ELSEVIER

Energy Economics 20 (1998) 347–373

Energy Economics

A computable general equilibrium model of energy, economy and equity interactions in Pakistan

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Abstract

This article introduces a computable general equilibrium model of the Pakistan economy. Some major extensions to a standard neoclassical model have been made to capture the interlinkages between economy, energy and equity. The model has been designed mainly to carry out policy oriented short-term studies especially for the energy sector. An illustrative application of the model shows its capability to provide detailed information which are useful in analysis of a policy issue.

JEL classifications: C50; C68; Q41

Keywords: Energy; General equilibrium

1. Introduction

Computable General Equilibrium (CGE) models have been shown to be a powerful tool for policy analysis. Various models based on general equilibrium theory have been developed to capture the energy–economy interaction in the developing countries. Devarajan (1988) surveyed energy CGE models and their applications and pointed out two weaknesses of most of the energy–economy models, applied to the developing countries. First, their coarse treatment of the economy apart from the energy sector that weakens the feedback effects from the

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PII S0140-9883(97)00027-3

rest of economy for any policy simulation. Second, their little connection with the theory of international trade. Recently, in most of the developing countries, the revival of economic liberalisation policy has put trade liberalisation at the top of economic planning agenda. Modelling of international trade theory, therefore, becomes imperative for these countries. Two issues closely related to trade and energy policies in the developing countries are tax revenues and equity. As pointed out by Devarajan (1988), the issues of taxation in developing countries are different from that of the developed countries for three reasons.

1. Limited administrative capacity prevents most developing countries from instituting a consumption tax, or even a viable income tax, therefore, indirect tax is the more commonly used instrument. The assumption frequently made for developed countries that the tax revenues are rebated in a lump-sum fashion can no longer be made. Because if the government has access to lump-sum transfers, it should also be able to levy lump-sum taxes. Hence, the revenue implications of any tax reform become crucial.
2. Due to wide income disparities, the effects of a tax change on the distribution of income are clearly important for the developing countries.
3. As most developing countries are inclined to become open economies, the impact of a tax reform on foreign trade deserves attention. According to Devarajan, only recently have CGE models of developing countries looked at all aspects of tax reform, namely, the welfare, revenue, equity and foreign trade implications.

The objective of this article is to present a static AGE model for Pakistan (from now on referred to as GE-PAK), that incorporates energy–economy interactions, international trade theory and an index of social equity. Furthermore, the model incorporates detailed income accounting of private and public sectors and inter-region labour migration. The model's application in this article aims to illustrate its capability to address various aspects of the policy analysis mentioned above.

The article is organised as follows. Sec. 2 describes dimensions of the model while Sec. 3 presents the core structure of the model. Sec. 4 then discusses parts of the core model which treat energy production and consumption pattern in detail. In this section, we illustrate features of the model through graphs only. All the equations of GE-PAK are documented and explained in Naqvi (1997) along with discussion on computer implementation of the model. Sec. 5 contains discussion of the data base and parameter values and Sec. 6 describes the solution method. As an illustrative example of the model's application, we present the short-term simulation result of removing import tax on high speed diesel in Pakistan in Sec. 7. Sec. 8 concludes the article.

2. Dimensions of the model

GE-PAK is built around a social accounting matrix, which contains a detailed input–output table and income-expenditure accounts of four types of institutions: households; corporations; government; and the Rest of the World (ROW).

The input–output table contains 131 commodities which are produced by 128 industries. There are 15 industries from the agriculture sector producing primary goods while coal, other minerals and oil and gas industries produce minerals. There are 50 industries in the large-scale industrial sector which include agro-based industries, such as the sugar refining industry and manufacturing industries such as the electric goods industry. Some of the agricultural and manufactured goods which are produced on a large-scale are also produced on a small-scale in the household and cottage industries. There are 31 industries in the small-scale industrial sector producing such goods. Four electricity industries, one gas refining and one oil refining industry belong to the energy sector. The remaining 29 industries belong to the construction and services sectors.

The two sources of commodity supplies are: (1) domestic and (2) foreign. Households demand 53 consumption items which are formed by 131 commodities. Labour, capital and land are the primary factors used in current goods production.

Households are grouped into 14 types based on two regions: urban and rural; three types of employment status: self-employed, employed and others and three income levels: low, middle and high in the first two employment categories. There is one government account while corporations are divided into public and private type.

3. The core structure of GE-PAK

Pakistan is a developing economy in South Asia. In this article, we present GE-PAK as a case of developing countries. This multi-sectoral model is predominantly neoclassical and is in the spirit of ORANI — a CGE model of the Australian economy (see Dixon et al., 1982).

The core part of the model consists of equations describing:

- commodity and primary factors demands for current production;
- commodity demands for capital formation;
- commodity demands for consumer item formation;
- consumer item demands for household;
- commodity demands for export;
- commodity demands for current expenditure of government;
- consumption function;
- an index of social welfare function;
- the relationship of basic prices to production cost and purchasers' prices; and
- market clearing equations for commodities and primary factors.

Fig. 1 illustrates the core structure of GE-PAK.

Commodity and primary factor demands for current production are derived from the solution to the cost minimization subject to the assumed production technology. A variety of functions for current goods production have been assumed which are based on energy consumption patterns specific to industries.

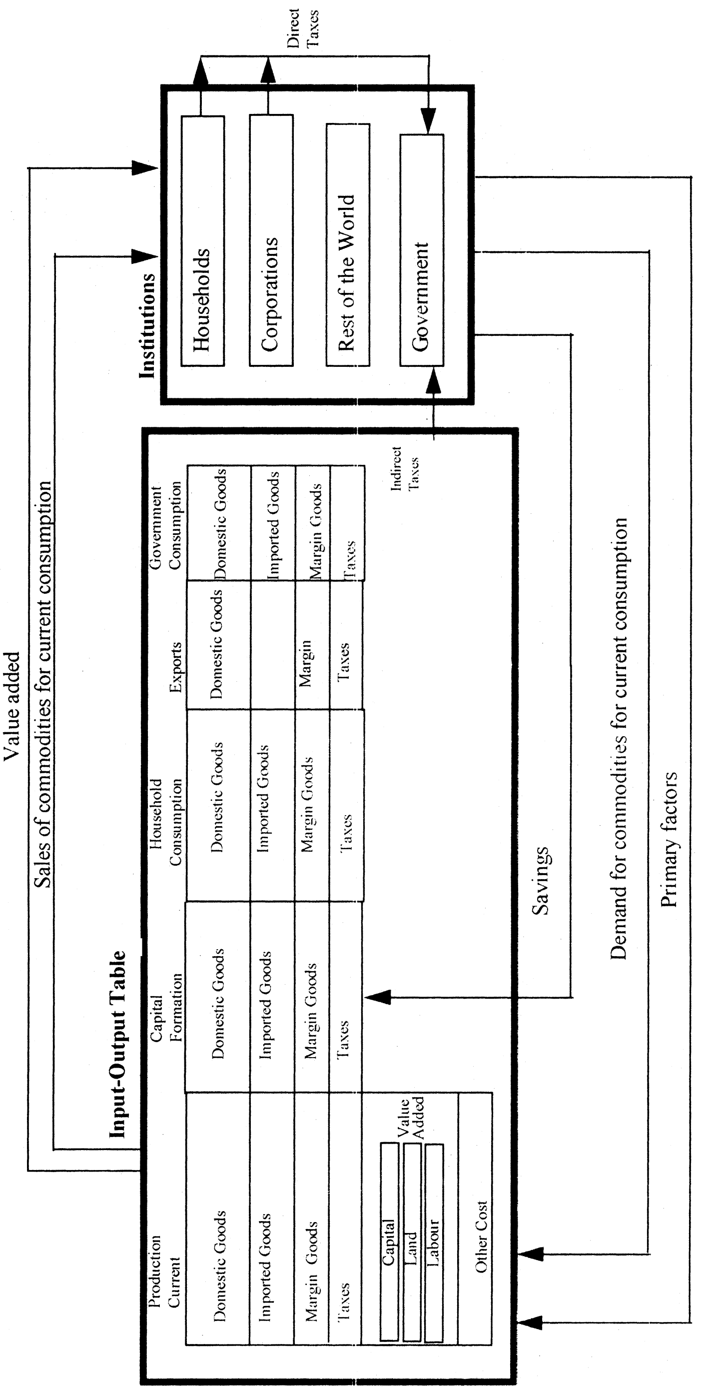


Fig. 1. Schematic representation of GE-PAK.

Petroleum products, electricity and natural gas are the major commercial energy products used in Pakistan. The supplies and prices of these three types of energy products are administered by the government and the model focuses on the demand and supply pattern of these energy products. Non-commercial energy products meet a significant fraction of household energy demand in Pakistan. In the rural and urban low-income households, non-commercial fuels are used for cooking and kerosene is used for lighting. Nevertheless, production and consumption patterns of these traditional fuels have not been a model in GE-PAK for two reasons. First, a major portion of these traditional fuels are not purchased but rather collected by the family members especially children and women. In the short term, any marginal change in the economy in terms of demand for and wages of labour will not substantially affect the opportunity cost of family hours used in supplying these fuels. Second, substitution of non-commercial fuels with commercial fuels is determined mainly by a household's access to the distribution system of natural gas and electricity and its income level to bear the initial cost of getting connection and gadgets. Thus, changes in the government pricing policy and the resultant marginal effects on household income will not affect this substitution pattern. Hence, the government policies in the short term will not neither effect the demand for and supply of these fuels. A small fraction of energy demand in Pakistan is also meet by coal which is mainly used in the bricks industry. Substitution of coal with any other fuel is not possible by existing production technology. Though, a separate coal industry has been defined in the model, a consumption pattern of coal has not been modelled in detail.

Demand and supply equations for private-sector agents are derived from the solutions to the optimisation problems (utility maximisation, cost minimisation, etc.), which are assumed to underlie the behaviour of the agents in conventional neoclassical microeconomics. The producers, assumed to be price takers, are operating in competitive markets. This prevents the earning of pure profits.

The input demand equations for the public sector agents such as electricity producers, are also derived from the solution to the cost minimisation problem. The only difference between the commodities produced by the private-sector agents and the public-sector agents, is in the determination of their purchasers' prices. The prices of the commodities produced solely by the private-sector agents are determined by market forces, while the prices of commodities produced by the public-sector agents are regulated by the government. The producers in both the sectors are price takers. The basic prices of commodities produced in the public sector are also determined endogenously in the model. We treat the differences between basic prices[1] and the regulated sales prices of these commodities as implicit taxes. In GE-PAK, we have modelled this implicit tax with other types of indirect tax.

Sec. 4 discusses the current goods production functions in detail which capture the energy economy interaction in Pakistan. We briefly discuss the remaining major components of the model in the following subsections.

[1] Basic price is defined as production cost exclusive of indirect taxes and trade and transport margins.

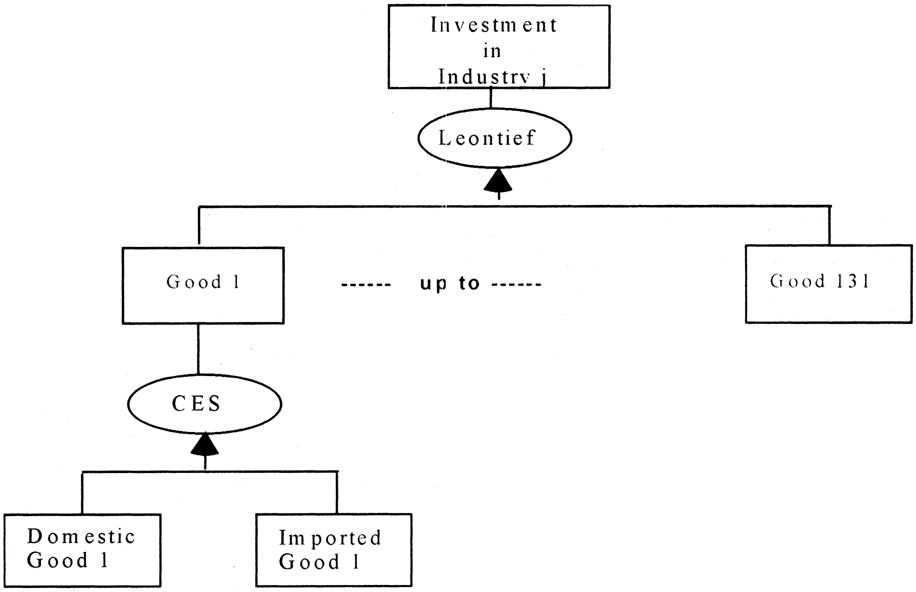


Fig. 2. Capital formation in industries.

3.1. Commodity demands for capital formation

The commodity demands for capital goods production are derived from the solution to the two-part cost minimization problem. The two-level nested production function is illustrated in Fig. 2. It has been assumed that to produce a unit of capital in an industry, no primary factor is required. The total cost of an input commodity supplied from domestic and foreign sources is minimised subject to the Constant Elasticity of Substitution (CES) production function, while the total cost of all inputs is minimised subject to the Leontief production function.

3.2. Household demand for items and commodity demands for item formation

It has been assumed that the households derive utility from the consumption of items, which are aggregated by a Stone–Geary function leading to Linear Expenditure System (LES) demand functions. Most of the micro level study for Pakistan have assumed LES to compute expenditure elasticities for households. The major benefit of this system is in its disaggregation of expenditure into subsistence and luxury parts. The consumption items include kerosene, natural gas, coal and electricity as well as purchased traditional items such as cow dung. No specific energy substitution patterns have been assumed for households. As mentioned above, the consumption pattern of energy products is constrained by access to these products or the level of household income rather than the relative prices of these products. Nevertheless, the model allows changes in relative energy prices to affect household energy consumption depending on share of energy products in households' luxury and subsistence level expenditure.

The household demands are for consumption items which are supplied only from domestic sources. These items are formed by domestic and imported commodities. The commodity demand equations for formation of consumer items are also derived from the solution to the two-part cost minimisation problem similar to that discussed for capital formation (see Fig. 2).

3.3. Commodity demands for export and government consumption

A downward sloping foreign demand schedule has been defined for exports. Export volumes have been defined as declining functions of their prices in foreign currency. However, two shift variables have also been included in the export demand function to allow for horizontal (quantity) and vertical (price) shifts in the demand schedules.

There is no budget constrain on government consumption which is assumed to be a function of real private consumption. Thus government demand for commodities are in direct proportion to real private consumption in the absence of any exogenous shift in them.

3.4. Investment and consumption functions

GE-PAK is a static model. It has been designed for comparative–static simulations of short-run effects of a policy. Thus, the model does not have as such a theory of investment. However, unlike some other CGE models that assume investment by industries given exogenously, GE-PAK contains a set of equations which distributes the given total investment funds across industries. It has been assumed that the net rate of return in an industry (relative to the economy-wide rate) is a positive function of the change in the industry's capital stock (relative to the economy-wide stock). This function can be interpreted as a risk-related relationship with relatively fast- (slow-) growing industries requiring premium (accepting discounts) on their rates of return. The ratio of the rental value of capital to the supply price minus the rate of depreciation determines the net rate of return. The investment function translates the demand for capital stock into an investment fund required by an industry. With these behavioural assumptions, the model can capture changes in the investment pattern in a response to a policy change.

Similarly, there is no theory for household savings in GE-PAK, instead the aggregate consumption of each household group is defined as a positive function of its disposable income and thus savings are determined as a residual. However, these functions can be used flexibly either to assume fixed average propensity to consume or a fixed level of consumption. For the other institutions also, savings are determined as residual. Any gap between investments and savings are accommodated by deterioration in the balance of payments.

3.5. An index of social welfare and elasticities of social welfare cost

A variety of functions have been applied in social welfare analysis of reforms in the public policy. These functions are based on a family of social welfare functions, which was first proposed by Atkinson (1970) and used by many others (Blackorby and Donaldson, 1978; Robert, 1980; Jorgenson and Slesnick, 1984). The popular social welfare measure of Atkinson is an index that incorporates distributional concerns in the aggregation of individuals' utilities [for a complete discussion of a variety of social welfare functions and their properties see Diewert (1985)].

GE-PAK computes a set of social welfare indices using Atkinson's welfare function of 'Mean of order τ' (Atkinson, 1970). The function is defined as:

$$W(\mathrm{PERCONR}_1,\text{---- up to ----},\mathrm{PERCONR}_{\mathrm{POP}}) = \left(\frac{1}{\mathrm{POP}}\sum_{i=1}^{\mathrm{POP}} \mathrm{PERCONR}_i^{\tau}\right)^{1/\tau}, \quad \tau \leq 1 \text{ and } \tau \neq 0, \tag{1}$$

where $\mathrm{PERCONR}_i$ is real consumption of individual i and POP is total population. As we assign different values to τ, the function takes various forms; each describing a different state of social equity concern. Table 1 reports these forms of the welfare function and their implications (see Naqvi, 1995a,b for a further discussion and application of these indices).

In the function, as τ decreases and becomes negative, more importance is given to the welfare of the poor and less to the welfare of the rich. When τ tends towards minus infinity, the function tends toward the Rawlsian welfare function

Table 1
Welfare functions

Atkinson inequality parameter (τ)	Welfare function forms	Implication
1	Utilitarian	A dollar increase in real consumption has equal weight for all persons
$\to 0$	Relativist	1% increase in real consumption for a rich person is equal to 1% increase for a poor person
-1	Mean of order 1	A 1% increase in real consumption for a low-income person has higher weight than a 1% increase in consumption for a higher income person
$\to (-\infty)$	Rawlsian	When changes in real consumption of the low-income group is counted

(Rawls, 1971), which takes into account welfare of the low income groups only. When $\tau = -1$, the value of the weight given to a household group depends on the income disparities in the base year. The bigger is the real per capita consumption of a household group relative to that of the low-income group, the smaller is the weight given to effects on its welfare when computing the welfare of the society. One may interpret τ as the Atkinson inequality aversion parameter. Its value depends either on judgments or can be inferred from the government policies such as the personal income tax structure[2].

4. Modelling of energy supplies and demands

In this section, we discuss production functions of current goods producing industries and the electricity supply structure of the model, which distinguishes GE-PAK as a model of energy–economy interaction.

4.1. Multiple output in the refinery industry and the oil and gas industry

In GE-PAK all industries use multiple inputs. Only two of these industries (i.e. the Refinery and the Oil and gas) produce multiple output. The Refinery industry produces six types of petroleum products, as shown in Fig. 3. The Constant Elasticity of Transformation (CET) specification allows us to choose the degree of transformation possible in the output of these products.

The multi-input and multi-output production specification is kept manageable by a series of separability assumptions, illustrated by the nesting shown in Fig. 3. The assumption of input–output separability implies that the generalised production function for an industry:

$$F(\text{inputs,outputs}) = 0 \tag{2}$$

may be written as:

$$G(\text{inputs}) = Z = H(\text{outputs}) \tag{3}$$

where Z is an index of the industry activity. This assumption reduces the number of estimated parameters required by the model. Fig. 3 shows that the H function in (3) is derived from a CET aggregation function, while the G function is broken into a sequence of nests. At the top level, commodity-composites, a primary factor-composite and 'other costs' inputs are combined using a Leontief production function. Consequently they are all demanded in direct proportion to Z. Each commodity composite is a CES production function of a domestic good and its imported equivalent. The primary-factor composite is a CES aggregation of land, capital and composite labour. The composite labour is a Leontief aggregation of composite

[2] For example Piggot (1982) estimated the elasticity of the social marginal valuation of income to derive welfare weights for different individuals in different income groups for Australia.

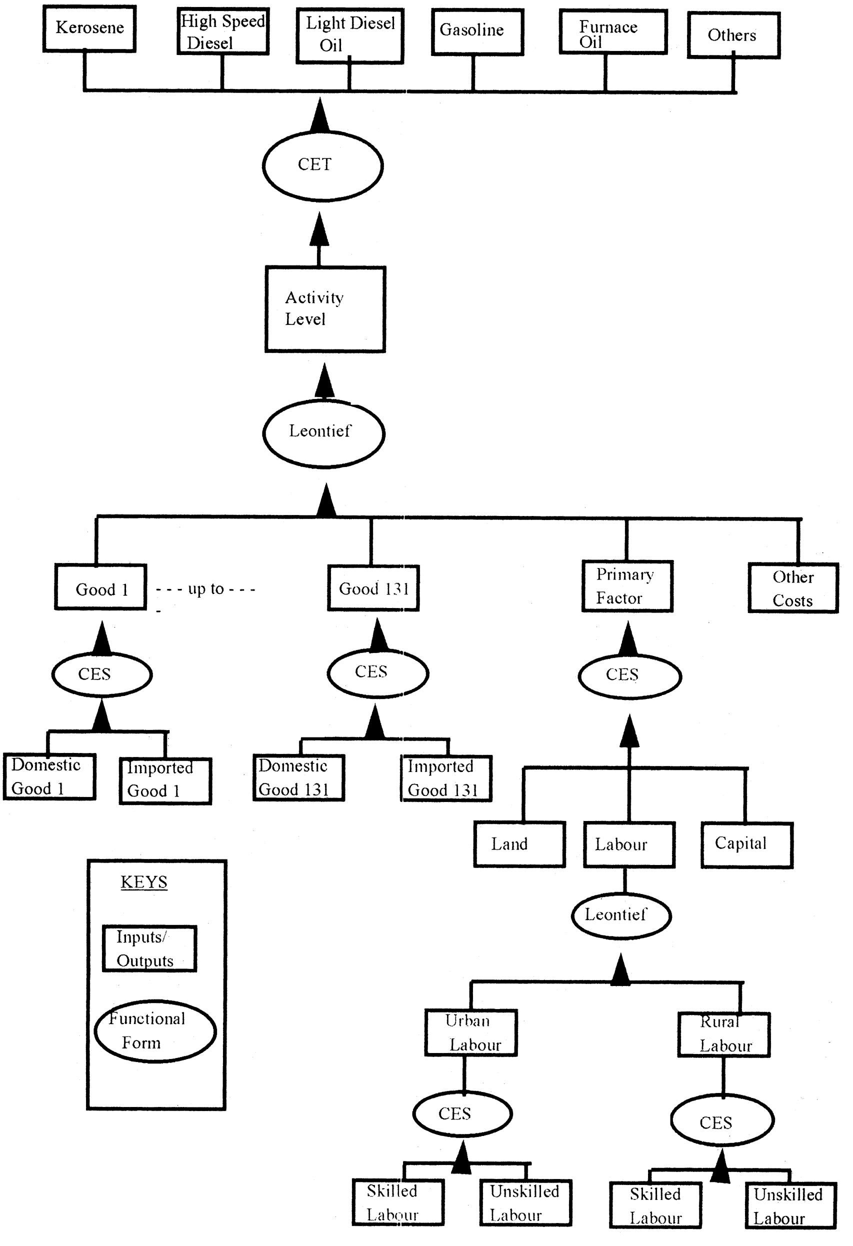


Fig. 3. Production structure of refinery industry.

urban labour and composite rural labour. The composite labour in each region is a CES aggregation of skilled and unskilled labour.

The Oil and gas industry produces crude oil and raw natural gas. A production structure similar to Fig. 3 is defined for the Oil and gas industry. The structure allows transformation between crude oil and raw natural gas production when their relative prices change.

4.2. Modelling of electricity supply structure

In Pakistan, there are two major sources of electricity generation, hydro and thermal. Thermal electricity is generated by three types of plants: (1) combined cycle; (2) steam generator; and (3) gas turbine. Each type of electricity plant has a different composition of capital costs, fuel costs and types of fuels consumed. The four types of plants also differ in their engineering characteristics. As consumers have a certain pattern of electricity demand, the utility aggregates electricity generated by the four industries according to the demand pattern and the engineering characteristics of these plants (see Naqvi, 1995b for a detailed discussion).

The four electricity industries can be grouped according to their technical characteristics into two categories, high-flexible and low-flexible. We have defined a two-level nested electricity supply function that combines electricity produced by the four electricity industries. The supply structure allows substitution of electricity produced by industries within a category and between the two categories as shown in Fig. 4. This structure takes into account the differences in costs of electricity production by different plants and the differences in their technical characteristics.

In Fig. 4, the top level nest shows that total electricity supply is a CES composite of electricity generated by the more flexible technology (elec_mflex) and electricity generated by the less flexible technology (elec_lflex). The top level nest represents substitution possibilities in electricity generation by industries with low and high flexibility. The bottom level nest shows the substitution possibilities in electricity generation by industries with similar type of technology. Electricity generated by the more flexible technology (elec_mflex) is a CES composite of generation from the gas turbine and hydro electricity industries. Electricity generated by the less flexible technology (elec_lflex) is a CES composite of generation from the steam and combined cycle industries.

4.3. Modelling of energy demands in industries

On the demand side, the model allows substitution between energy products and several other inputs to production. Based on energy consumption patterns in industries, six types of input demand structures have been defined. The five input structures correspond to industries in: (1) the agriculture sector; (2) mining, manufacturing, construction sectors; (3) the road transport industry; (4) the steam electricity industry; and (5) the combined cycle electricity industry. The sixth group correspond to the rest of the industries which are mainly service sector industries. In these industries energy cost is an insignificant part of the total production costs,

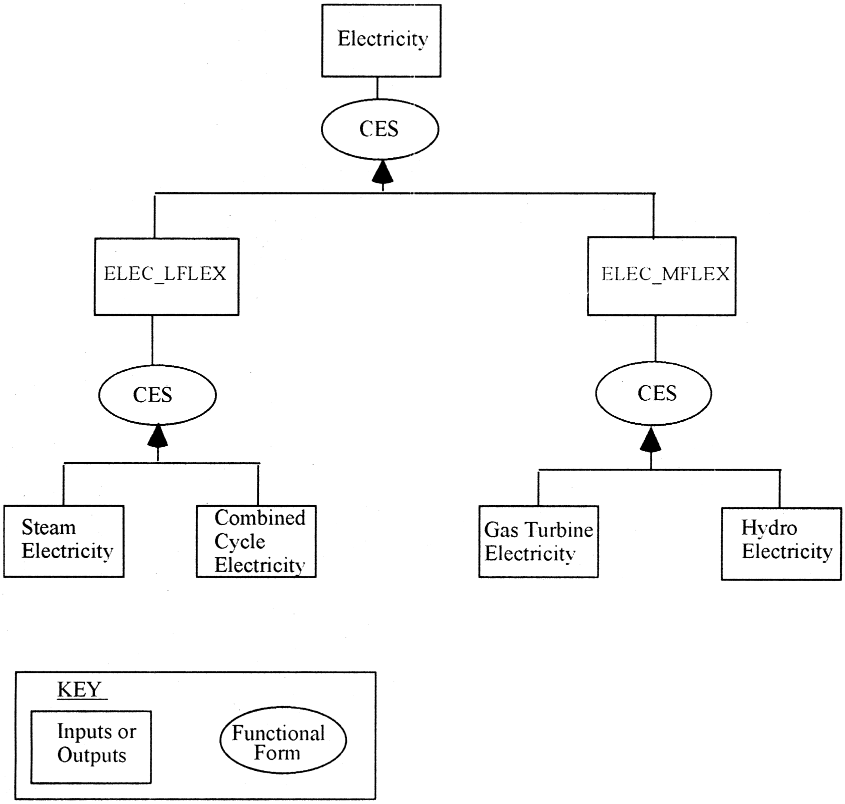


Fig. 4. Electricity supply structure.

no specific energy substitution pattern has been assumed for them. The input structure of Fig. 3, discussed in Sec. 4.1, is applied for the sixth group of industries.

Figs. 5–9 present the first five types of input structures to elucidate specific energy substitution patterns in production. We discuss these structures in the following paragraphs.

4.3.1. Input structure for agricultural industries

Fig. 5 shows the assumed input structure for agricultural industries. The inputs to the agricultural industries in Pakistan include two petroleum products, electricity and one energy-intensive input; Chemical fertilizer. High speed diesel is used to run tractors and accessories. The consumption of high speed diesel depends on the stock of equipment, their usage and their fuel intensities. In the agricultural industries, the capital stock mainly represents tractors and accessories, hence, we allow substitution between high speed diesel and capital. The 'motor fuel–capital' input is a CES composite of these two inputs. Furthermore, our assumption is that

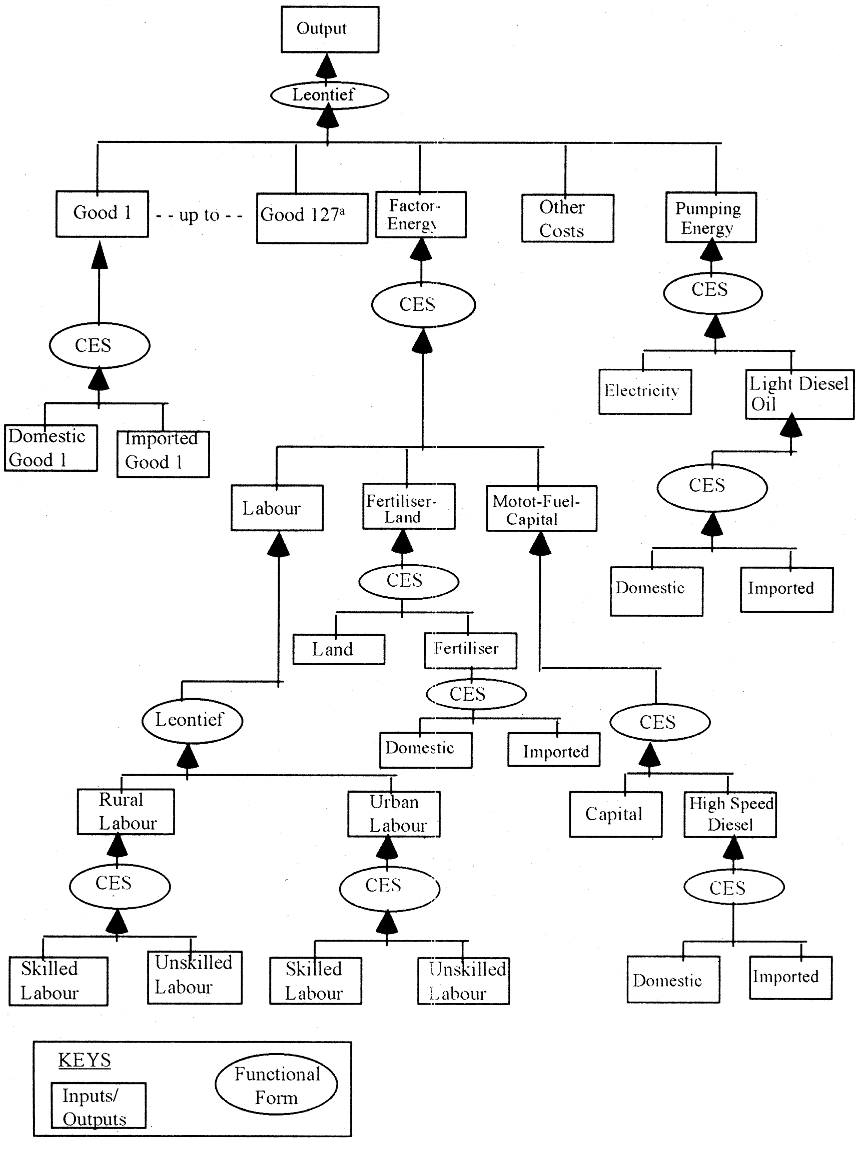
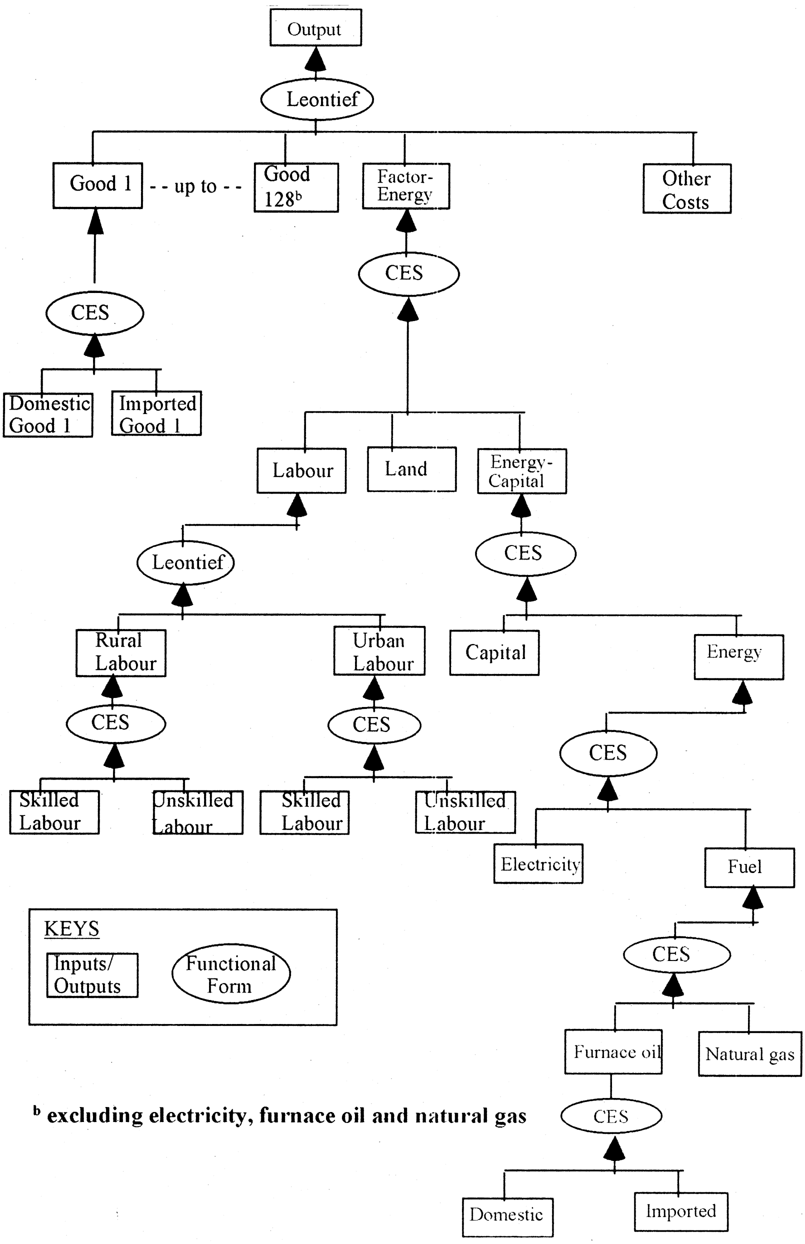


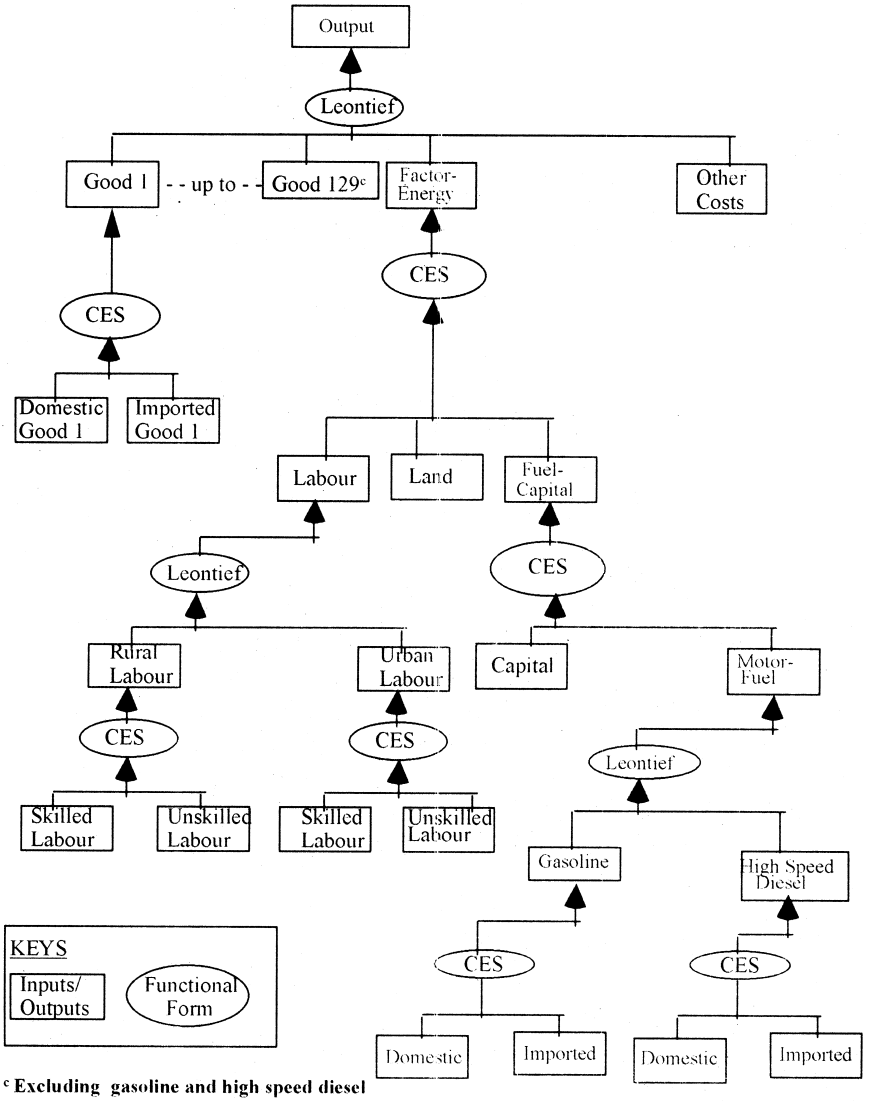
Fig. 5. Input structure for the agricultural industries.

fertilizer consumption is related to land use. The 'fertilizer–land' input is defined as a CES composite of land and fertilizer. As shown in Fig. 5, the composite inputs 'motor–fuel–capital', 'fertilizer–land' and 'effective labour' are assumed to be substitutes in a CES production function to form the 'factor–energy' input.



[b] **excluding electricity, furnace oil and natural gas**

Fig. 6. Input structure for mining, manufacturing and construction.



[c] **Excluding gasoline and high speed diesel**

Fig. 7. Input structure for the road transport industry.

Electricity and light diesel oil are used for water pumping. The model allows substitutions between these two inputs. The 'pumping energy' input is defined as a CES composite of electricity and light diesel oil. Riaz (1984) has estimated own and cross-price elasticities of coal, oil, natural gas and electricity for the services, manufacturing and agriculture sectors. According to his estimates, the only substitute of electricity is oil in the agricultural and services industries. In Riaz's study,

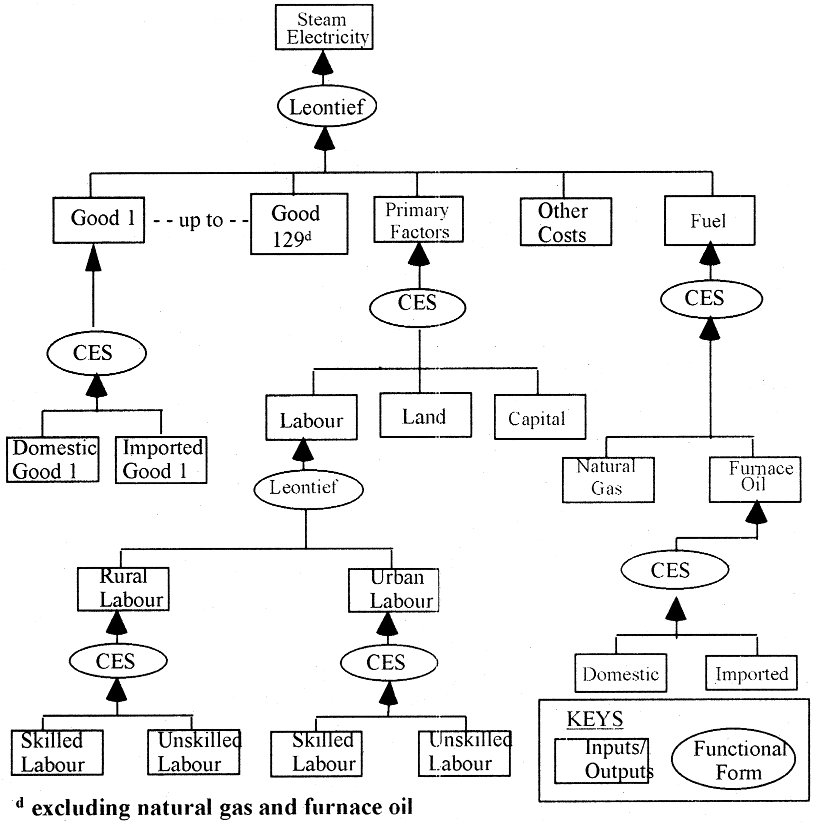


Fig. 8. Input structure for the steam electricity industry.

oil represents aggregated petroleum products. In view of the energy consumption pattern in the agricultural industries, electricity is most likely to be substituted for light diesel oil, which is used for the same operation.

In Fig. 5, the top-level nest shows that along with other intermediate inputs, the two energy composite inputs, 'energy–factor' and 'pumping energy', are determined in fixed proportion to the output level.

4.3.2. Input structure for the mining, manufacturing and construction industries

Fig. 6 shows the assumed input structure for the mining, manufacturing and construction industries. In these industries, natural gas, furnace oil and electricity are the major commercial energy inputs. Riaz (1984) estimates shows that furnace oil can be substituted only with natural gas in the manufacturing industries. As shown in Fig. 6, 'fuel' is defined as a CES composite of natural gas and furnace oil. The second nest shows that electricity is a substitute of the 'fuel' input. The

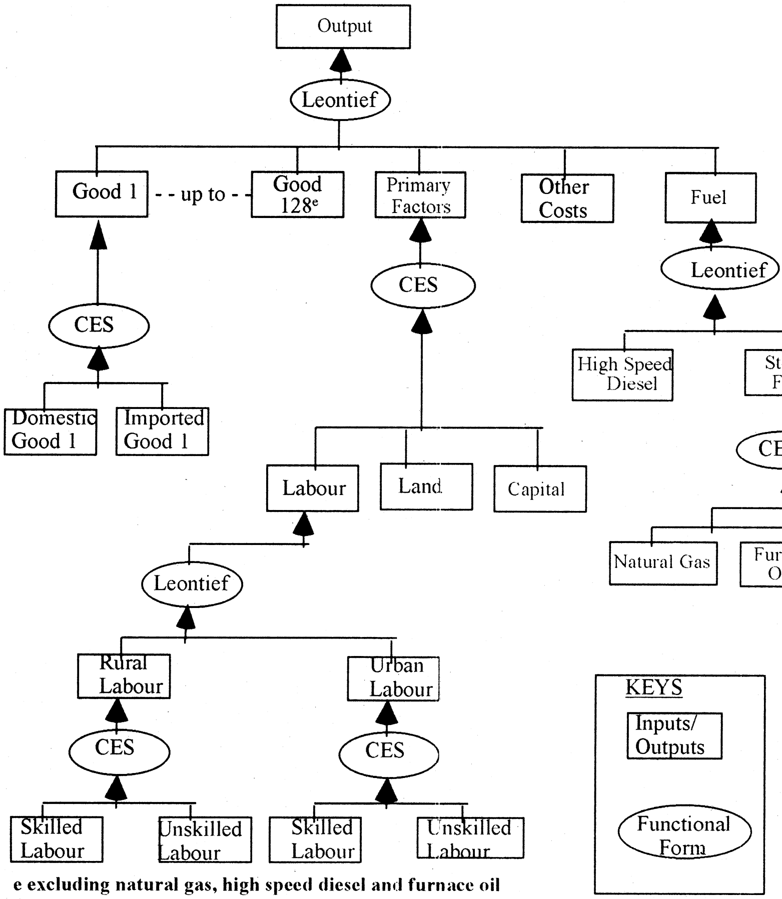


Fig. 9. Input structure for the combined cycle electricity industry.

'energy' input is a CES composition of electricity and 'fuel'. A CES production function of the 'energy' and capital forms the 'energy–capital' input. Labour, land and 'energy–capital' inputs constitute the 'factor–energy' input using a CES production function. The top level nest shows that the 'factor–energy' composite input is determined in a fixed proportion to the industry's output.

4.3.3. Input structure for the road transport industry

Fig. 7 shows the input structure for the road transport industry. Gasoline and high speed diesel are the two major fuels used in road transport. Gasoline is mainly used in taxicabs, while all other motor vehicles in public transport use high speed diesel [Khan et al. (1986) provides details of this consumption pattern]. For a given capital stock, the composition of the two fuels is fixed. As shown in Fig. 7, at the bottom level, a Leontief production function combines gasoline and high speed diesel to make 'motor fuel'. The 'fuel–capital' is then defined as the CES composite of 'motor fuel' and capital stock. The rest of the production structure resembles that for the manufacturing industries.

4.3.4. Input structure of the steam electricity industry

In our model, there are four electricity industries. This disaggregation is discussed in detail in Sec. 4.2. Here we discuss the input structure for the two electricity industries (combined cycle electricity and steam electricity) for which specific input patterns are defined. The input structures of the other two electricity industries resemble the structure given in Fig. 3.

Furnace oil and natural gas are the two major fuels used in steam electricity generation. In Pakistan, all steam plants have a dual-firing system and, therefore, the 'fuel' input is a CES composition of natural gas and furnace oil (see Fig. 8). It may be pointed out that electricity generation process is not composed of various small independent production processes as is the case with manufacturing industries. Hence, in the ex-post production technology, there is no substitution possibility between primary factors and energy inputs. Therefore, total fuel demand is determined in fixed proportion to the output level.

4.3.5. Input structure for the combined cycle electricity industry

Fig. 9 shows the pattern of energy substitutions for the combined cycle electricity industry. In this industry, natural gas and high speed diesel are the major fuels. A combined cycle plant consists of two steam plants and one gas turbine plant. Since steam plants can be operated on furnace oil or natural gas, we assume that 'steam fuel' is a CES composite of natural gas and furnace oil. At the middle level, a Leontief production function aggregates 'steam fuel' with high speed diesel. The latter is used by the gas turbine plant. The total 'fuel' input is assumed to be determined in fixed proportion to electricity output.

5. The base-year data and parameter values

To implement the model, we have selected 1983–1984 as the bench mark year as the most recent, comprehensive and consistent data set was available in the form of a social accounting matrix. It is a 273×273 matrix developed by Dhanani 1986a, Dhanani, 1986b) which was expanded and modified to build the data base for GE-PAK.

There are two major categories of the model's parameters: (1) elasticities of substitution in production functions; and (2) expenditure elasticities for multiple household groups. Ideally, all these elasticities should be estimated econometrically from cross-sectional and time series data. Given limited time and resources as well as data constraints, it was not possible to estimate all the elasticity parameters for this study. Therefore, it was decided to adopt plausible values based on the existing econometric studies for Pakistan and values assumed in CGE models for other developing countries.

Literature on estimates of elasticity of substitution between primary factors for many developed and developing countries is voluminous (Bandara, 1989). This literature suggests that time-series studies in most countries have produced sectoral estimates centred around 0.5. Almost all such studies for Pakistan have been carried out only for the manufacturing industries (Kazi et al., 1976; Kazmi, 1981; Kemal, 1981; Battese and Malik, 1987; Khan, 1989; Mahmood, 1990). Of these studies, only Khan (1989) has estimated a two-level nested CES function that allows substitution between capital and energy at the bottom level and between labour and an energy–capital composite at the top level. Khan's estimated substitution elasticity between capital and energy was 0.175, while the elasticity of substitution between the energy–capital composite and labour was 0.48. Considering this information, we assumed elasticities of substitution between primary factors or between a commodity–factors composite input and other factor to be 0.5, between a commodity and a primary factor to be 0.2 and between energy products to be 0.5.

A review of the literature on CGE models of other developing countries shows that assumed values for elasticities of substitution between imported and domestic goods fall in a wide range (see Vincent, 1986; Bandara, 1989; Dhanani, 1989; Clarete and Warr, 1992). In view of the nature of commodities imported in Pakistan, substitution possibilities between imported and domestic goods seemed to be low and we assumed their elasticity values to be 0.5 for all commodities.

Using 1984–1985 household survey data, Burney and Khan (1991) estimated marginal expenditure shares for urban and rural households in six income groups. These estimates were made for 12 groups of consumption items. We used average expenditure on items in each households group from the GE-PAK's data base and the corresponding expenditure elasticities from the survey to compute marginal expenditure shares for items by household type. We also computed the Frisch parameter for each household group using the functional relationship defined by Lluch et al. (1977) and per capita income by household group compiled by Ahmad and Ludlow (1988) from the survey data. The Atkinson's inequality parameter was set to 1 for the illustrative application (see Naqvi, 1995a,b for the application of the model using the welfare index).

Since export commodities of Pakistan have insignificant shares in the world market, elasticities for major exports have been assumed to be quite low and have assigned a value of -20.0 in line with the values assumed for other developing countries.

In the short-run simulations performed in this article, it has been assumed that investment in each industry is given exogenously and the capital stock in each industry is fixed. Hence, parameters related to investment allocation have no role to play in these simulations. The ratio of the gross to the net rate of return is still required to determine rates of return in industries. To implement the model, we have assumed a uniform value of 2.0 for all industries. The assumed value has no effects on the results except for the rates of returns.

6. Solution method and interpretation of results

Many of the model's equations are non-linear, however, following Dixon et al. (1982), GE-PAK is solved as a series of linear equations relating percentage changes in the model's variables. One advantage of the linearised system is its simplicity which reduces the data requirement for defining parameter values (see Horridge et al., 1993 for further details).

The linearised approach starts by assuming that we already possess some solution to the system. Normally, the initial solution is drawn from the base year data: we assume that our system of equations was true for this point in the past. The model generates the percentage change in the endogenously determined variables, showing how these variables would be affected in the short period in response to a given policy. The short-run period is being defined as a period long enough for the prices and quantities of all commodities and factors to adjust to the given shock, but sufficiently short that we can ignore changes in industry capital stock available for use in production. This period could be 2 years.

One limitation of this solution method is that the larger is the change in the exogenous variable the larger is the error margin. However, there are various techniques to minimise this error margin. The general-purpose economic modelling software (GEMPACK) used to solve the model offers a variety of such techniques (see GPD-1 to GPD-4, Impact Project, 1993a–d).

7. The effects of eliminating the import tax on high speed diesel — an illustrative application

The model has been applied to evaluate the energy pricing policy in Pakistan (Naqvi, 1995b). Here, we present the results of one of the simulations from that application as an illustrative example. In this application, we simulate the short-run effects of removing import tax on high speed diesel (referred to as SIM1) as the adjustment costs of such reform is generally perceived to be high in the short term. It is assumed that industry-specific capital stocks are fixed. Supplies of labour from households by profession and income groups are fixed, implying that the choice between leisure and work remains unchanged. However, the labour is mobile across industries and region. Real government spending and real investments by industries are also fixed. The average propensity to consume for each of the 14 types of household is fixed implying that choice between consumption and savings remains unaffected. The nominal exchange rate is fixed and acts as the numeraire. All the regulated prices are also determined endogenously to analyse the full effects of the reform. Export quantities are held fixed at the base year level for all but 13 commodities. We assume that the export demand curves for the 13 commodities are downward sloping and their export quantities are determined endogenously.

Since all other tax rates (direct or indirect) are exogenously held fixed, the change in the import tax on high speed diesel reallocates income from the public budget to private consumption. Hence, the results of SIM1 are the combined effects of changes in the tax on high speed diesel and private consumption. We analyse these two effects separately to understand their combined net effects. To disaggregate the two effects, we simulate the model using the SIM1 closure but assume that real consumption for each household group is fixed (we refer to this as Case 1 of SIM1). These results are reported in column 1 of Table 2. Results of Case 1 show a decline in average propensities to consume for 14 types of households. The model defines a consumption function for each household group. With fixed real consumption, any increase in the real income is offset by the decline in the average propensity to consume. In Case 2 we modify the SIM1 closure to increase the real consumption of household by the same extent without removing the tax on high speed diesel. These results are reported in column 2 of Table 2. This disaggregation allows us to see the effects on the economy solely induced by the decline in the price of high speed diesel relative to other commodities. Thus, Case 1 captures the direct effects which are specific to the price of high speed diesel. As it can be seen from the results of the two cases that the impact of the two phenomena, i.e. reduction in a commodity price and increase in the private consumption have different impacts on the economy. In the next few paragraphs, we analyse the results of Cases 1 and 2 before discussing the combined effects given in the SIM1 results reported in column 3 of Table 2.

7.1. Effects of removing import tax on high speed diesel with fixed real consumption

The purchaser price of high speed diesel falls by 3.2% when the import tax on it is eliminated. A large share of high speed diesel (approx. 80%) is used as an intermediate input to two margin goods industries; the Road transport and Rail transport industries. The fall in the purchaser price of high speed diesel reduces the production cost of these margin goods and, as a result, reduces the purchaser prices of all commodities. This leads to reductions in domestic costs of production. Exports expand because, with their selling prices determined in world markets, exporters enjoy a cost-price improvement. Import-competing industries also become more competitive and expand. Some of the non-traded goods industries which supply intermediate inputs to these traded-goods industries, such as some agricultural and electricity industries also expand. The balance of trade improves and so does the real GDP as the domestic absorption is fixed. There is an expansion in labour demand from the traded goods industries which results into high real wages for all four types of labour.

In Table 2, the sectoral effects are the weighted-average of the effects on industries in that sector. The weights are the shares of the value added of the industries in the total value added of the sector they belong to in the base year.

The effects on sectoral output show that the increase in output of the traded goods industries from the large-scale manufacturing sector is smaller than the increase in output of small-scale industries sector. This is caused by the difference in energy consumption pattern of the industries. The industries in the small-scale manufacturing sector are all non-traded except the Rice-husking industry. In this

Table 2
Effects of removing import tax on high speed diesel in SIM1 (percentage changes)

	(1) Removal of the import tax with fixed real consumption Case 1	(2) Exogenous change in real consumption Case 2	(3) Total effects in SIM1
Real GDP	0.01	0.01	0.02
Real private consumption	0.00	0.13	0.13
Trade balance[a]	0.03	−0.37	−0.34
Indirect tax revenue	−0.79	0.10	−0.69
CPI	−0.10	0.39	0.29
GDP deflator	−0.09	0.42	0.33
Real wages			
Rural-skilled	0.05	0.18	0.23
Urban-skilled	0.02	0.21	0.23
Rural-unskilled	0.17	0.03	0.20
Urban-unskilled	0.11	0.03	0.14
Sectoral output			
Agriculture	0.03	−0.01	0.02
Oil and gas	0.00	−0.01	−0.01
Large-scale manufacturing[b]	0.02	−0.06	−0.04
Small-scale manufacturing	0.03	0.03	0.06
Services and construction	0.03	0.02	0.05
Fertiliser	0.09	−0.05	0.04
Refinery	−0.15	−0.01	−0.16
Cement	−0.00	0.0	0.00
Natural gas	0.02	−0.01	0.01
Electricity	0.04	−0.06	−0.02

[a] Rs billion.
[b] Including coal and other mineral industries and excluding the fertilizer, refinery and cement industries.

industry electricity intensity is higher than that in other export industries of the large-scale manufacturing sector, which have a higher demand for furnace oil. Our results on energy prices show that the increase in electricity price is smaller than the increase in furnace oil price. The production structure of the manufacturing industries allows substitution between furnace oil and electricity. Due to the higher share of electricity in its energy demand, there is a bigger substitution of electricity with furnace oil in the small-scale Rice-husking industry compared to that in other large-scale manufacturing industries. Thus the export industry in the small-scale manufacturing sector enjoys a bigger decline in its production costs. The increase in output of the Rice-husking industry outweighs the decline in output of other non-traded goods in the sector and consequently the sectoral output rises.

Real wages for producers (nominal wages deflated by the aggregate CPI) rise for all four types of labour. The increase in real wages for unskilled labour is, however, higher relative to the real wage of skilled labour. This is explained by the employment pattern of labour in the industries. In the base year, the unskilled labour has a big share in the labour demand from traded-goods industries, while most of the non-traded-goods industries employ a balanced mix of the four types of labour. Expansion in the traded- and some of the non-traded-goods industries increases the demand for unskilled labour. Consequently, the nominal and real wages of unskilled labours rise. Contrary to this, contractions in most of the non-traded goods industries reduce the demand for skilled labour and their nominal wages decline. Nevertheless, there is a small increase in their real wages due to a bigger decline in the CPI relative to that in their nominal wages.

7.2. Effects of increase in real consumption

Our results from Case 1 show that average propensities to consume for 14 types of household decline by 0.02–0.15%, when we remove the import tax on high speed diesel with fixed real consumption. Conversely, it implies that this tax reform increases real income of the households by between 0.02 and 0.15%. We use these values to shock real consumption of 14 types of household in Case 2 of SIM1 to compute the effects generated by the increase in real consumption in SIM1. In the short run, an expansion in domestic absorption has the following effects (see column 2 in Table 2).

- Overall consumer prices and nominal wages increase. The increase in nominal wages is bigger than the increase in consumer prices as the latter are a weighted average of prices of domestic and imported goods.
- Production in most of the non-traded goods industries increases; especially in those industries which sell largely to private consumers.
- The expansion in domestic production increases the basic prices of domestically produced goods. This reduces exports and increases imports as import-competing and export industries become less competitive. The trade balance declines by Rs 0.37 billions.
- Structure of labour demand changes due to expansion in the non-traded-goods industries and the contraction of the traded-goods industries. The demand for skilled labour increases more than that for unskilled labour. As a result, increase in the real wage of skilled labour is bigger than that of unskilled labour.
- The contractions in the traded goods industries are shown by the decline in output of the large-scale manufacturing sector. The small-scale manufacturing and services sectors expand as the expansion of non-traded goods industries in these sectors outweighs the decline in output of the traded goods industries in these sectors.

7.3. Total effects of eliminating import tax on high speed diesel-SIM1

Column 3 in Table 2 shows the net effect of the two phenomena:

- the reduction in the import tax on diesel; and
- the resulting increase in real private consumption.

The increase in real consumption in Case 2 reverses some of the Case 1 effects, such as the improvement in the trade balance and the decline in domestic prices. However, the increase in real private consumption outweighs the decline in the balance of trade. The net effects are a 0.02% increase in real GDP. The real wages for all four types of labour increase in both cases, but to different extents. The total effect is a bigger increase in the real wage of skilled labour relative to unskilled labour in both urban and rural regions. This is explained by the difference in the sectoral composition of GDP in the two cases (see Columns 1 and 2 in Table 2). The results on sectoral output show that most of the non-traded goods industries expand in both the cases, while export and import-competing industries expand only in the first case; where real household consumption is fixed. The net effects are an increase in output of non-traded goods industries and a decline in output of traded-goods industries. This causes a bigger increase in the demand for skilled labour relative to unskilled labour.

The difference in real wages of unskilled labour in the two regions is due to their employment patterns. In the base-year, the traded goods industries of the large-scale manufacturing sector mainly employ urban-unskilled labour. The demand for this labour increases from the expanding non-trading goods industries, but they also face reduction in their demand from the traded goods industries. The rural-unskilled labours are mainly employed in the agriculture sector, which supply inputs to the non-traded and traded goods industries. The rural-unskilled labours enjoy an increase in the demand from these agricultural industries which switch from supplying inputs to the export industries to the non-traded goods industries.

Though total labour supply is fixed by profession, the labour supply function in a region is upward sloping for each profession. A change in relative real wages for a profession between two regions induces migration of labour to the region with higher real wage. Our labour migration results show that there is no inter-region migration of skilled labour, implying that the demand for them increases to the same extent in the two regions. For unskilled labour, we observe an increase of 0.01% in rural employment and a decline of 0.01 in urban employment. Changes in sectoral composition of GDP in this simulation favour demand for rural-unskilled labour more than urban-unskilled labour. A relatively lower increase in the demand for urban-unskilled labour creates a difference between real wages of unskilled labour in the two regions. As a result unskilled labour migrates from urban to the rural region. An upward shift in the supply of unskilled labour increases their wages with a small decline in the employment of urban skilled. On the other hand, this migration improves the supply of unskilled labour in the rural region, which reduces the upward pressure on their prices and increases the employment of unskilled labour in the region.

With real government expenditure fixed, reduction of tax revenue by one base-period dollar increases the government deficit by $1 and increases household incomes by the same amount. With fixed propensities to save, household savings increase by less than \$1. Since real investment is fixed, the gap between domestic savings and investments increases. This gap is filled by the deterioration of Rs 0.34 billion in the trade balance.

Table 2 reports real GDP at market price. The small increase in real GDP is explained by changes in its industry composition, since the supply of primary factors and technology is held fixed. The detailed results show that industry composition of GDP changes in favour of high-tax commodities. Thus, resources initially used in production of low-tax commodities now produce commodities which have higher worth in the market.

7.4. Distributional effects in SIM1

All the household groups enjoy an increase in real per capita consumption between 0.04 and 0.19%, when we remove import tax on high speed diesel (Column 1 of Table 3). The two urban low-income groups and the two rural high-income groups experience the smallest increase in their consumption in their respective regions. Variations are caused by the differences in the pattern of consumption and sources of income between household groups. In both regions, the highest increase in real per capita consumption is enjoyed by the middle-income group in the employed category. These groups own skilled and unskilled labour. Due to a bigger increase in real wages of skilled labour, income increases relatively more than their consumer price indices.

8. Conclusion

The objective of this article was to present a model of energy–economy interaction which also incorporates the trade theory and the issue of social welfare. The role of international trade and social welfare are the key factors in the economic policy of a developing country. Moreover, most developing countries have a poor energy-resource base and they rely on imported energy. A rapidly growing energy demand for their development makes energy a vital part of their economic planning. Implementation of such a CGE model, that incorporates all these aspects of developing economies, will help the planners and policy makers of these countries.

Acknowledgements

This article is based on my Ph.D thesis submitted to the University of Sydney in 1994. I am extremely grateful to my Ph.D supervisors, Dr. Mark Horridge and Prof. Peter B Dixon for their advice, comments and guidance. I also wish to thank an anonymous referee for his or her valuable comments on this article.

Table 3
Effects on real per capita consumption in SIM1

Household categories	Percentage change
Self-employed	
Rural-low-income	0.15
Urban-low-income	0.06
Rural-middle-income	0.10
Urban-middle-income	0.10
Rural-high-income	0.04
Urban-high-income	0.16
Employed	
Rural-low-income	0.15
Urban-low-income	0.06
Rural-middle-income	0.17
Urban-middle-income	0.19
Rural-high-income	0.03
Urban-high-income	0.17
Others	
Rural	0.10
Urban	0.14

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