i^d XA_i \left(\frac{PA_i - \sum_p \pi_{i,p}^{Cons} \tau^{Poll}}{P_i^D} \right)^{\sigma_i^m}$$

$$(26.3') \quad X_i^M = \alpha_i^m XA_i \left(\frac{PA_i - \sum_p \pi_{i,p}^{Cons} \tau^{Poll}}{P_i^M} \right)^{\sigma_i^m}$$

$$(24.4') \quad S_g = H^{TAX} + \sum_i (Y_i^{INDTAX} + Y_i^{TARIFF}) - P^G X^{TotG} - P^{CPI} G^{TRA} + \sum_p \tau_p^{Poll} E_p$$

The consumption based pollution tax is added to the Armington price, see Equation (27.1'). However, the Armington decomposition occurs using basic prices, therefore, the taxes are removed from the Armington price in the decomposition formulae, see Equations (26.2') and (26.3'). Equation (24.4') determines the modification to the government saving equation.

Table 38 presents the equations that are used to evaluate ancillary benefits. Equation (38.1) represents the simple dispersion model used here: air concentration levels are determined using a matrix of dispersion coefficients, which vary according to the pollutant and stack height. Once concentrations are calculated, diseases intensity is estimated through the dose-response equation (38.2); notice that the parameter *dose* maps concentration levels for various pollutants into intensities of a range of diseases.²² Finally, equation (38.3) calculates a damage value by multiplying a unit cost parameter, *uc*, times the disease intensity.

Table 38. **Dispersion, Disease and Damage Equations**

$$(38.1) \text{Concentr}_{r,p} = \sum_{stack} \text{dispers}_{r,p,stack} E_{r,p,stack}$$

$$(38.2) \text{Disease}_{r,d} = \sum_p (\text{dose}_{d,p} \text{Concentr}_{r,p}) \text{Pop}_r$$

$$(38.3) \text{Damage}_r = \sum_d \text{uc}_d \text{Disease}_{r,d}$$

22. It may be useful to recall that the set *d*, *p*, and *stack* group respectively disease types, pollutants and stack heights.

IV. CONCLUSION

This Technical Paper presents the technical specification of the RE-GEM (Regional and Environmental General Equilibrium Model) for India and a complete description of the data used in the model as well as their estimation methods and their sources. A coherent climate policy should be designed on a reliable assessment of its economic and environmental impacts and these may be estimated if sufficiently high quality data have been gathered and a suitable model employed. In the particular context examined here, we have been able to produce firm estimates based on an original fully consistent regional dataset for India and on a regional general equilibrium model that can trace all the policy direct and indirect effects.

The CGE model presented in this paper continues a tradition of detailed modelling exercises developed at the OECD Development Centre. In particular RE-GEM embodies a high level of disaggregation for pollutants, products, and sectors. It can be used to simulate the impacts of abatement policies targeted to specific air emissions and the induced resource reallocation, not uniform across sectors can be fully studied. Besides, this model explicitly includes dynamic features, allowing the introduction of exogenous factors such as productivity shifts and demographic changes that affect the growth and pollution trajectory. Finally, most economy-wide studies on growth and environment linkages rely on effluent intensities associated with output, and do not take into account substitution between non-polluting and polluting factors. Abating pollution is then achieved principally by reducing output in pollution intensive sectors, with a significant cost in terms of growth. By contrast, in RE-GEM pollution emissions are linked to polluting input use, rather than output. Technical adjustment by substituting non-polluting factors for polluting factors may therefore be assessed.

Although the above characteristics are quite conventional in the literature, some features of RE-GEM stand out as particularly innovative. *Firstly*, RE-GEM includes benefits in the assessment of climate policy changes. Improved atmospheric conditions achieved via a reduction of air pollutants contribute through dose-response functions to positive health effects: an economic evaluation of decreased mortality and morbidity rates makes up the ancillary benefits measured in this model. Clearly these benefits are experienced at a local geographical level and their consistent aggregation at an India-wide macro level would require detailed spatial modelling of concentration level, emissions, and economic activity. This ideal solution would enable a precise comparison of costs and benefits of climate policy but at very high

(probably prohibitive) costs in terms of data requirements. We therefore adopted an intermediate solution and this constitutes the *second* novel aspect of RE-GEM. The model disaggregates India into a number of regions, calculates emissions at the regional level and links them to concentration in the major regional population centres. This additional regional dimension also provides important information on the potential regional imbalances ensuing from climate policy changes thus providing important information on which to base corrective measures.

V. ANNEX

Social Accounting Matrix for India – Aggregate version
(1995 – 10 billion current Rupees)

			Primary	Manuf.ng	Oil Prod.	Coal Prod.	Services	Electricity	Capital	Labour	House.Id	CapitalAc	VStocks	Ind. Taxes	Govern.t
Nor	Primary	Nor	16.343	18.720	0.000	0.001	4.088	0.001			58.161	0.207	1.243		0.431
Nor	Manuf.ng	Nor	5.461	56.024	0.220	0.414	22.684	0.393			39.207	26.908	7.227		3.055
Nor	Oil Prod.	Nor	0.981	2.617	3.694	0.084	4.575	0.563			2.138		-0.273		0.199
Nor	Coal Prod.	Nor	0.013	1.603	0.008	0.246	0.623	1.467			0.042		-0.139		0.000
Nor	Services	Nor	6.196	22.930	0.498	0.347	25.280	2.425			49.007	25.401			21.489
Nor	Electricity	Nor	0.810	4.756	0.037	0.119	2.185	2.550			0.712				0.058
Nor	Capital	Nor	40.601	13.282	0.352	0.243	49.156	1.522							
Nor	Labour	Nor	40.504	17.670	0.897	0.623	46.642	3.336							
Nor	House.Id	Nor							105.156	109.673					18.726
Nor	CapitalAc	Nor									73.783				
Nor	VStocks	Nor										8.058			
Nor	Ind. Taxes	Nor	-4.185	20.256	2.314	0.018	0.747	0.357							
Nor	Govern.t	Nor									11.065				
Nor	Primary	Wes	9.809												
Nor	Manuf.ng	Wes		0.582											
Nor	Oil Prod.	Wes													
Nor	Coal Prod.	Wes													
Nor	Services	Wes					1.381								
Nor	Electricity	Wes													
Nor	Primary	Sou		3.200											
Nor	Manuf.ng	Sou													
Nor	Oil Prod.	Sou													
Nor	Coal Prod.	Sou													
Nor	Services	Sou					1.979								
Nor	Electricity	Sou						0.087							
Nor	Primary	Eno		3.495											
Nor	Manuf.ng	Eno													
Nor	Oil Prod.	Eno													
Nor	Coal Prod.	Eno													
Nor	Services	Eno					0.260								
Nor	Electricity	Eno						1.299							
Wes	Primary	Nor	0.261												
Wes	Manuf.ng	Nor		7.863											
Wes	Oil Prod.	Nor			1.224										
Wes	Coal Prod.	Nor				0.095									
Wes	Services	Nor					0.026								
Wes	Electricity	Nor													
Wes	Primary	Wes	11.666	18.391	0.000	0.000	5.567	0.002			66.179	0.147	0.883		0.307
Wes	Manuf.ng	Wes	4.064	102.701	0.321	1.027	32.002	0.753			54.572	46.416	18.491		6.017
Wes	Oil Prod.	Wes	0.780	4.580	8.830	0.237	6.801	2.901			3.658		-0.612		0.483
Wes	Coal Prod.	Wes	0.009	2.642	0.022	0.493	0.839	2.479			0.057		-0.335		0.001
Wes	Services	Wes	4.637	44.421	1.188	0.973	36.475	4.408			66.661	34.429			29.450
Wes	Electricity	Wes	0.579	12.117	0.082	0.335	3.306	5.601			2.168				0.115
Wes	Capital	Wes	30.943	27.095	0.950	0.684	68.864	1.914							
Wes	Labour	Wes	31.068	39.667	2.916	1.893	66.215	5.987							
Wes	House.Id	Wes							130.449	147.746					24.145
Wes	CapitalAc	Wes									95.546				
Wes	VStocks	Wes										18.427			
Wes	Ind. Taxes	Wes	-2.748	37.872	5.986	0.051	1.196	0.700							
Wes	Govern.t	Wes									14.225				
Wes	Primary	Sou	0.038												
Wes	Manuf.ng	Sou		3.103											
Wes	Oil Prod.	Sou			0.001										
Wes	Coal Prod.	Sou				0.011									
Wes	Services	Sou					0.836								
Wes	Electricity	Sou						0.028							
Wes	Primary	Eno		15.823											
Wes	Manuf.ng	Eno			1.166										
Wes	Oil Prod.	Eno				0.177									
Wes	Coal Prod.	Eno						0.477							
Wes	Services	Eno													
Wes	Electricity	Eno						0.413							

Social Accounting Matrix for India (continued)

			Primary	Manuf.ng	Oil Prod.	Coal Prod.	Services	Electricity	Capital	Labour	House.Id	CapitalAc	VStocks	Ind. Taxes	Govern.t
Nor	Primary	Nor	16.343	18.720	0.000	0.001	4.088	0.001			58.161	0.207	1.243		0.431
Nor	Manuf.ng	Nor	5.461	56.024	0.220	0.414	22.684	0.393			39.207	26.908	7.227		3.055
Nor	Oil Prod.	Nor	0.981	2.617	3.694	0.084	4.575	0.563			2.138		-0.273		0.199
Nor	Coal Prod.	Nor	0.013	1.603	0.008	0.246	0.623	1.467			0.042		-0.139		0.000
Nor	Services	Nor	6.196	22.930	0.498	0.347	25.280	2.425			49.007	25.401			21.489
Nor	Electricity	Nor	0.810	4.756	0.037	0.119	2.185	2.550			0.712				0.058
Nor	Capital	Nor	40.601	13.282	0.352	0.243	49.156	1.522							
Nor	Labour	Nor	40.504	17.670	0.897	0.623	46.642	3.336							
Nor	House.Id	Nor							105.156	109.673					18.726
Nor	CapitalAc	Nor									73.783				
Nor	VStocks	Nor										8.058			
Nor	Ind. Taxes	Nor	-4.185	20.256	2.314	0.018	0.747	0.357							
Nor	Govern.t	Nor									11.065				
Nor	Primary	Wes	9.809												
Nor	Manuf.ng	Wes		0.582											
Nor	Oil Prod.	Wes													
Nor	Coal Prod.	Wes													
Nor	Services	Wes					1.381								
Nor	Electricity	Wes													
Nor	Primary	Sou		3.200											
Nor	Manuf.ng	Sou													
Nor	Oil Prod.	Sou													
Nor	Coal Prod.	Sou													
Nor	Services	Sou					1.979								
Nor	Electricity	Sou						0.087							
Nor	Primary	Eno		3.495											
Nor	Manuf.ng	Eno													
Nor	Oil Prod.	Eno													
Nor	Coal Prod.	Eno													
Nor	Services	Eno					0.260								
Nor	Electricity	Eno						1.299							
Wes	Primary	Nor	0.261												
Wes	Manuf.ng	Nor		7.863											
Wes	Oil Prod.	Nor			1.224										
Wes	Coal Prod.	Nor				0.095									
Wes	Services	Nor					0.026								
Wes	Electricity	Nor													
Wes	Primary	Wes	11.666	18.391	0.000	0.000	5.567	0.002			66.179	0.147	0.883		0.307
Wes	Manuf.ng	Wes	4.064	102.701	0.321	1.027	32.002	0.753			54.572	46.416	18.491		6.017
Wes	Oil Prod.	Wes	0.780	4.580	8.830	0.237	6.801	2.901			3.658		-0.612		0.483
Wes	Coal Prod.	Wes	0.009	2.642	0.022	0.493	0.839	2.479			0.057		-0.335		0.001
Wes	Services	Wes	4.637	44.421	1.188	0.973	36.475	4.408			66.661	34.429			29.450
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Wes	Capital	Wes	30.943	27.095	0.950	0.684	68.864	1.914							
Wes	Labour	Wes	31.068	39.667	2.916	1.893	66.215	5.987							
Wes	House.Id	Wes							130.449	147.746					24.145
Wes	CapitalAc	Wes									95.546				
Wes	VStocks	Wes										18.427			
Wes	Ind. Taxes	Wes	-2.748	37.872	5.986	0.051	1.196	0.700							
Wes	Govern.t	Wes									14.225				
Wes	Primary	Sou	0.038												
Wes	Manuf.ng	Sou		3.103											
Wes	Oil Prod.	Sou			0.001										
Wes	Coal Prod.	Sou				0.011									
Wes	Services	Sou					0.836								
Wes	Electricity	Sou						0.028							
Wes	Primary	Eno		15.823											
Wes	Manuf.ng	Eno			1.166										
Wes	Oil Prod.	Eno				0.177									
Wes	Coal Prod.	Eno													
Wes	Services	Eno					0.477								
Wes	Electricity	Eno						0.413							
Sou	Primary	Nor	0.125												
Sou	Manuf.ng	Nor		0.673											
Sou	Oil Prod.	Nor			0.263										
Sou	Coal Prod.	Nor				0.065									
Sou	Services	Nor					3.193								
Sou	Electricity	Nor													
Sou	Primary	Wes	4.653												
Sou	Manuf.ng	Wes		1.071											
Sou	Oil Prod.	Wes			0.507										
Sou	Coal Prod.	Wes													
Sou	Services	Wes					0.975								

Social Accounting Matrix for India (continued)

			Primary	Manuf.ng	Oil Prod.	Coal Prod.	Services	Electricity	Capital	Labour	House.Id	CapitalAc	VStocks	Ind. Taxes	Govern.t
Nor	Primary	Nor	16.343	18.720	0.000	0.001	4.088	0.001			58.161	0.207	1.243		0.431
Nor	Manuf.ng	Nor	5.461	56.024	0.220	0.414	22.684	0.393			39.207	26.908	7.227		3.055
Nor	Oil Prod.	Nor	0.981	2.617	3.694	0.084	4.575	0.563			2.138		-0.273		0.199
Nor	Coal Prod.	Nor	0.013	1.603	0.008	0.246	0.623	1.467			0.042		-0.139		0.000
Nor	Services	Nor	6.196	22.930	0.498	0.347	25.280	2.425			49.007	25.401			21.489
Nor	Electricity	Nor	0.810	4.756	0.037	0.119	2.185	2.550			0.712				0.058
Nor	Capital	Nor	40.601	13.282	0.352	0.243	49.156	1.522							
Nor	Labour	Nor	40.504	17.670	0.897	0.623	46.642	3.336							
Nor	House.Id	Nor							105.156	109.673					18.726
Nor	CapitalAc	Nor									73.783				
Nor	VStocks	Nor										8.058			
Nor	Ind. Taxes	Nor	-4.185	20.256	2.314	0.018	0.747	0.357							
Nor	Govern.t	Nor									11.065				
Nor	Primary	Wes	9.809												
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Nor	Electricity	Wes													
Nor	Primary	Sou		3.200											
Nor	Manuf.ng	Sou													
Nor	Oil Prod.	Sou													
Nor	Coal Prod.	Sou													
Nor	Services	Sou					1.979								
Nor	Electricity	Sou						0.087							
Nor	Primary	Eno		3.495											
Nor	Manuf.ng	Eno													
Nor	Oil Prod.	Eno													
Nor	Coal Prod.	Eno													
Nor	Services	Eno					0.260								
Nor	Electricity	Eno						1.299							
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Wes	Manuf.ng	Wes	4.064	102.701	0.321	1.027	32.002	0.753			54.572	46.416	18.491		6.017
Wes	Oil Prod.	Wes	0.780	4.580	8.830	0.237	6.801	2.901			3.658		-0.612		0.483
Wes	Coal Prod.	Wes	0.009	2.642	0.022	0.493	0.839	2.479			0.057		-0.335		0.001
Wes	Services	Wes	4.637	44.421	1.188	0.973	36.475	4.408			66.661	34.429			29.450
Wes	Electricity	Wes	0.579	12.117	0.082	0.335	3.306	5.601			2.168				0.115
Wes	Capital	Wes	30.943	27.095	0.950	0.684	68.864	1.914							
Wes	Labour	Wes	31.068	39.667	2.916	1.893	66.215	5.987							
Wes	House.Id	Wes							130.449	147.746					24.145
Wes	CapitalAc	Wes									95.546				
Wes	VStocks	Wes										18.427			
Wes	Ind. Taxes	Wes	-2.748	37.872	5.986	0.051	1.196	0.700							
Wes	Govern.t	Wes									14.225				
Wes	Primary	Sou	0.038												
Wes	Manuf.ng	Sou		3.103											
Wes	Oil Prod.	Sou			0.001										
Wes	Coal Prod.	Sou				0.011									
Wes	Services	Sou					0.836								
Wes	Electricity	Sou						0.028							
Wes	Primary	Eno		15.823											
Wes	Manuf.ng	Eno			1.166										
Wes	Oil Prod.	Eno				0.177									
Wes	Coal Prod.	Eno													
Wes	Services	Eno					0.477								
Wes	Electricity	Eno						0.413							
Sou	Primary	Nor	0.125												
Sou	Manuf.ng	Nor		0.673											
Sou	Oil Prod.	Nor			0.263										
Sou	Coal Prod.	Nor				0.065									
Sou	Services	Nor					3.193								
Sou	Electricity	Nor													
Sou	Primary	Wes	4.653												
Sou	Manuf.ng	Wes		1.071											
Sou	Oil Prod.	Wes			0.507										
Sou	Coal Prod.	Wes													
Sou	Services	Wes					0.975								

Note: The first and second columns in the table represent the recipient region and account, whereas the third column and the first row represent the outlaying region and account; so that for example the Primary sector in the North region is selling to the manufacturing sector of the same region 18.720 billion of current Rupees in intermediate goods. A full 35-sector version is available upon request.

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