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Integrated Environmental-Economic Model of China

A paper for initial discussion

Statistics Norway

Statistisk sentralbyrå

Preface

This paper is memorizing some initial thoughts about the upcoming process of developing an integrated environmental economic model in State Statistical Bureau of The People's Republic of China. The topics dealt with partly reflect a need to become familiar with statistical data and definitions, partly a wish to associate the economic and environmental scenary of China with some relevant modeling options.

Statistiscs Norway is acting as advicor to this task, which is part of a program for assistance to environmental statistics and analysis agreed upon by The Norwegian Agency for Development Coop (NORAD) and State Environmental Protection Administration (SEPA).

1. Introduction

As part of a program for assistance to environmental statistics and analysis in China agreed upon by Norwegian Agency for Development Cooperation (NORAD) and National Environmental Protection Agency (NEPA), Statistics Norway (SN) will support State Statistical Bureau, Peoples Republic of China in the development of analytical tools for integrated environmental economic analysis. This work will rely heavily on a description of energy flows through the economy. In the initial phase of the project, an energy account and an air pollution emission inventory will be established. These accounts will - in combination with a suitable economic model- facilitate projections of energy consumption, emissions and air pollution levels.

Total commercial energy use in China amounts to about 1240 million tons of coal equivalents per year, of which coal represented 78 percent in 1995. This means that China's coal consumption amounts to roughly 80 percent of total coal consumption in the whole OECD area (OECD/IEA, 1996). With an expected economic growth of about 7 percent a year over the next couple of decades, the energy demand will also tend to increase, even though high investments and new technology will allow for improved energy efficiencies and less pollution per unit of GDP. Energy intensity (energy use per unit of GDP) has fallen by 50 percent since 1980 (4.5 percent a year), while total energy use has more than doubled. A main purpose of the energy-environmental economic modeling as part of this cooperation between State Statistical Bureau (SSB) and Statistics Norway (SN) is to create a basis for systematic and consistent analysis of various - and to some extent contradictory - forces affecting the energy consumption in the future.

Energy, and in particular coal consumption, is a main determinant of air pollution, which is a significant problem in China. The annual environmental costs associated with energy use are calculated to be 3-4 percent of GDP if estimated through the human capital approach. Health costs constitute a dominant share, and particulate matter from combustion is a major source of damage (World Bank, 1997).

Energy is certainly not only a «bad», but also a «good» in relation to economic growth and increased welfare. However, China's energy endowments are well below (28% of) world average per capita, while energy use per unit GDP ranks among the highest in an international context (World Bank, 1997) This raises serious energy conservation concerns and highlights the relevance of models which can be utilized to analyze energy demand and supply in explicit consistency with economic growth.

This paper presents some ideas and suggestions for development of a model framework suitable for analysis of energy consumption and environmental impacts in close relation to economic development. In this paper, the topic is mainly limited to the question of how a suitable economic model for this purpose might look like. This is discussed around a simple model example which basically reflect to I-0 modeling which is carried out today. A key issue is how to make energy production, transformation and deliveries to intermediate and final consumption sufficiently explicit in the model structure and in the priorities of relevant economic agents.

In the following, section 2 briefly refers to some Norwegian experience and general milestones in development of integrated energy-economy models at the macro level. Then main elements in such a model is illustrated in section 3, while a simple formal model to depart from is described in section 4. Section 5 initiates the research on data requirements and availabilities. In section 6 some more general concerns about model relevans are commented on to prepare a discussion for future model development beyond a first very simple approach.

The purpose of this paper is to bring SSB and SN towards joint perceptions of problems and options concerning initial attempts at and future development of an integrated economy-energy-environment model for China.

2. Model background

During the last couple of decades, the industrialized countries have made considerable efforts to model energy demand and supply due to the dependence upon energy in their economies. Increasingly, the modeling of energy markets have been incorporated in macroeconomic models to capture the thorough interaction between energy use and economic growth.

In Norway, the energy flows were incorporated in the macroeconomic planning model used by The Ministry of Finance in the early eighties (Bjerkholt et al. (eds) 1983). There were two main objectives behind this modeling effort. One objective was to improve forecasts of demand for hydro-electricity by securing consistency between forecasted economic growth and energy demand. Hydropower is a dominant source of energy for stationary purposes in Norway. The long planning and construction phase in mostly state owned hydropower plant strengthened public demand for reliable forecasts. The other objective concerned the impacts on the economy of oil price fluctuations like those imposed by OPEC policies, which concerned Norway both as an oil exporting and oil consuming economy. To assess their impacts, expenditure on energy goods, energy substitutes and flexibility in switching between these goods had to be dealt with explicitly in economic analysis.

From the mid eighties, the environmental concerns associated with air pollution from fuel combustion gained importance, and emission modules were added to the model framework to overlook the implementation of national policies and international protocols on abatement of local and regional air pollutants. In Norway, emission modules were developed by Statistics Norway in cooperation with the Norwegian Pollution Control Authorities. Currently the emission model is operated by the Ministry of Finance for analysis of economic policies where the impact of environment is of significant concern. The economic core model has later been further developed to improve description of energy use for transportation, and of the markets for electricity production and distribution that has been deregulated in 1991 (Alfsen, Bye and Holmøy (eds.) !996).

For the US, similar model tools were developed, and refined to reflect genuine dynamic considerations. A genuine dynamic or intertemporal model takes into account future implications of acting today (for instance saving) and the impact on current decisions from alternative future circumstances or policies. Important environmental trade-offs relates to the level of the interest rate/ discount rate. Low discount rate makes future environmental damage costly to the society, but at the same time keeps capital costs low, making investments and economic growth that generate pollution more attractive. Jorgensen and Wilcoxen (1990a, 1990b, 1992) utilized an intertemporal model to assess the economic costs of emissions reductions implemented through either regulations, which historically has dominated pollution control in the US, or fuel taxes.

Industrialized countries have developed quite detailed emission inventories and created a basis for a variety of environmental analysis related to energy use. More recently, integrated economy-energy-environment models with feedback from environmental quality to economic productivity and public expenditures are developed for Norway (Rosendahl (ed).1998).

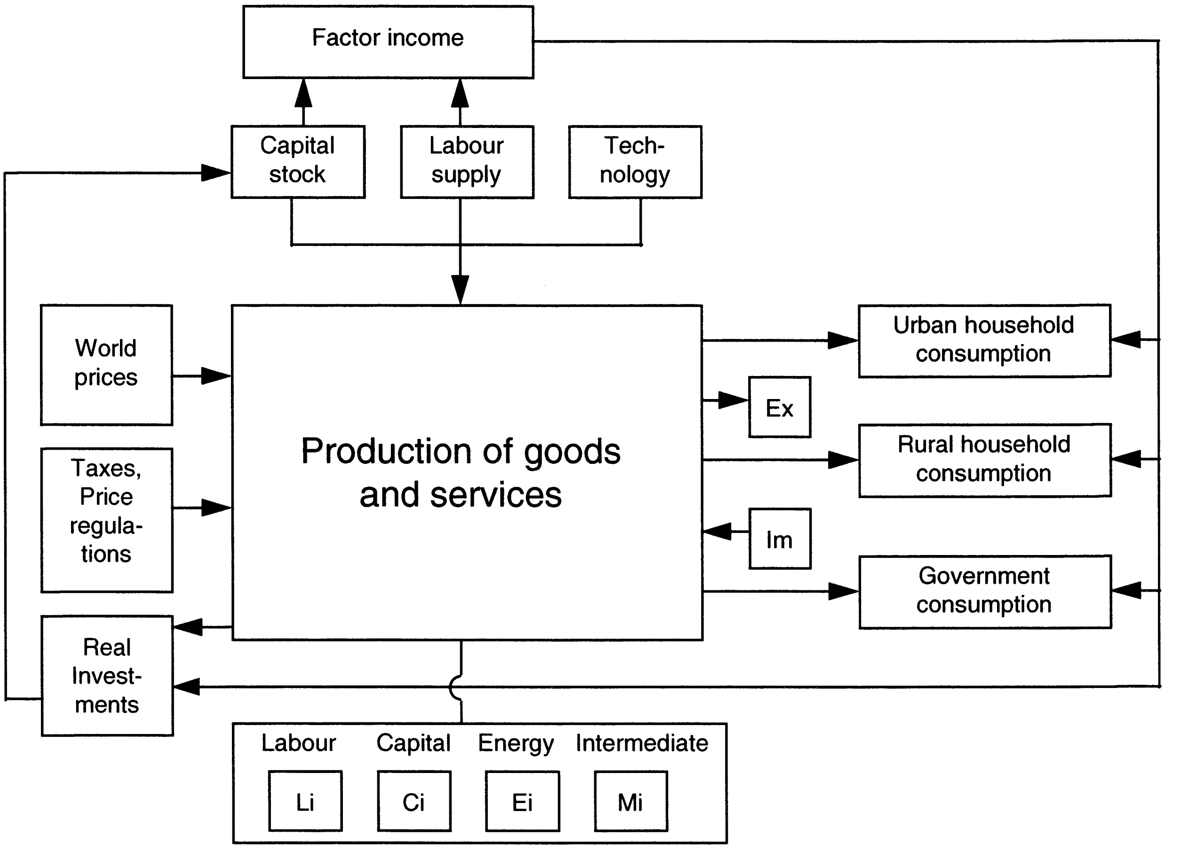
The energy flows and CO_2 emissions in the Chinese economy has more recently been incorporated in a CGE model of China (Zhang, 1996) which is used for further economy-energy-environment analysis of energy policies (Zhang, 1998). The model covers the production and consumption of coal, oil, natural gas and electricity.

The model of Zhang has an experimental character in the sense that some of the data are compiled somewhat ad hoc and not developed in explict relation to the national accounts. Within this project, the aim is to establish a core model for energy-environmental analysis in China which is generated, documented and can be routinely updated from the national account statistics , the energy accounts and emission inventory. Below we look into some basic model relations before turning to more technical aspects of model building.

3. Sketch of a core model

Like in the real economy, the model must contain decision makers like households, enterprises and government sector. In this context we think of two kinds of households:urban and rural. Further, there are 33 representative "enterprises" corresponding to to the sector definitions of the 1995 Input Output Matrix of the national Accounts. Finally, there is one single public sector (government). Between these decision makers (or institutions) goods, services and payments keep flowing. To facilitate discussion of data demand and basic assumptions behind a simple formal model framework, we first take a bird's view at the activities in a model economy, as illustrated in figure 1.

Figure 1. Sketch of core model



The economy as a whole has endowments of capital, labour and technolgy. These resources merge into the production sphere under condition associated with domestic regulations and plans, taxes and world market prices. Final output (net of intermediate deliveries) is consumed by households and government, or invested (ignoring foreign trade for a moment). Net investments add to the capital stock and raises the (future) capacity to generate output.

Flows of goods are met by payments which leave a operative surplus in enterprises (sectors) as factor income i.e. income generated by the use of labour and capital. This is allocated to wages as compensation to households for providing the labour . Operating surplus or capital income is allocated to the enterprise owner (households or government). The government share of operating surplus consists of taxes in addition to operating surplus in state owned enterprises (SOEs).

The center of the diagram is the production sphere, where allocation of productive resources to public and private enterprises is taking place. As a result of sector priorities, corresponding to their respective objective function, each sector (i) determines the optimal combination of the input factors. To present the structure of input demand in a simple, but operational way, the input goods and services are usually aggregated, conventionally to Labour, Capital, Energy and interMediates (Materials) (L,C,E,M). These input factors are subsets of several individual products (single sector outputs), and the composition within each aggregate will differ between consuming sectors. For instance, the energy input in heavy industries will basically be a combination dominated by coal varieties, while energy input in transportation will consist of various liquid fuels and coal etc. Hence, it is important to specify different energy carriers as sector output to be able to follow their "individual" path into the various sectors' energy aggregates. Labour is usually dealt with as a single, homogenous input factor.

In principle, there could be different qualities of labour (education, experience), but lack of data usually precludes this option.

Energy products sometimes enter the production as elements of the intermediates aggregate (M) because they serve as raw materials (feedstock). This use to be the case with coal and coke in metallurgic industry. There are two reasons for distinguishing between energy goods used for combustion and energy as raw material. One is that the substitution possibilities may differ significantly in those two cases. Use of energy as a raw material may be more tied up to the output level, while energy for combustion can more easily be replaced by other types of energy or subject to efficiency improving measures. The other reason relates to the fact that the environmental effects may differ significantly between those two purposes of energy use. The energy account will (strive to) distinguish between energy goods used as raw materials and for energy generating purpose.

National Account (NA) input-output data show the outcome of priorities concerning input factor use by sectors in the *base year*. In a modeling context, the question arises how to describe input factor demand of an industry in the future when the framework conditions differ from those in the base year. Framework conditions relate to domestic and foreign market prices, taxes and policy regulations.

An NA production sector is an aggregate of single enterprises which all seek to fulfill their objectives. If these enterprises have widely different objective functions, assuming uniform aggregate behavior in the model might be misleading. Being in the process of transition from a centrally planned to a socialist market economy, China has both market oriented enterprises which maximize generated income and State Owned Enterprises (SOEs) which incorporate social criteria in addition to income in their objective function: Among the first, price changes may affect the choice of input factors significantly, while SOEs stick to the factor shadow prices (shortage indication) implicitly determinated by the 5 Year Plan and unaffected (in the short term) by changing market prices. The production based on market incentives should ideally be described as price sensitive, while fixed (exogenous) technology would be more relevant in the planned sector.

The transition process has already come quite far, however, and price sensitive producer behaviour seems to be valid as a general characteristic. Currently, about 90 percent of production is market based (Wei, 1998; Colin Xu, 1998). However, this share is not uniform among sectors, and the share tends to be lower in heavy industries (like steel production), which generally are quite energy intensive. For simplicity, it can be useful to assume fixed input technology in an initial in phase It should be realized, though, that this ignores both the possibilities for single enterprises to substitute input factors, as well as potential shifts in sector mix of enterprises with different objective functions.

The activity of the production sphere is contingent upon access to capital, labour and technology, which constitute the long term capacity constraints for the economy. Technological change is of particular interest to forecasting as it rises the productivity of labour and invested capital. Technological change can result from better organization and human control of process or be embedded in particular equipment or machines. An example of the former is the potential for energy saving from better management of available boilers, while embedded technological growth is taking place when new and more efficient boilers are installed.

In a modeling context, the technology factor can be incorporated as an exogenous growth rate of productivity, based on historical trends and adjusted for expected future policies or shocks that might affect technological improvements. The rate of technological growth is sometimes modeled as a factor neutral parameter shifting the amount of output generated by a given factor input combination upwards over time. In other cases a rate of efficiency improvement is linked to a specific input factor.

Supply of labour can be modeled as determined by the population growth and fixed in the model (as done by Zhang, 1996). Alternatively, under a short to medium term time horizon one may assume that labour is not a limiting factor and let total demand for labour in production sectors determine the level of employment, assuming that the labour force somehow is rationed with respect to work opportunities and ready to take employment if demand for labour is increasing.

In industrialized economies, the labourer's decision of allocating time between work and leisure is partically de-linked from the question of subsistence. Hence, the level of real wages and prices might more easily influence the preferred amount of work. An endogenous supply of labour like modeled in Bye (1996) reflects this situation in materialisticly more matured economies. However, for China, in spite of rapid economic growth, it may be realistic to assume that the supply of labour is closely related to population growth, and not very sensitive to income and wage increases for still many years to come.

A particular feature of the labour market in China has been the urban employment guaranty and strict regulation of rural-urban migration. This should be kept in mind when interpreting model output if a single wage is used in all production sectors as a simplification.

The cost constraints for incentive based production are more or less strict dependent on the available stock of the basic input factors labour and capital. Further, government policies through taxes and price regulations set conditions for market oriented production activities. World market prices will generally also affect the productions costs and potential for exports. The exchange rate is a policy variable which affect the cost of imports and income from exports.

Produced final output is consumed domestically, exported or invested to expand the stock of production capital.

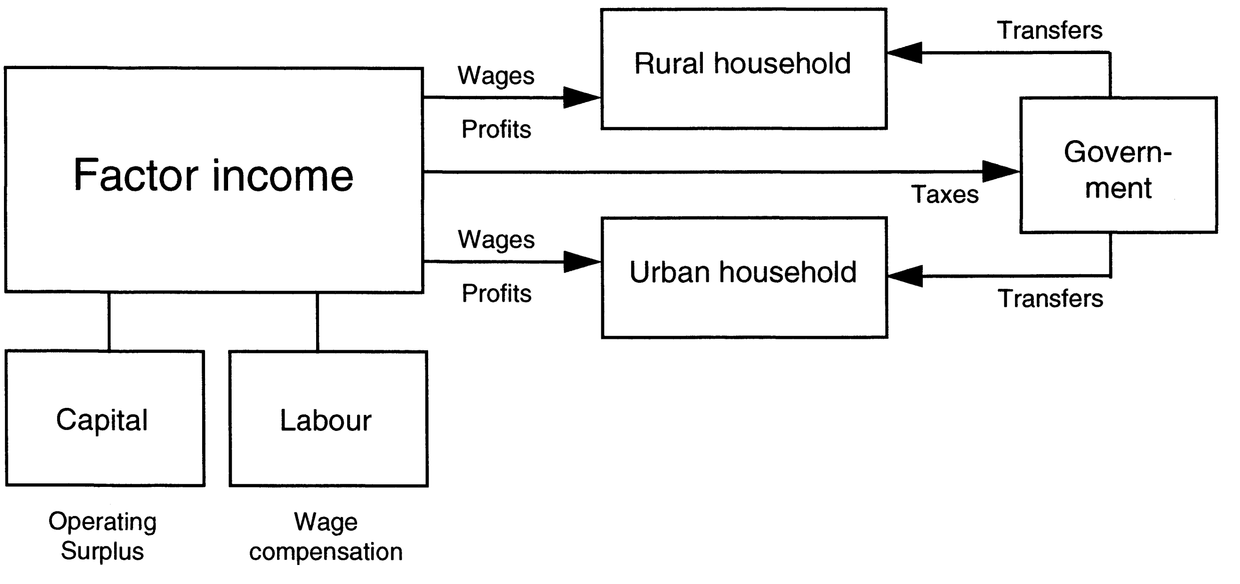
When describing household consumption, it will clearly be useful to deal separately with urban and rural households. The reason is that urban and rural populations have different consumption patterns, and rely on different sources of income. Hence, distribution of income growth between rural and urban areas might affect pattern of demand, including energy demand, significantly.

The allocation of real resources will be reflected in income flows between enterprises, households and governments. The total value added in the economy is distributed as wage income, taxes and operating surplus after tax. When distinguishing between different consumer groups, like urban and rural households, the financial flows have to be equally detailed (figure 2).

Household income consists of wage income, a share of surplus from production activities and transfers (from government). The government receives tax revenue plus a share of operating surplus. At the expenditure side the government transfers income to households. Transfers to households might be in goods (food, housing, health care etc.) or cash. It is important to distinguish between genuin social transfers (in goods) and goods as part of remuneration to workers in state owned enterprises. A system of employment related benefits is common in cities, but not in rural areas.

The intermediates made available for SOEs as part of the economic plan are not defined as transfers, but accounted as costs in the production sectors.

Figure 2. Aggregate flows of income and transfers



4. A simple formal model

A modeling effort might start up with a straight forward approach based upon the I-O matrix and the description of main income flows between economic decision makers corresponding to their provisions of goods and labour.

The model set of equations presented below has a multiple sector production system, and the technology in each sector is characterized by fixed input coefficients as in the I-O matrix:

1) $L_i = l_i X_i$

2) $K_i = k_i X_i$

3) $XC_i = XD_i + M_i$

4) $m_i = M_i \,/\, (M_i + XD_i) = M_i \,/\, XC_i$

5) $XC_i = \sum_j a_{ij} X_j + C_i + J_i + G_i$

6) $X_i = XD_i + E_i$

7) $VA_i = \alpha_i X_i$

8) $C_i = b_i (1 - s) \sum VA_i$

9) $J_i = c_i \left[s \cdot (\sum_i VA_i + \sum_i \ (M_i - E_i) \right]$

10) $K_i = K^0{}_i (1 - \delta_i) + J_i$

11) $G_i = \overline{G_i}$

Equations 1-11 represent 11 (times i) equations to solve for the 11 (times i) variables XC, X, XD, K, L, C, J, G, E, M, VA

The index i (j) relates to any single sector/good among the 33 sectors/goods in the 1995 I-O matrix and will be omitted in comments for convenience.

Labour (L) and capital (K) are proportional to output X in every sector as indicated by equations 1 and 2. We assume in the following that capital by sector (K) is the growth limiting factor. The growth of the capital stock is determined in the model. As for equation 1, it only determines the use of labour by sector, after the capital stock and output level by sector has been determined. Total demand of labour is here regarded as completely adaptive. However, there must be consistency in the sense that total use of labour in the economy must be less or equal to the total labour force.

The amount of each good available for domestic final use (XC) is defined in eq. 3 as the sum of domestic produce sold at the domestic market (XD) plus the imported variety of the same type of good (M). We can think of XC as a composite good where imported and domestic produced contributions to supply are homogenous. Hence, the domestic market is indifferent to whether an extra unit provided is imported or home made. However, the import share m_i (equation 4) in this mixed supply is assumed to be constant, or a policy variable like with case ??? foreign trade regulations (import licensing).
Equation 5 states how total absorption XC of a good is used as intermediates in fixed proportions to receiving sectors' outputs, consumption by households (C)), gross investments (J) and government consumption (G). This equation balances the market of each good or service available to domestic final use.

The domestic production (eq.6) is partly sold at the domestic market and partly exported.

Value added (net of taxes) by sector is assumed to be a constant share of sector output in eq. 7. Private consumption of each good is proportional to income (value added) less saving. The saving rate is exogenous.(eq. 8)

Value added net of taxes (VA) is proportional to output. Total value added is allocated to private consumption and gross investments (private and public). There is a uniform general saving rate for all disposable income.

Gross investment is determined by domestic and foreign saving, the latter equal to the import surplus. (eq.9) Capital (K) is given by initial stock plus gross investments less depreciation (eq.10).

Finally, equations 11 says that the level and composition of government consumption is exogenously determined.

The use of labour, capital and intermediates is proportional to output in each sector. With this fixed technology there are no opportunities for enterprises to switch to a different combination of input factors and in particular not to less energy intensive production methods. It is important to notice, however, that by distinguishing between a number of production activities (sectors) the model will capture structural changes, i.e. changes in relative magnitude between sectors caused by changes in composition of aggregate demand. In this way, the technology on *macro* level is not fixed, but sensitive to policies and changing consumer preferences in the growth process, even though single industries' production technology is assumed to be totally rigid.

Gross investment equals domestic and foreign saving (total import surplus) and is allocated to single sectors in fixed shares, for instance according to the distribution pattern in the base year directly or adjusted for expected reorientation of the growth pattern. Gross sector investments less deprectation of initial capital stock determines the level of capital available for production in the current period.

Interpretations

The model ignores prices at this stage, as they are somehow assumed to be stable supporters of the existing fixed technology and distribution rules. A model like this which is based on fixed I-O coefficients (Leontief technology) is suitable for analysis when resources of the economy are not fully utilized and changes in policy variables are not expected to generate bottlenecks and affect relative prices of consumer goods and input factors significantly. Except under influence of special shocks, the fixed technology assumption can serve well for short and medium term analysis. The time horizon of the analysis may be prolongued by adjusting the fixed parameters to take certain development trends and policies into account. It still is useful to operate the model, since it ensures considerable consistency. A precondition is that the assumptions are made explicitly and documented.

Investments are determined by (domestic) private sector saving and foreign saving. We could have defined a share of exogenous public expenditure as invesments (in productive capital) to make explicit the importance of political action to capital accumulation and growth. It is important to that in a "real" economy somehow must mobilized the savings necessary to finance these investments. The mechanisms for doing this can differ between systems and depend upon changes in income distribution between household categories to various degrees. In some cases, the relative prices of goods and labour works as the means to redistribute income to generate the necessary profit and associated high saving (see Taylor et al. 1980). In economies with well functioning government sector, taxes can be targeted to provide the necessary funds for investments with less unfortunate impacts on income distribution between labour and capital.

Public consumption is politically determined (exogenous), and represents an active source of change in the system. The import share (m_i) might also be seen as a policy variable related to the regulation of import license and access to foreign currency. Government policy is further seen behind the allocation of income to private sector and in the saving rate which at the aggregate level clearly depends upon distribution of income between classes.

The underlying mechanism figures exports as the residual variable of the system, while private consumption and investments are linked up to income generation and saving propensity. The export markets may obviously be less flexible than is assumed here. We might rearrange the picture by assuming that exports are exogenously determined $E_i = \overline{E}_i$ import shares flexible, and let the household consumption be residual. It is important to notice that the result of a model analysis generally depends upon the model closure, which in practical terms means how the correspondense between savings and real investments is imposed. (see Rattsø, 1982).

Modifications

Flexible prices

The model assumes fixed prices, and deals with income generation and income distribution as if irrelevant to technology, effort and consumer preferences. In an integrated environment-economy model, the price equations should be included to draw the relations between prices and income on the one hand, and technology, and growth structure on the other, A complete framework for a model with flexible prices will not be discussed at this stage. However, some main modifications related to price - flexible modeling will be mentioned below.

Foreign trade

When we proceed to model the markets of single goods, the question arises how to determine the import share in total supply (and demand). The market absorbes a mix (or composite) of imports and domesticly produced varieties. In the simple linear form of defining the composite good above, a unit of the domestic good is contributing as much to the aggregate supply as a unit of the imported variety, i.e. they are perfect substitutes. This is genereally not the case due to quality differences. More complex modeling might account for this by introducing a non-linear formula for composing the (abstract) aggregate supply good and let changing price differentials between the two varieties determine to which extent the domestic variety is substituted for imports or vice versa (the Armington approach).

A similar method can be used for allocating output to the domestic and foreign markets. The essense in this case is that the enterprise (sector), when facing a price reduction in one marked can shift (deliveries) towards the other market, but not costlessly. Hence, there is flexibility, although constrained. To reflect the current role of markets in China, supply and demand most reasonably should be modeled as price flexible. However, investment demand is hard to describe well in the presence of imperfect credit markets. import regulations etc. Even in countries with well functioning markets for credit and foreign exchange, uncartainty and expectations strongly affect investment decisions and make static and deterministic modeling of the capital accumulation process insufficient. Hence, even in fairly elaborate price-felxible models the capitall market is frequently being dealt with as a simple allocation mechamisme like in our model above.

Household demand

The consumption of goods is seen as realised by one representative consuming unit. Hence there is a single fixed consumption pattern. It would be better if urban and rural household consumption was described seperately since they differ considerably with respect to energy use and potential for income growth. This necessitates data on seperate income flows to the two household categories.

Below, we focus on data demand related to the simple fixed coefficient model in section 5, before discussing some ideas for further model development in section 6.

5. Model data

The data to fill in the model structure are conventionally organized in a social accounting matrix (SAM) based on national account statistics.

The core of a SAM is the Input-Output (I-O) table which provides the information about how single industries combine basic input factors like labour and various produced intermediates. In our context it is in particular interesting how energy flows are described.

The 1995 I-O matrix with 33 sectors can be a basis for an energy-economy model when combined with the energy accounts. The energy account will describe energy flows throughout the economy both in physical and value terms. In the near future, cross sector deliveries of goods and services will be available in a 124*124 sector format for the year 1997. One major difference between this level of aggregation and the 33 sectors level is that transportation is split on several production sectors/services in the 1997 version. As the various transportation activities are fairly heterogeneous both with respect to energy use and environmental impacts, the sector list of the *energy accounts* 1995 is expanded to match the 124 sector level in this field in order to facilitate analytical works with a more detailed focus on energy use in transportation sectors.

The energy flow

Current status is that fossil fuel flows are fairly well mirrored in the Energy Balance (SSB) in quantitative terms, but household consumption and transport services are incompletely covered. So far, there is no information on values of energy flows, but data collection will take place during spring 1999. The consistency of this information will be assessed when the energy account is being completed and balanced.

Below, we first discuss the role of energy production and transformation sectors of the NA model context, and consider some adjustments for our modeling purpose.

NA sectors for energy production and transformation

1997		
Sector	Code	Title
6	206006	Coal mining, cleaning and screening
7	307007	Crude petroleum production
8	307008	Natural gas production
36	1125036	Petroleum refineries
37	112537	Coking
86	2444086	Electricity production and supply
87	2444087	Steam and hot water production and supply
88	2545088	Coal gas production and supply

1995	
Sector	Title
2	Coal mining, cleaning and screening
3	Crude petroleum and natural gas production
12	Petroleum refineries
13	Coking, manufacture of gas and coal products
11	Electricity, steam and hot water production and supply

The 1995 classification of energy producing sectors and energy output distinguishes between the most important energy goods. However, there are a few inconveniences which we will discuss below.

Crude oil and natural gas production are lumped together in the 1995 sector list. These activities may to a large extent be resource and policy determined, and future sector output can possibly be treated as exogenous supply of the two goods in the model. An information loss occurs, however, if flows of gas and oil cannot be followed through the economy, which means that separate equilibrium prices on oil and gas cannot be calculated and for instance the effect of (gas market) deregulation cannot be studied.

Electricity and heat production are also aggregated. It should be investigated if it creates significant problems to add heat to the electricity aggregate (probably coal is used for both heat and thermal power, which dominates the electricity sector).

There is one sector only for electricity even in the detailed 1997 sector list. Output from hydro power plants and thermal power plants are perfect substitutes, but the input and cost structures are quite different. Hydro power is generally far more capital intensive (also including investments for flood control ?) than fuel power plants. This implies for instance that expansion of supply from hydro power will draw more heavily on input deliveries from the rest of the economy, thus creating more substantial repercussions in the whole economy from an expansion of the hydro power production. It also means that the mix of hydro and thermal power in principle is sensitive to the social discount rate and user cost of capital. Due to these differences, the two electricity sectors should preferably be separate sectors. However, hydro power constitute a minor share of power generation, and might be treated as an exogenous element in the electricity supply consistent with long term hydro investments plans. Moreover, the environmental impacts of thermal and hydro power are very different, this is another reason for keeping the two activities separate.

Coal mining, cleaning and screening is a quite inhomogenous sector with respect to output (at both 1995 and 1997 aggregation levels). The energy content of washed coal is higher and the environmental impacts less serious than untreated coal. Hence, there are several reasons for having washed coal as a separate output. This is further discussed in section 6.

Distribution is lumped together with production both in the case of electricity and heat.

Social accounting matrix (SAM)

The SAM completes a picture of economic interactions by associating economic institutions like households, enterprises and government to the I-O matrix. (see De Melo) The SAM depicts a consistent pattern of monetary and real resource flows between these economic agents, but does not say anything about the motivation behind their decisions, and how those might be influenced by economic policies or shocks. This motivation factor, driving the so-called behavior of economic agents can be a topic for further model development after the basic interlinkages have been established. Here we will just mention some data that are needed for our basic model approach.

The NA table of 1995 presents value added by sector, but does not present the information on how value added is distributed among households and government. Compensation to labour is not split on rural and urban households. Neither are transfers from government to households presented. Value added absorbed by the public sector through taxes is available from the NA table of 1995, though. It should be clarified to which extent data on income flows to consumer groups are available now, or in the near future.

A question is to what extent supplementary data can be gathered from other statistical sources like the rural and urban household surveys which both specify multiple sources of income. Possibly there are indicators available which can split wage expenditures paid by single industries (or major aggregates like agriculture, manufactoring, services etc.) in flows to rural and urban households.

The breakdown of domestic final consumption of goods and services are available from the NA (1995) tables both for urban households, rural households and the public sector. Even though a first model version might only include one type of consumers, the need for splitting urban and rual consumer demand should be kept in mind.

6. Further model development

The simple model sketched above does take account of some major structural differences in production by operating at a fairly disaggregated sector level. Even if the technology in each production sector is assumed to be fixed (i.e. input factors are used in constant proportions in each sector) the disaggregation will reflect some economy-wide flexibility as the change in demand composition will rearrange sector importance with respect to energy use and emissions to air.

However, by keeping sector technology fixed, the model will not be able to answer the question of how energy demand and economic growth will respond to changing prices, for instance prices on energy goods. Prices of energy goods will increasingly be market determined, and environmental policy might affect energy costs significantly through specific regulations or taxes.

The overall situation in the markets for different energy goods can be described as a mix of market driven allocation and government intervention. Coal sales are recently deregulated, and price differences might mainly reflect variation in distance to markets and associated transport costs. Gas distribution is still regulated. For electricity in coastal provinces, the prices are roughly in line with marginal costs in the quite rapidly expanding utility sectors. However, interior provinces' power plants are generally older and free of capital costs (before 1980) and under price regulation. Finally, if environmental measures are considered to be implemented as emission taxes, energy prices might increase significantly. To be able to analyze impacts of market and price reforms, flexible adjustment to changing prices and costs is preferable in the model beyond the initial stage of work.

In the next section we first discuss various options for incorporating energy substitution and general price flexibility into enterprise behaviour (demand).

6.1. Energy substitution

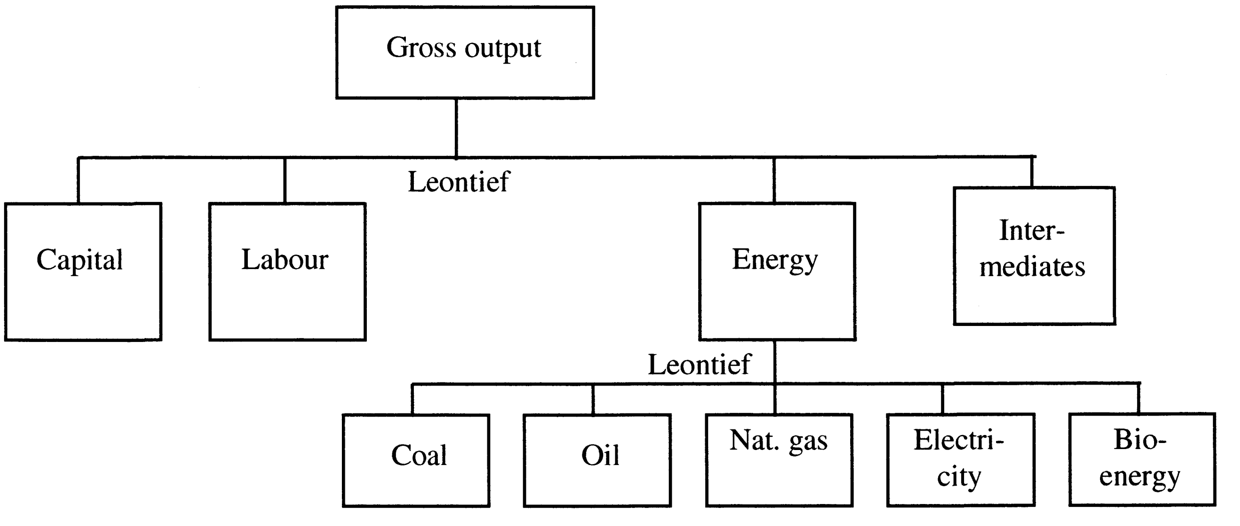
Below, the input structure of a production sector is described by different input trees which demonstrate how single input goods are bundled and whether these bundles potentially are in a position to substitute each other.

Production tree no. 1 depicts the simple fixed coefficient (Leontief) technology which is suggested as a first approach and reflected in the model equations (section 4). Although the various energy goods are shown in the figure, there is no difference between how energy and the other intermediates are dealt with. The intermediates consist in principle of 33 individual goods less the energy goods, but the specific mix of these goods vary among user sectors. So with energy goods

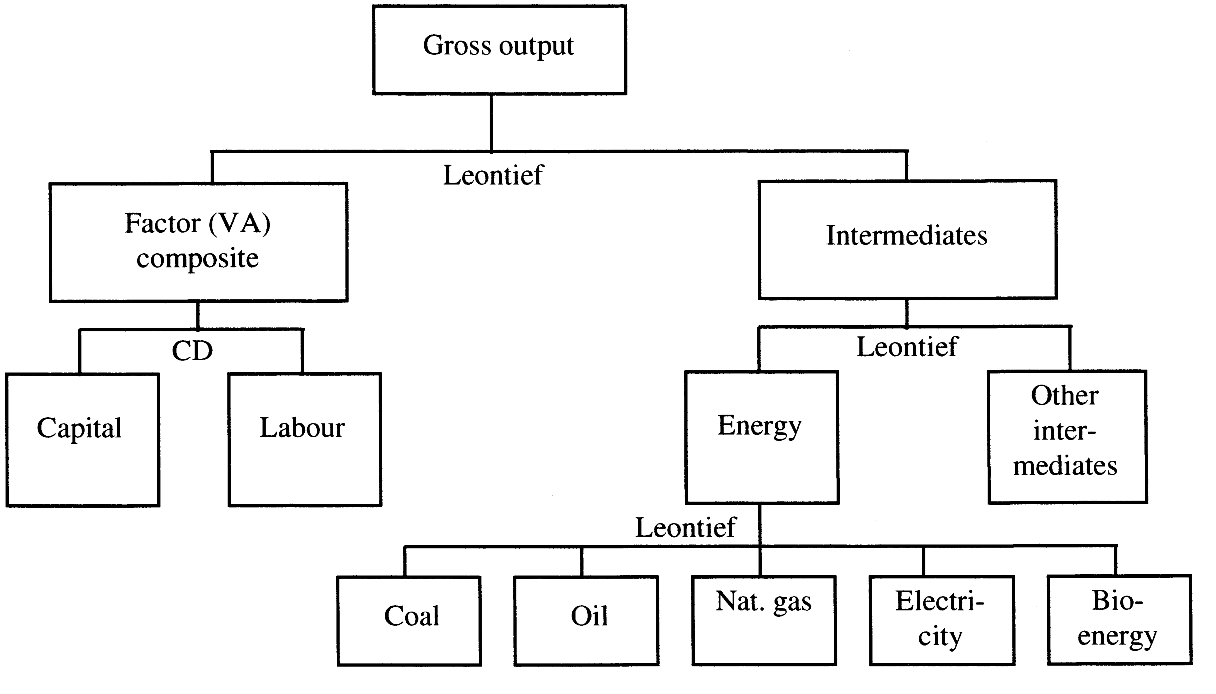
Some models are introducing substitutability between capital and labour, while intermediates in general remain determined by fixed input coefficients. However, this ignores the possible close link between the capital stock and the energy consumption associated with it. To focus on this connection, a capital-energy aggregate is often constructed to reflect that when you mechanize processes, you'll have to substitute the whole capital-energy package for labour. This is practiced by Zhang (1998).

The empirical evidence and relevance of making these assumption for China should be discussed. The energy intensity of China was about 4 times that of the US in 1995. Compared with OECD countries, the sectoral pattern of energy demand is highly skewed; with a large industrial share and relative smaller shares in transportation and services. It is clearly a high potential for energy efficiency improvements in the industrial sector, and likely that capital accumulation and *reduced* energy demand will go hand in hand for still some time. Particularly in the heavy industries it might be misleading to assume optimal input structure and calibrate/deduct parameters in correspondence with such economic behavior.

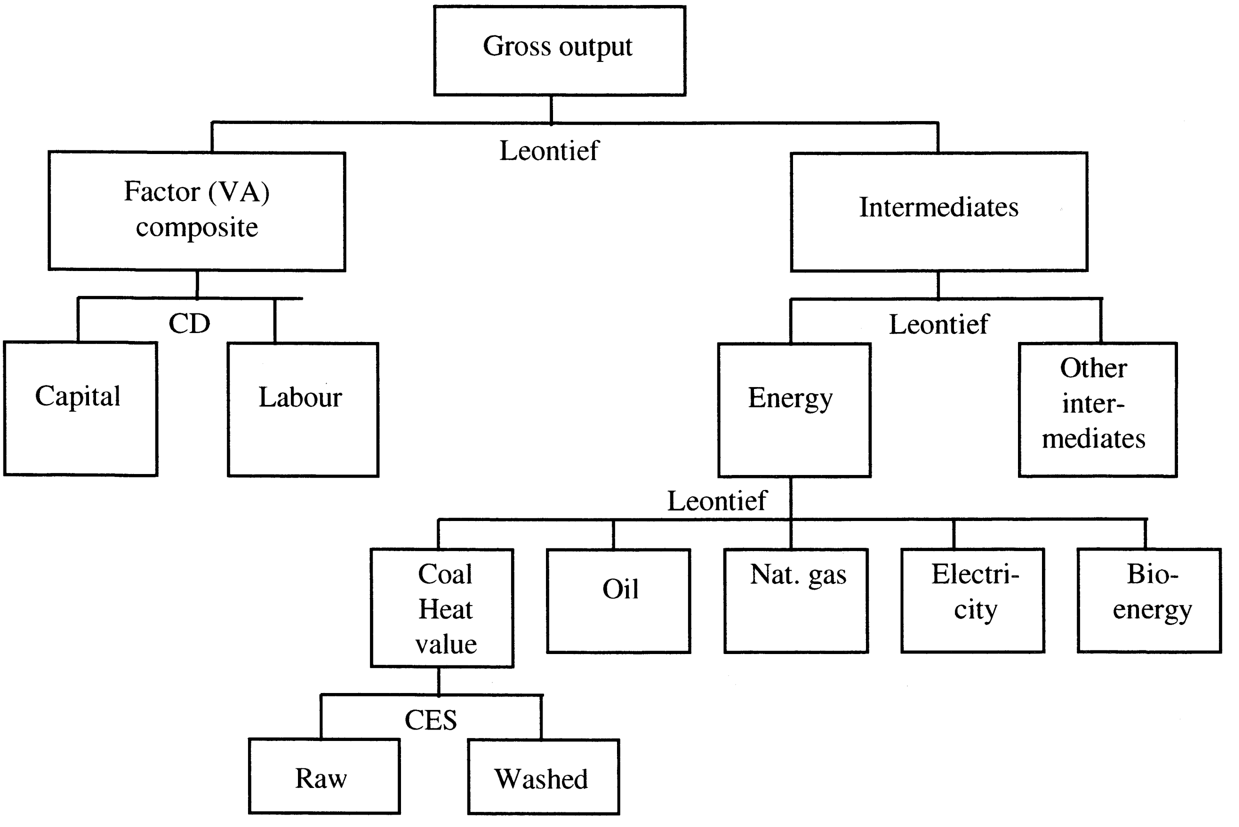
Production tree 1



Production tree 2



Production tree 3



Production tree no.2 introduces substitutability between capital and labour, which generate the valuaeadded (VA) in the production. Intermediates (including energy) are used in fixed proportions to output.

In production tree no. 3 a new detail concerning coal is introduced. Coal as input in the energy aggregate is representing the heat value of coal (efficiency units), and this heat value of coal can be generated by a mix of raw coal and washed coal. The washed coal has a higher (25%) energy content than the raw coal, but is more costly to produce. For analytical purposes, the cost structure and output of coal washing can be separated form the mining activity based on supplementary statistics and process knowledge.

The role of coal in relation to energy and environment in China is briefly discussed below.

Coal technology

Coal is and will remain a dominant energy source for a long time, and the model should go as far as possible in depicting the essential features of coal in relation to energy and environmental aspects.

Coal is a major source of emissions of particulate matter, which can be reduced by coal cleaning processes. Presently, about 20 percent of coal is washed and mainly absorbed in metallurgic industries. The average ash content of commercial coal is about 20 percent. Internationally traded steam coal has an ash content of about half this level.

The high ash content contributes to a relative low heating value of coal (most internationally traded coal has a heating value 25 percent above Chinese coal average (World Bank, 1997)) and coal cleaning offers gains in energy efficiency in addition to an improved environment.
Hence, through coal cleaning there are options for increasing the energy content of coal and at the same time reducing emissions, specially of Coal mining and cleaning (in sector 6) consequently represent a mix of outputs which play different strategic roles in energy and environmental policies. Due to the potential benefits of coal cleaning in China (to reduce ash content and emission of particulate matter) the cleaning sector should be considered as a separate production activity. The associated production cost of coal cleaning may then be given an explicit role as «investment» in energy efficiency and clean air, i.e. a key tool in future policies. The composite of ordinary and washed coal could be defined as «coal energy units», which could enter production sectors in fixed proportion to output (for instance)

It is important to figure out the amount of own (sector internalised) transportation which is included in energy producing activities, especially for coal which is high volume and where distribution itself might contribute significantly to energy consumption and air pollution.

Transportation costs accounts for up to 70 percent of delivery price of coal. The efficiency and cost of transportation will significantly affect the price of coal. For instance, a tax on transport fuels implemented for energy conservation, environmental concerns or simply fiscal reason mightclearly affect coal prices. The use of transport in coal distribution will be dealt with in the energy accounts, and the implications for coal model sector assessed accordingly. It might be considered if own transportation should be de-linked from the production activity if reforms or deregulations make this relevant within the model horizon.

The coal and electricity system of China has been modeled in a joint study by the State Planning Commission (SPC) and the World Bank (1995) Investments in transportation were optimized along with investments in production of energy goods (in a MARKAL type of model with spacial dimensions). This coal transport study has later been developed to also include investments in demand side energy efficiency, and the cost of fulfilling specific emission targets (Kuby and Xie, 1997).

The input data and model analysis may provide very useful information to the work with energy accounts and in particular to analytical approaches to energy and environmental problems. The SPC's Energy Research Institute seems to be an important source of technical information about equipment and energy efficiency in various sectors.

6.2. Plan and market

The economic reforms in China has introduced various incentive systems which may generate different economic behavior within an otherwise fairly homogenous production sector. Even within single firms there may be different incentive systems in work. In such cases, a share of resources allocated to the firm is made available for market oriented production, while the rest is used according to the production plan. To mirror this phenomenon, some CGE models of China explicitly deal with a two-tier plan/market structure where one part of a sector is regarded as exogenous, policy regulated activity, while the rest is price sensitive.

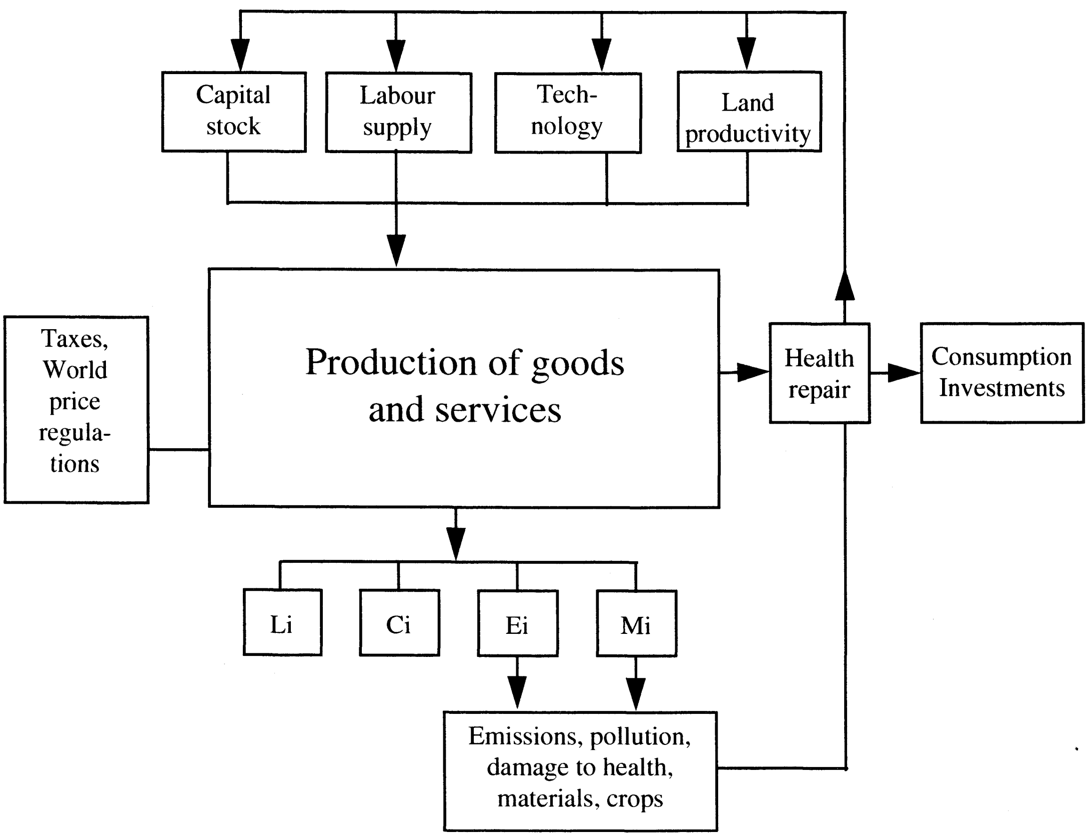
Byrd (1989) examines the impacts of planning and the efficiency of markets in a theoretical model with such a two-tier approach. Garbaccio (1994) traces sectoral effects of price and tax reforms in an empirical two-tier CGE model. Xu (1996) focus on the impact of reducing planned quotas on the structure of demand for urban labour in a similar model.

The two-tier structure has been an important characteristic of the transitional period, and is reflected in the preoccupation with this structure in the model literatur. However, it should be considered whether a two -tier structure is still relevant for describing producer behavior properly. At this more advanced stage of the economic reform process, a significant part of light industry might already be basically market oriented. Only 5 percent of prices may now be determined outside markets. Still, planning may dominate in state owned enterprises within heavy industry which tend to be energy intensive. If necessary, some two-tier activities can be specified if data are available for splitting output and input on the respective incentive regimes by using information in plan documents and determine the market oriented resource base residually.

6.3. Linking the environment to the economy and vice versa

The project aims at describing and modelling some main interlinkages between environmental indicators and costs to the society. Air pollution from energy use is a major concern associated with energy use, and the human health hazards and material/nature impacts of pollution have already reached serious dimensions. The environmental costs are so far estimated to be around 3-4 percent of GDP when estimated through the human capital approach which basically covers lost workdays, reduced productivity of labour, land and capital, and medical expenditures. Statistics Norway has taken the human capital approach in their own modelling efforts for Norway in this field. .The structure of an integrated economy-environment model can be illustrated as in figure 3 below.

Figure 3. Integrated environment-economy model



Capital, labour and land are basic inputs in production of goods and services. For given taxes and regulations (we ignore foreign trade for the moment) the production sectors decide on their input structure. In general the use of energy (Ei) and material (Mi) by sector i generates emissions which reduce environmental quality.

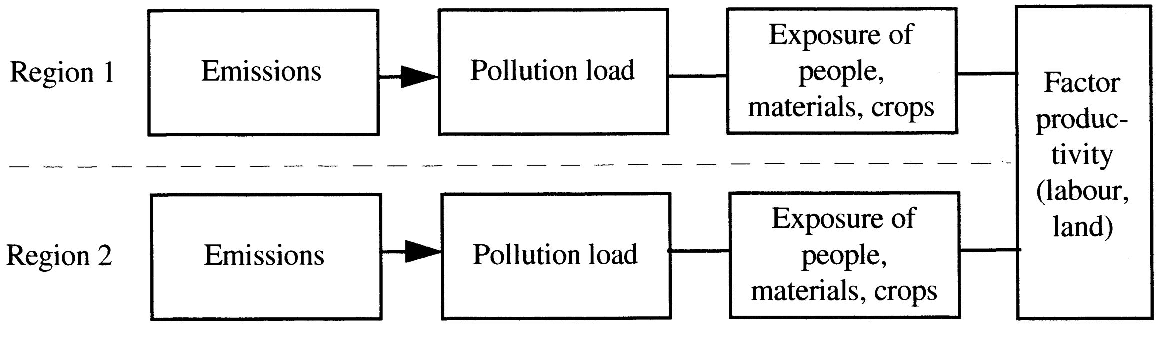
A degraded environment involves damages to health, materials and crops. Consequently, the productivity of capital (buildings, machines, vehicles), labour and land is reduced.

The impact on the labour force is partly modified by health (repair) expenditures, for instance through public health care, but also paid by private households. This repair element is partly policy and market determined. In the figure, only health treatment and costs are shown. However, there are also other types of such defensive expenditure with the purpose of keeping up productivity and welfare in response to the current pollution level.

Land is not an explicit asset in the National Account,. However, land productivity can be represented as a special rate of technological change in the agricultural sectors.This rate is in turn sensitive to agricultural practises in addition to pollution loads.

The link from the emissions to factor productivity and health expenditures contains several intermediate steps of calculation. Figure 4 below illustrates the usual procedure:

Figure 4.



To carry out an.environmental impact and cost assessment, some regional/local emission data must be provided because pollution problems usually are unevenly geographicly distributed. Air pollution spread models based on meteorological (wind) data are in some cases used to identify the pollution load (consentration of polluting components in the air). Data on regional exposure can be collected from statistics on population, building stock, land use etc. A linear function between emissions and pollution levels can in many cases serve as a useful proxy when air-dispersions models are not available.

Empirical evidence of environmental impact on health, crops and materials are usually represented as so-called dose-reponse functions. These functions express the (estimated) relation between pollution exposure and the incidence of various damages in a certain population/stock.

6.4. Regional concerns

Coastal provinces versus the interior

The income gap between coastal China and the interior is significant. In 1992, the average income in coastal provinces were 50 percent higher than in the interior. A main reason is that the coastal areas were in a better position to benefit from economic reforms and the open doors policy. Important factors were proximity to world markets, better infrastructure and more educated work force. (World Bank,1997).

Both embedded dynamics and policy changes will affect the future distribution of growth between the two main regions of China. For economic and distributional analysis, it might be useful to deal with the two economies separately. Moreover, a two-region model would benefit energy and environment analysis as well. One of the main differences between the two parts is the access to infrastructure. This leaves the better equipped coastal provinces more options and flexibility in energy use and basic consumption pattern.

Another difference relates to the diverse agro-ecological characteristics and their implications for the environment and the economy. The coastal plains are suitable for paddy rice (a main source of methane emissions), while wheat is the basic staple grain in the interior. The growth in grain production might differ between the two parts. (IPCC, Regional impacts of CC) indicates that output level of paddy is stagnant). From soil conservation perspective, it makes a difference whether paddy or wheat is being grown.

City module

Some major cities are heavy users of energy, dominant polluters and expose disproportionally many people to health hazards. Pollution costs in China are estimated in a human capital approach to be US$24 billion a year, or roughly 3.5 percent of GDP, of which urban air pollution health damage is the single largest environmental in China today (World Bank, 1997). The project will develop an urban submodule which describes feedbacks from the air quality to health, material damage, and finally economic productivity and public health expenditures.

The urban economic base may deviate considerably from the national «average», and national growth in energy use and emissions might be lousy indicators of environmental pressure in the mega-cities. For the purpose of environmental analysis, it might be better to keep a separate account of the economic development and energy demand/emissions in Beijing and/or possibly other mega-cities. This may be done in a simplistic manner, by assuming city share of each sector activity to be constant. This opens up for integrated environmental-economy analyses with a specific urban module emissions, environmental regulations and feedback effects.

This approach has been followed when integrated economy-environment modeling in Norwegian (Rosendahl (ed.)1998). The feedback effects to factor productivity and public expenditures from health damages and intensified capital depreciation are better described with a focus on urban centers where a major share of the exposed population and capital stock is located.
In the case of Beijing, an environmental masterplan is developed, and research is initiated to build an integrated economy-energy-environment model which will be linked to the existing emission dispersion model for Beijing developed by USEPA (Ph.D. student at BI, Jiang Lin from Beijing Municipal Research Institute).

Agriculture

Agriculture in China has the important duty of feeding a quarter of world population on very limited land resources (6-7 percent of global land suitable for agricultural production). Long traditions in land resource management (terracing) and recent investments in chemical fertilizer production has made a huge increase in yields possible. Still, however, soil erosion and land degradation represent serious threats.

Fertilizer production is highly energy intensive, and energy for this purpose is subsidized. A third of total (natural ?) gas supply enters fertilizer production at the lowest prices. This links energy policy to agricultural productivity and development.

Agriculture generates 21 percent of GDP but represent a modest commercial energy consumption in spite of the rural population making up about 80 percent of the total population.

The rural population so far mainly rely on bio-energy (crop residues, fuelwood) for heating and cooking. Rural energy consumption amounts to 250 million t coal equivalents or 17 percent of total energy consumption in China. A crucial question is how rapid the income level at the countryside will rise, and increase energy demand and substitute commercial energy for own produced bioenergy.

Farmers are producing bio-energy which partly is additional output from crop cultivation. If markets for straw etc. is lacking, for instance due to high transportation costs, the impact of changes in commercial fuel prices might be quite different from the response in urban households. This is because local farmers operating according to local shadow costs, not always the general market prices.

Environmental problems associated with agriculture are manifold. For the rural population, the highly damaging pollution from current biofuel combustion is a serious problem especially the high indoor concentration levels of particulates.

From a global perspective, the emissions of greenhouse gases from fields are important, mainly methane from paddy. Livestock is also a significant contributor. Hence, the activity level of some segments within agricultural production are important indicators for greenhouse gas emission forecasts. Income growth may lead to consumption patterns which deviate significantly from the current as to rice and livestock demand. Grain production and Livestock are separate sectors in the NA. 1997 code, but not in the 1995 table. Agricultural production will in the future (1997) be represented by the sectors Crop cultivation, Livestock and Other agricultural production. (Forestry and Fishing are the two other primary sectors).

If a model had separate regions for coastal and interior provinces, a side effect would be to catch some main differences with respect to soil erosion/nutrients. Also, the role of bioenergy production and use might differ between those two production systems. Crops may provide different amounts of bioenergy potential (residuals). For instance, the crop-residue ratio for rice is 1.0, while it is 1.2 /1.3 for wheat and maize respectively, which means that the latter two provides more residue for burning per ton harvested than rice.

7. Concluding remarks

There are many considerations to make in a modeling initiativ, but fortunately they don't have to be dealt with simulatoneously. However, along with making a first technical effort in modeling producer and consumer behaviour it might be useful to keep the broader economic and environmental suroundigs in mird. Hopefully, this paper is useful in establishing some initial capital of modeling ideas for further discussion of relevance.

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