INDONESIA’S CLEAN AIR PROGRAM

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Unprecedented industrial development during the last two decades, accompanied by a growing population, has increased the amount of environmental damage in Indonesia. A critical environmental problem is the rising level of air pollution in several large cities. This has stimulated the government to develop a national program designed to control the quantity of pollutants in the air. However, the program’s impact on economic performance and incomes has not yet been studied systematically. This paper analyses the expected impact of the clean air program on national economic performance and household incomes for various socio-economic groups.

INTRODUCTION

Industrial development, coupled with an expanding population, has increased the amount of environmental damage in Indonesia. One of the most important environmental problems is that air pollution levels in several large cities have become alarming, particularly in the last few years (World Bank 1994; Resosudarmo and Thorbecke 1996; Soedomo, Usman and Irsyad 1991). In parts of Jakarta, Surabaya and Bandung, for example, the air pollution concentration levels for suspended particulate matter (SPM), nitrogen dioxide (NO₂) and lead are far above the allowable World Health Organization (WHO) standards for air quality (table 1). Indeed, Jakarta is reported as having one of the worst air pollution situations in the world.

<table>
<thead>
<tr>
<th></th>
<th>SPM</th>
<th>NO₂</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jakarta</td>
<td>290</td>
<td>250</td>
<td>2.9</td>
</tr>
<tr>
<td>Surabaya</td>
<td>190</td>
<td>120</td>
<td>2.7</td>
</tr>
<tr>
<td>Bandung</td>
<td>110</td>
<td>100</td>
<td>2.5</td>
</tr>
<tr>
<td>WHO standard</td>
<td>60</td>
<td>40</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*Levels shown are maximum levels occurring in each city. Levels for Jakarta are for 1998, and data for Surabaya and Bandung are for 1990.

Sources: Jakarta: Biro Pengendalian Lingungan Hidup, Jakarta; Surabaya and Bandung: Soedomo et al. (1991).
worst urban air pollution levels in the world (World Bank 1998).

These disturbing air pollution levels in large urban areas prompted the government to develop a national clean air program, the Blue Sky Program (BSP), to control the ambient level of air pollutants in urban areas. The government plans to begin implementing this program in the near future (Sutamihardja 1994).²

Studies analysing the potential benefits of the national clean air program are very limited. Ostro (1994) argued that reducing the ambient level of air pollutants in Jakarta to the WHO standard for allowable air pollutants could substantially reduce certain health problems. The Indonesian Environmental Impact Management Agency (Bapedal) is currently analysing the benefits of improvement in air quality and the costs of imposing a national clean air program throughout large cities.

Both these studies have limitations. They examine the partial impact of a national clean air program on the economy without taking into account the overall or general equilibrium impact of the program. Furthermore, neither study analyses the impact of air quality improvement on national economic performance and on the household incomes of different socio-economic classes. For Indonesia, especially during the current period of economic crisis, strong economic performance and protecting the incomes of poor households are major goals. The government wants to implement only environmental policies that are compatible with solid economic performance and maintaining or increasing the incomes of poor households; it would be reluctant to sacrifice growth and equity objectives in order to improve the environment.

This paper aims to determine the overall impact of air quality improvement that might be expected from the implementation of the clean air program on national economic performance, measured by Gross Domestic Product and by household income for various socio-economic groups. It also suggests strategies that would allow Indonesia to improve air quality while maintaining relatively strong economic performance and raising the incomes of low income households.

THE BLUE SKY PROGRAM

At the beginning of the 1980s it was felt that air pollutants in urban areas had become intolerable. As a result, several government agencies undertook separate activities to monitor air pollution and to observe its impact on health in large cities. As of 1991, the Bureau of Meteorology and Geophysics had approximately 20 air pollutant monitoring stations in large cities throughout the country. Other agencies, such as the Health Ecology Division of the Ministry of Health, the Jakarta municipal government, and the Jakarta Research and Development Centre for Urban Areas and the Environment, also operated air pollutant monitoring stations. The majority of the monitoring stations in large cities showed that the ambient level of air pollutants such as SPM, NO₂, lead, carbon monoxide (CO) and sulphur dioxide (SO₂) had increased during the 1980s (Sutamihardja 1994). They also indicated that the concentrations of SPM, lead, CO and NO₂ in certain areas of large cities exceeded the WHO standards for air quality.

In 1991 the Bandung Institute of Technology (ITB) produced maps of levels of air pollutants such as SPM, NO₂, CO and SO₂ for the Java cities of Jakarta, Bandung and Surabaya for 1989 (Soedomo, Usman and Irsyad 1991). These maps show the annual average ambient levels of air pollutants in different neighbourhoods in each city. In 1993 the Agency for the As-
Indonesia’s Clean Air Program

Assessment and Application of Technology (BPPT), working together with the German Ministry of Technology, published average 1991 ambient levels of air pollutants for the entire island of Java (BPPT and KFA 1993).

Following these air pollution monitoring activities, researchers in the Health Ecology Division of the Ministry of Health and in the Department of Public Health at the University of Indonesia studied the impact of air pollutants on human health in large cities, particularly Jakarta. Tri-Tugaswati et al. (1987) showed that the level of lead in the blood and urine of public transport drivers was twice as high as its level in farmers living in the environs of Jakarta. In a study analysing the impact of CO and lead on human health, Achmadi (1989) found that public transport drivers, street vendors, and people who live in high traffic areas have a 12.8 times greater risk of developing health problems associated with CO and lead than people who live in suburban areas.

The results of air pollution monitoring activities and of studying the health impact of air pollutants in large cities stimulated government agencies to create programs to control urban air pollutants. In 1992 Bapedal began to develop the Blue Sky Program. The BSP has two components: the BSP—Air Pollutants from Mobile Sources and the BSP—Air Pollutants from Stationary Sources. The BSP is designed to serve as an umbrella for various government programs and activities to control air pollution.

BSP—Air Pollutants from Mobile Sources

The main focus of the first component of the BSP is the control of air pollutants from motor vehicles. Policies under consideration include the following.³

Reducing the Lead Content of Gasoline. The lead content of gasoline is presently about 0.40 g/l (grams per litre). The government wants to reduce this to 0.04 g/l (‘unleaded’ gasoline). Since mid 1997 unleaded gasoline has been available on the market, but annual sales are only 0.025% of total oil-based fuel consumption in the transport sector, because the price of unleaded gasoline is still approximately 30% higher than that of leaded gasoline.

Increasing the Prices of Gasoline and HSDO. By reducing subsidies, the government has gradually been raising the price of gasoline and high-speed diesel oil (HSDO) towards world parity. Prices were increased several times between 1998 and 2002, and by the end of 2002 the price of gasoline was very close to the world market price, while that for HSDO was still approximately 25% lower.

Promoting the Recovery of Vapour Emissions. The goal of this policy is to reduce the amount of gasoline vapour emitted into the atmosphere when gasoline tanks are filled. The government will require gas station owners to adopt technologies to achieve this end.

Introducing an Emission Standard for New Vehicles. The government plans to implement a very strict emission standard for new vehicles. With the new standard, new vehicles will probably need to be fitted with catalytic converters. This policy aims to limit the increase in air pollution levels as vehicle numbers rise.

Establishing a Roadside Inspection Program. This policy is designed to control air pollutants from vehicles in use. It is suspected that the worst 10% of polluting vehicles generate about half of total pollution (World Bank 1993). To implement this policy, the government plans to build vehicle emission testing centres in several large cities. An emission standard for existing vehicles will also be introduced.
**Phasing Out Two-Stroke Engines.** A two-stroke engine generates approximately 40% more pollution than a four-stroke engine of the same size (World Bank 1993). Currently, approximately 50% of motorcycles in Indonesia have two-stroke engines, and these contribute approximately 20% of the SPM, $NO_2$, and lead pollutants in the air.5

**Substituting Compressed Natural Gas (CNG) for Other Fuels.** Substituting CNG for gasoline could reduce SPM and CO emissions by up to 90%. The reduction will be even greater when CNG is substituted for HSDO. Several types of public transport will be required to undertake this substitution. Vehicle owners will be given an incentive to install conversion kits that enable their vehicles to switch from gasoline and HSDO to CNG.

**BSP—Air Pollutants from Stationary Sources**
The second component of the BSP will attempt to control air pollution from stationary sources such as factories and open burning municipal wastes. This program is still in its very preliminary planning stages, and no detailed studies have yet been conducted to estimate the investment costs of the different components of the program.

To control air pollutants from factories, the government plans to introduce industrial emission standards; promote energy-efficient technologies; require every factory to conduct a detailed environmental impact analysis; and increase public pressure by announcing to the general public the environmental performance of companies in reducing pollution. To reduce pollution from the open burning of municipal wastes, government plans include the building of incinerators to improve municipal waste management.

**THE MODEL**
This paper uses a Computable General Equilibrium (CGE) model to study links between air pollution and the economy.6 The model focuses on the relationships between urban production activities, urban air quality, and health problems in urban areas, as shown in figure 1. The use of oil-based fuels in production activities contributes to air pollution in urban areas. A high level of ambient air pollutants in these areas causes a correspondingly high number of air pollutant related illnesses. These illnesses cause urban households to spend money on medical care, and also reduce the productivity of labour in urban production activities. It is assumed that urban production activities are non-agricultural.

Facts and relationships important to understanding the impact of implementing a national clean air program on air quality and the economy, as simulated in this paper, are as follows. First, a national clean air program might require the government and the private sector to spend money on the adoption of different technologies and the implementation of services to reduce the quantity of pollutants released in the air. In this model, the government and the private sector must therefore reallocate these capital budgets. Second, implementation of a clean air program reduces the quantity of pollutants released into the air by various economic activities and thus improves ambient air quality in urban areas. The improvement in urban air quality reduces the number of air pollutant related illnesses.
Third, reduction in the number of air pollutant related illnesses improves the productivity of labour in urban production activities. This improvement in labour productivity ultimately increases the overall effectiveness of all other factor inputs in urban production activities. Fourth, reductions in the number of air pollutant related illnesses also lower the amount spent by urban households on health treatments. These lower health costs enable urban households to consume more of other goods and services.

**NATIONAL ECONOMIC AND AIR POLLUTANT HEALTH PROBLEM DATA**

The main data source used in this paper is the 1990 Social Accounting Matrix (SAM) from the Central Statistics Agency (BPS). The paper modifies the SAM so that the commodity classification includes five different types of oil-based fuel: gasoline, HSDO, industrial diesel oil, kerosene and fuel oil. Furthermore, in the modified classification, the Air Pollutant–Health Service sector (health service activities associated with air pollutants) is separated from the Public Service sector.

The procedure for estimating the number of occurrences of health problems associated with air pollutants uses dose–response functions collected by Ostro (1994) from epidemiological literature. Dose–response functions estimate the number of people who contract certain kinds of air pollutant health problems given the number exposed to a pollution level above the WHO standard. The same approach can also be used to determine the number of restricted activity days (i.e. days away from work) associated with air pollutants.

This paper limits itself to estimating the health problems associated with SPM, NO$_2$ and lead, for which relevant data are available; data for other air pollutants are inadequate.

The maps published by BPPT focus on Java, and indicate that three cities have air pollution levels above the WHO standard for air quality: Jakarta, Bandung and Surabaya. To estimate the health effects of air pollutants in these
three cities the detailed city maps of air pollution developed by ITB are used. On the basis of these maps, population distribution data and dose–response functions, the total number of health cases associated with air pollution in Jakarta, Bandung and Surabaya can be estimated. In 1990, these health problems included 40 million cases of respiratory symptoms, 560,000 cases of asthma attacks, and 190,000 cases of hypertension.

Since no air pollution map is available for regions outside Java, an approximation must suffice. Note that all cities outside Java other than Medan have populations much lower than Jakarta, Bandung and Surabaya. Since the population of Medan is close to that of Bandung, Medan is assumed to have as many cases as Bandung does of health problems associated with air pollution. Other cities outside Java are assumed to have no serious health problems associated with air pollution.

Information on the costs of medical treatment (including information on government subsidies) is derived from interviews with medical doctors working in public hospitals and public health centres in Jakarta. The total treatment cost for health problems associated with air pollutants in 1990 is estimated to be approximately Rp 45.5 billion.

SIMULATION SCENARIOS

This section describes the simulation scenarios that show the impact of selected BSP air pollution abatement policies on the national economy. The policies simulated below are those that the government will probably implement in the near future and for which data are available on implementation cost and on the air pollution reductions that they would achieve. All are from the Air Pollutants from Mobile Sources program. Because the main data source for the CGE in this paper is the 1990 SAM, before the simulation scenarios are run the model is calibrated so as to mimic performance of the economy from 1990 to 2000. The model is then run to simulate the following scenarios for a 20-year time horizon, from 2001 to 2020.

Base Case. This scenario assumes that the government does not introduce any air pollution abatement policies during the period 2001–20.

Unleaded Gasoline Policy. While unleaded gasoline is already available, its price is higher than that of leaded gasoline. This scenario assumes that the government equates the prices of leaded and unleaded gasoline, and requires the national oil company to reduce the supply of leaded gasoline while increasing the supply of unleaded gasoline. In the first year, only 25% of the total gasoline consumed is unleaded. In the second, third and fourth years, the percentages become 50, 75 and 100, respectively, of total gasoline consumed. The national oil company needs to invest Rp 60 billion in 1990 prices to be able to produce unleaded gasoline for the whole country. Because it is common for the switch to unleaded gasoline to be followed by a requirement to install catalytic converters in new vehicles, this paper adopts two variants of the unleaded gasoline policy.

1. With Catalytic Converters: Along with the unleaded gasoline policy, from 2001 the government requires new vehicles to be fitted with catalytic converters. Using private sector funds, automotive factories modify their assembly lines so that they can produce catalytic converters and install them in new vehicles.

2. Without Catalytic Converters: During the simulation period there is no requirement to install catalytic converters.
**Policy of Phasing Out Two-Stroke Engines.** This scenario assumes that, from 2001, the government bans the use of two-stroke engines in large cities and requires factories to stop producing two-stroke engines. Existing two-stroke engines are assumed to be sold to users in rural areas. Using private sector funds, automotive factories modify their assembly lines so that they do not produce two-stroke vehicles after 2003. It is estimated that the total investment required is approximately Rp 15 billion. This policy is expected to reduce SPM, NO₂ and lead emissions from gasoline by approximately 8%.

**Vehicle Emission Standard Policy.** This scenario assumes that, from 2001, the government requires vehicle owners to comply with the Indonesian Vehicle Emission Standard for new and existing vehicles. It is further assumed that in 2001 the government builds eight emission testing stations—five in Jakarta and one each in the cities of Bandung, Surabaya and Medan. Then, every year beginning in 2002, the government builds two more emission testing stations and locates them in various large cities.¹⁴ Vehicle owners must test their vehicles’ emissions once every year at these testing stations. Roadside inspection on a random basis is also conducted to help ensure that all functioning vehicles in these cities comply with the emission standard. This scenario assumes that no significant investment is needed for vehicle factories to improve the performance of new vehicles. Another assumption is that owners of existing vehicles either improve vehicle maintenance so that the vehicle complies with the emission standard, or move the vehicle to a rural area.¹⁵ Well maintained vehicles are assumed to be 5% more efficient in gasoline and HSDO use than poorly maintained vehicles. Air pollutant emissions from vehicles are expected to decrease by approximately 15%.

**Gasoline and HSDO Pricing Policy.** Government subsidies on gasoline and HSDO were approximately 40% and 70% of total production costs, respectively, in 2000. This scenario assumes that in 2001 the government reduces subsidies on gasoline to approximately 35% of the total production cost, and on HSDO to approximately 60% of the total production cost. In 2003, the government again reduces the subsidies on gasoline and HSDO by the same amounts, to approximately 30% and 50% of their total production costs. In 2005, the government once more reduces these subsidies by the same amounts. It is believed that when subsidies are reduced and the prices of these fuels increase, people will improve their efficiency in using gasoline and HSDO. It is not clear, though, by how much they will do so. Hence this paper focuses on two extreme outcomes, with the actual outcome falling somewhere in between. These extremes are as follows:

1. **Pessimistic:** This scenario assumes that people are not able to improve their gasoline and HSDO efficiency, even though prices increase.
2. **Optimistic:** This scenario assumes that people are capable of increasing their efficiency in using gasoline and HSDO by as much as the percentage increases in prices, so that their net cost of fuel is unchanged.

**Combined Policy.** This scenario simulates a situation in which the government implements all of the above policies together, beginning in 2001. This combined policy will have two possible outcomes, reflecting the pessimistic and optimistic outcomes of the gasoline and HSDO pricing policy.
<table>
<thead>
<tr>
<th></th>
<th>Base Case: No Air Pollution Program</th>
<th>Estimated Air Pollution Indicators in 2020 under Each Policy (Base Case in 2000 = 1.0) (and Percentage Changes Compared to the Base Case in 2020)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>SPM</td>
<td>1.00</td>
<td>2.91</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₂</td>
<td>1.00</td>
<td>2.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>1.00</td>
<td>3.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Column (2) indicates how many times higher average ambient levels of SPM, NO₂, and lead are expected to be in 2020 than in 2000. Columns (3–10) show expected levels of urban air pollutants in 2020 under various abatement policy scenarios, compared with their levels in 2000, and percentage reductions in pollution levels under various abatement policies relative to the base case in 2020.
RESULTS AND DISCUSSION

In this section the simulation results from the various air pollution abatement policy scenarios are compared with the base case, in which no air pollution abatement program is implemented. Note that all policies are assumed to begin implementation in 2001, with the initial conditions established in 2000.

Table 2 sets out indicators of urban air pollution levels under all scenarios, including the base case, in 2020. Table 3 shows the number of cases of various health problems caused by air pollutants in urban areas, the estimated total cost associated with these health problems, and the expected impact of air pollution abatement policies on these health problems and their costs. Table 4 presents the estimated impact of various air pollution abatement policies on the total present value of GDP, and household income gains during the 20-year time horizon for implementation of these policies (as depicted in figure 2).

Impact on Ambient Levels of Air Pollutants

Columns (3) and (4) in table 2 show that the introduction of the unleaded gasoline policy, with or without catalytic converters, will effectively reduce the ambient concentration of lead in urban air to approximately zero, thus more than fulfilling the WHO air quality standard for lead. The unleaded gasoline policy with catalytic converters is also the most effective single policy for countering the increasing trend of SPM and NO\textsubscript{2} air pollution,\textsuperscript{16} although it is not able to reduce these pollutants to below their 2000 levels, for the following reasons.

First, the transport sector only contributes about 30\% of SPM pollution in urban areas. Hence, although catalytic converters reduce SPM emitted by cars

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**FIGURE 2** GDP Gains under an Air Pollution Abatement Policy\textsuperscript{a}

\begin{center}
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline
\textbf{Pollution abatement policy} & \textbf{Base case} & \multicolumn{5}{c|}{\textbf{GDP gain (Rp billion)}} \\
\hline
\textbf{Year} & \textbf{2000} & \textbf{2005} & \textbf{2010} & \textbf{2015} & \textbf{2020} \\
\hline
\textbf{A} & 0 & 0 & 0 & 0 & 0 \\
\textbf{B} & -15 & -10 & -5 & 0 & 15 \\
\hline
\end{tabular}
\end{center}

\textsuperscript{a}The shaded area is the gain in present value of GDP for each year shown (which may be negative). Hence, the total gain in present value of GDP for 20 years is area A minus area B.
<table>
<thead>
<tr>
<th>Annual Cases of Health Problems: Base Case</th>
<th>Total Reduction in Health Cases and Costs from 2001 to 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unleaded Gasoline</td>
</tr>
<tr>
<td></td>
<td>No Catalytic Converter</td>
</tr>
<tr>
<td>Health problems</td>
<td></td>
</tr>
<tr>
<td>Hospital admission</td>
<td>4,963</td>
</tr>
<tr>
<td>(no. of cases)</td>
<td>97%</td>
</tr>
<tr>
<td>Non-fatal heart attack</td>
<td>3,754</td>
</tr>
<tr>
<td>(no. of cases)</td>
<td>536%</td>
</tr>
<tr>
<td>Emergency room visit ('000 cases)</td>
<td>249</td>
</tr>
<tr>
<td>Lower respiratory illness ('000 cases)</td>
<td>249</td>
</tr>
<tr>
<td>Asthma attack ('000 cases)</td>
<td>1,111</td>
</tr>
<tr>
<td>Respiratory symptoms ('000 cases)</td>
<td>79,530</td>
</tr>
<tr>
<td>Chronic bronchitis ('000 cases)</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>512%</td>
</tr>
</tbody>
</table>
TABLE 3 (continued)  *Impact of Pollution Abatement Policies on Pollutant Related Illnesses and Health Costs*\(^a\)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Health Problems</td>
<td>Base Case</td>
<td>No Catalytic Converter</td>
<td>Catalytic Converter</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Hypertension ('000 cases)</td>
<td>438</td>
<td>2,786</td>
<td>26,528</td>
<td>26,528</td>
<td>2,150</td>
<td>5,247</td>
</tr>
<tr>
<td>Restricted activity days ('000 cases)</td>
<td>15,279</td>
<td>93,453</td>
<td>158</td>
<td>208,593</td>
<td>9,551</td>
<td>60,255</td>
</tr>
<tr>
<td>Health costs</td>
<td>Air pollutant-health costs (Rp billion)</td>
<td>90</td>
<td>551</td>
<td>223</td>
<td>788</td>
<td>45</td>
</tr>
</tbody>
</table>

\(^a\)Percentages in column (2) are increases in the number of health problems and in air pollution related health costs from 2000 to 2020. Columns (3–10) show cumulative reductions in health problems and in present values of air pollution-related health costs associated with the various abatement policies during the 2001–20 time horizon, relative to the base case. Present values are calculated using a 5% discount rate. All changes in cases and costs are also shown as percentages.
by up to 90% (Nurrohim, Boedoyo and Malik 1994), this policy is only able to reduce total SPM such that in 2020 it is still 2.05 times its level in 2000. Second, the transport sector contributes only about 60% of NO₂ pollution in urban areas, and catalytic converters are only able to reduce NO₂ emitted from cars by approximately 40%. Therefore, this policy fails to reduce the 2020 level of NO₂ in urban air below its level in 2000.

Indeed, columns (9) and (10) show that, even after implementing all four pollution abatement policies together, concentrations of SPM and NO₂ in 2020 remain significantly higher than those in 2000. Recall that the 2000 ambient levels of SPM and NO₂ in many parts of Jakarta, Bandung and Surabaya were higher than the WHO air quality standard.

One can conclude, then, that implementing air pollution abatement policies in the transport sector (i.e. focusing on mobile sources) can reduce lead concentration in urban areas to meet the WHO air quality standard for lead, but it cannot reduce SPM and NO₂ concentrations sufficiently to meet the WHO standards for these pollutants. To do this, air pollution abatement policies will also need to focus on stationary sources such as manufacturing, burning of waste, and construction activities.

**Impact on Air Pollution Health Problems and Costs**

From table 3 it can be seen that by far the most effective single policy in reducing health problems and costs associated with air pollution is the shift to unleaded gasoline with catalytic converters. Clearly this policy is important to air pollution abatement.

It is interesting to observe the simulated results of the gasoline and HSDO pricing policy. Table 3 shows that its impact on air pollution health costs is quite different under the pessimistic and optimistic assumptions. Under the pessimistic assumption, this policy is only able to reduce the total present value of health costs by about Rp 12 billion. With the optimistic outcome, however, the reduction is Rp 287 billion—almost 24 times higher—making it the second most effective pollution abatement policy for reducing total air pollution health costs. In implementing this policy it is thus crucial to ensure that the optimistic outcome will obtain.

To bring about this outcome, the government needs to socialise the pricing policy, conducting an effective educational campaign about how to improve the efficiency of fuel consumption by, for example, more regular and effective tuning, better planning of vehicle use, and more careful and effective driving. Another strategy that the government needs to consider is a gradual approach to increasing prices, so that vehicle owners have enough time to keep improving the efficiency of their fuel consumption.\(^{17}\)

Column (2) in table 2 shows that urban air quality in 2020 will be approximately three times worse than in 2000, while column (2) in table 3 shows that the number of air pollution health problems in 2020 will be more than six times higher than in 2000. The reason the increase in health problems is much more rapid than the worsening of urban air quality is that more and more people each year will be living in urban areas. Thus the number of people who contract air pollutant related illnesses will grow faster than the level of air pollutants in urban areas. Hence, in order to avoid more air pollutant related illnesses in urban areas, the implementation of air pollution abatement policies should begin as soon as possible.
Impact on GDP
Table 4 shows that the impact of all the pollution abatement policies on GDP is small. Among the policies considered here, the only one that causes a reduction in total present value of GDP during the 20-year simulation period is the unleaded gasoline policy without catalytic converters. The explanation is as follows. From 2001 to 2004, the government must invest relatively heavily in the national oil company so that it can increase the supply of unleaded gasoline. Such investment involves forgoing opportunities to invest in other sectors. This has a negative impact on the economy, which can be thought of as the societal cost of shifting to unleaded gasoline.

During this investment period (2001–04) there are, nevertheless, some benefits from the implementation of this policy. Using unleaded gasoline significantly reduces the level of lead in the air, and hence the number of urban residents who contract air pollution illnesses, in particular, hypertension and non-fatal heart attacks. With fewer health problems, urban workers—most of whom belong to the urban low income household group—are able to work more productively and to enjoy additional income net of health expenditures by virtue of spending less on health treatments. More productive workers and higher incomes for urban low income households affect the economy positively. This can be thought of as the societal benefit of shifting to unleaded gasoline.

During the investment phase it turns out that the benefit from having unleaded gasoline is smaller than the cost. Figure 3 shows that GDP under this policy is lower than under the base case during the 2001–05 period, with the gap increasing steadily. From 2006 the gap decreases, because there is virtually no further societal cost from switching to unleaded gasoline, while the societal benefit remains; GDP thus begins to increase faster than under the base case. Nevertheless it increases relatively slowly, such that up until 2020 it is still lower than under the base case. On the other hand, if the shift to unleaded gasoline is accompanied by a requirement to install catalytic converters, it can be seen that the societal benefit is greater, since this policy also reduces SPM and NO\textsubscript{2} pollutants. The total present value change in GDP over the 20-year period becomes positive if catalytic converters are required (table 4). Thus it is apparent that the implementation of the unleaded gasoline policy should be accompanied by a requirement to install catalytic converters in cars, in order for this policy to have a positive impact on GDP.

Impact on Household Incomes
Table 4 shows that the impact of each pollution abatement policy on household income for each socio-economic group is small. Even so, it is important to ensure that the implementation of such policies does not negatively affect the incomes of households, particularly poor households. These are typically found in the agricultural employee, small and medium farmer, rural low income, rural non-labour and urban low income household categories. Agricultural employee households are, on average, the poorest in the country (Thorbecke 1992; Resosudarmo 1996).

Two policies need to be observed carefully. The first is the unleaded gasoline policy without catalytic converters. Under this policy most households, other than those in the rural non-labour, urban low income and urban non-labour household groups, experi-
TABLE 4  Impact of Pollution Abatement Policies on GDP and Household Incomes*  
(Rp billion and percentage change)

<table>
<thead>
<tr>
<th>Base Case: No Air Pollution Program</th>
<th>Cumulative Changes in Present Value of GDP and Household Incomes Resulting from Abatement Policies from 2001 to 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unleaded Gasoline Ban Two-Stroke Emission Gasoline &amp; HSDO Pricing Combined Policies a</td>
</tr>
<tr>
<td></td>
<td>No Catalytic Converter Catalytic Strokes Standard Pessimistic Optimistic Pessimistic Optimistic</td>
</tr>
<tr>
<td>2000</td>
<td>GDP (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)</td>
</tr>
<tr>
<td>GDP</td>
<td>313,304 969,627 209% −1,853 128 123 1,169 7,837 27,839 9,671 28,533</td>
</tr>
<tr>
<td>Household incomes</td>
<td></td>
</tr>
<tr>
<td>Agriculture employee</td>
<td>10,123 32,796 224% −44 57 6 49 −181 607 −74 666</td>
</tr>
<tr>
<td>Small-scale farmer</td>
<td>53,784 190,555 254% −380 201 38 289 −795 4,275 −259 4,518</td>
</tr>
<tr>
<td>Medium-scale farmer</td>
<td>12,567 45,199 260% −90 49 9 69 −598 657 −480 704</td>
</tr>
<tr>
<td>Large-scale farmer</td>
<td>16,653 59,141 255% −116 65 12 90 −799 839 −644 901</td>
</tr>
<tr>
<td>Rural low income</td>
<td>14,801 46,102 211% −45 32 6 50 −437 580 −344 621</td>
</tr>
<tr>
<td>Rural non-labour</td>
<td>3,853 9,926 158% 38 57 1 6 424 344 490 407</td>
</tr>
<tr>
<td>Rural high income</td>
<td>44,625 144,692 224% −249 −34 17 159 368 3,869 600 3,936</td>
</tr>
<tr>
<td>Urban low income</td>
<td>32,801 94,320 188% 145 587 35 213 −368 1,287 363 1,831</td>
</tr>
<tr>
<td>Urban non-labour</td>
<td>10,152 31,568 211% 47 138 6 42 −721 −271 −571 −161</td>
</tr>
<tr>
<td>Urban high income</td>
<td>67,759 201,478 197% −5 124 11 146 −2,164 1,387 −1,850 1,546</td>
</tr>
</tbody>
</table>

aGDP and household incomes in this table are calculated net of the costs of treating health problems caused by air pollution. Columns (3–10) show cumulative gains (and percentage gains) in present value of GDP and of income for each household group (calculated using a 5% discount rate) between 2000 and 2020, relative to the base case.
ence reductions in the total present value of their income relative to the base case. On the other hand, under the unleaded gasoline policy with catalytic converters, only rural high income households suffer such a reduction. The second policy needing careful observation is the gasoline and HSDO pricing policy under the pessimistic assumption, under which all households other than rural non-labour and rural high income households experience a decline in the present value of income. By contrast, if the optimistic outcome obtains, only urban non-labour households are negatively affected.

**Impacts on Sectoral Value Added**

Switching to unleaded gasoline without catalytic converters lowers the value added of many production sectors compared to the base case (table 5). Hence the income of most households under this policy is lower than under the base case. Switching to unleaded gasoline with catalytic converters results in a much greater reduction in the number of most air pollution related illnesses than occurs under the unleaded gasoline policy without catalytic converters. Thus urban low income households will have more income with which to purchase goods and services other than air pollution health services. In particular, they will consume more food, increasing the value added of the food processing and food crop sectors relative to the base case. These increases lead to higher incomes for all households, particularly agricultural and rural households, compared to the base case. Thus most households benefit from the introduction of unleaded gasoline along with catalytic converters, although only to a very small extent.

Under the pessimistic assumption, the implementation of the gasoline and
HSDO pricing policy lowers value added in many production sectors compared to the base case. On the other hand, if the optimistic outcome obtains, the value added of most production sectors is higher (table 6). Therefore, most household incomes are lower under this policy with the pessimistic assumption than under the base case, while most are higher under the optimistic assumption.

It is important to note that, under the policy of switching to unleaded gasoline without catalytic converters, and under the pessimistic assumption of the gasoline and HSDO pricing policy, most poor households suffer lower income compared to the base case. Hence, it would seem advisable to require catalytic converters and to find ways to ensure that the impact of implementing the gasoline and HSDO pricing policy is as close to the optimistic outcome as possible, e.g. public education programs on efficient care and use of vehicles. Overall, the simulation results would appear to support introducing unleaded gasoline along with catalytic converters, banning two-stroke engines, imposing vehicle emission standards, and adjusting gasoline and HSDO prices to world parity levels.

CONCLUSION
Bearing in mind the relatively small size of changes in many of the variables discussed above, these results need to be qualified. Since data are limited, the CGE model in this paper cannot capture perfectly all relationships within the economy, within the environment, and between the economy and the environment. The underlying assumptions and structure of the CGE model and the simulation scenarios should also be carefully examined, and be borne in mind when interpreting the results (Resosudarmo 1996).

Given these caveats, several important conclusions can be drawn from the simulations described above. First, to be able to reduce all air pollution levels in urban areas to below WHO standards, abatement policies should be applied not only to mobile sources, but also to stationary sources of air pollution.

Second, to reduce the occurrence of air pollution illnesses, abatement policies should be implemented as soon as possible. From the simulation one learns that, even if the concentration of air pollutants in urban areas is relatively constant, more air pollutant related health problems will occur over time because the rate of urbanisation is relatively rapid. The sooner the concentration of air pollutants can be lowered, the more health problems that might otherwise occur can be avoided.

Third, the decision to produce unleaded gasoline should be accompanied by a requirement that catalytic converters be installed on new cars. The results of the simulation show that introducing unleaded gasoline alone lowers total GDP and incomes of poor households compared with the base case during the 20-year simulation period. On the other hand, if unleaded gasoline is accompanied by catalytic converters, total GDP and incomes of all households other than rural high income households can be increased.

Fourth, phasing out two-stroke engines and implementing vehicle emission standards are good for the economy and for household incomes, although their impacts on the economy and on air pollution are small. Implementation of these policies, whose costs are relatively small, brings about higher GDP and household incomes for all groups than would obtain under the base case.

Fifth, when adjusting gasoline and HSDO price upwards, it will be impor-
TABLE 5  *Impact on Sectoral Value Added of Switching to Unleaded Gasoline*\(^a\)

<table>
<thead>
<tr>
<th>Without Catalytic Converter</th>
<th>With Catalytic Converter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Negative</strong></td>
<td><strong>Positive</strong></td>
</tr>
<tr>
<td>Food crops</td>
<td>Other mining</td>
</tr>
<tr>
<td>Estate crops</td>
<td>Gasoline</td>
</tr>
<tr>
<td>Other crops</td>
<td>HSDO</td>
</tr>
<tr>
<td>Coal</td>
<td>Electricity &amp; gas</td>
</tr>
<tr>
<td>Natural gas</td>
<td>Services</td>
</tr>
<tr>
<td>Food processing</td>
<td>Industrial diesel oil</td>
</tr>
<tr>
<td>Kerosene</td>
<td>Natural gas</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>Kerosene</td>
</tr>
<tr>
<td>Other manufactures</td>
<td>Fuel oil</td>
</tr>
<tr>
<td>Trade &amp; storage</td>
<td>Other manufactures</td>
</tr>
<tr>
<td>Land transport</td>
<td>Trade &amp; storage</td>
</tr>
<tr>
<td>Air pollution health</td>
<td>Land transport</td>
</tr>
<tr>
<td></td>
<td>Air pollution health</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Negative</strong></td>
<td><strong>Positive</strong></td>
</tr>
<tr>
<td>Estate crops</td>
<td>Food crops</td>
</tr>
<tr>
<td>Other crops</td>
<td>Other mining</td>
</tr>
<tr>
<td>Coal</td>
<td>Coal</td>
</tr>
<tr>
<td>Natural gas</td>
<td>Natural gas</td>
</tr>
<tr>
<td>Industrial diesel oil</td>
<td>Industrial diesel oil</td>
</tr>
<tr>
<td>Kerosene</td>
<td>Kerosene</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>Fuel oil</td>
</tr>
<tr>
<td>Other manufactures</td>
<td>Other manufactures</td>
</tr>
<tr>
<td>Trade &amp; storage</td>
<td>Trade &amp; storage</td>
</tr>
<tr>
<td>Land transport</td>
<td>Land transport</td>
</tr>
<tr>
<td>Air pollution health</td>
<td>Air pollution health</td>
</tr>
</tbody>
</table>

\(^a\)The ‘negative’ and ‘positive’ columns indicate sectors in which value added falls or rises relative to the base case, depending on whether catalytic converters are introduced along with unleaded gasoline.

TABLE 6  *Impact on Sectoral Value Added of Gasoline and HSDO Pricing Policy*\(^a\)

<table>
<thead>
<tr>
<th>Pessimistic Outcome</th>
<th>Optimistic Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Negative</strong></td>
<td><strong>Positive</strong></td>
</tr>
<tr>
<td>Food crops</td>
<td>HSDO</td>
</tr>
<tr>
<td>Estate crops</td>
<td>Industrial diesel oil</td>
</tr>
<tr>
<td>Other crops</td>
<td>Kerosene</td>
</tr>
<tr>
<td>Coal</td>
<td>Fuel oil</td>
</tr>
<tr>
<td>Natural gas</td>
<td>Electricity &amp; gas</td>
</tr>
<tr>
<td>Other mining</td>
<td>Land transport</td>
</tr>
<tr>
<td>Food processing</td>
<td>Services</td>
</tr>
<tr>
<td>Gasoline</td>
<td>Other mining</td>
</tr>
<tr>
<td>Other manufactures</td>
<td>HSDO</td>
</tr>
<tr>
<td>Trade &amp; storage</td>
<td>Industrial diesel oil</td>
</tr>
<tr>
<td>Air pollution health</td>
<td>Kerosene</td>
</tr>
<tr>
<td></td>
<td>Fuel oil</td>
</tr>
<tr>
<td></td>
<td>Electricity &amp; gas</td>
</tr>
<tr>
<td></td>
<td>Services</td>
</tr>
</tbody>
</table>

\(^a\)The ‘negative’ and ‘positive’ columns indicate sectors in which value added falls or rises relative to the base case, under the pessimistic and optimistic assumptions.
tant for policy makers to find ways to ensure that the actual outcome is closer to the assumed optimistic outcome than to the pessimistic one. If the optimistic outcome is achieved, total present value of GDP and incomes of most household groups will be higher than those under the base case during the 20-year simulation period. If the pessimistic outcome occurs, the total present value of GDP during the simulation period will still be higher than under the base case, but not that of the income of most household groups. In particular, poor households will have lower total incomes under this outcome.

These results suggest that the government should consider producing only unleaded gasoline, requiring cars to have catalytic converters installed, phasing out two-stroke engines from urban areas, and imposing vehicle emission standards, as soon as possible. Gasoline and HSDO prices should be allowed to increase gradually but in significant steps, and public education activities should be stepped up to promote more efficient fuel consumption. By implementing these policies, the government can expect to achieve an improvement in urban air quality, as well as higher GDP and higher incomes for poor households.

NOTES
1 Below this standard undesirable human health effects do not occur.
2 The economic crisis that began in 1997 has delayed the implementation of this program.
3 Information on air pollutant abatement policies being considered by the Indonesian government was provided by Bapedal, unless otherwise stated. This paper includes as much information as is currently available on each of the policies. Only limited information exists for certain policies and this is reflected in correspondingly brief descriptions.
4 Gasoline vapour contains nitrogen monoxide, nitrogen dioxide and volatile organic compounds (VOC).
5 Motorcycles include the bajaj and the bemo (three-wheeled vehicles used for public transport).
6 See Resosudarmo (1996) for the full CGE program used in this paper.
7 A more recent SAM cannot be used in this paper, since no more recent map of air pollution is available.
8 See Lewis (1993) on how to disaggregate the oil refinery sector into these five sub-sectors.
9 See Resosudarmo (1996) for a detailed methodology for estimating the number of health problems related to air pollution.
10 Prices in any year of the simulation are in real terms.
11 This cost is based on information from a consultant firm hired by Bapedal.
12 Catalytic converters work effectively with unleaded gasoline.
13 To avoid any vehicle price increase caused by this requirement, the government subsidises the cost of producing new cars with catalytic converters for the first three years. It is estimated that the subsidy needed is approximately 0.5% of the total cost of producing new cars.
14 Further emission testing stations will be built in Jakarta, Surabaya, Bandung and Medan, and when there are enough stations in these four cities, stations will also be built in other large cities, such as Semarang, Solo and Yogyakarta. Vehicles from other areas must comply with the emission standard if they enter these cities. The cost of one monitoring station is assumed to be approximately Rp 1 billion.
15 Improving maintenance of existing vehicles in this scenario is assumed not to be costly. Existing vehicles should be tuned up two or three times a year. If this regular tune-up does not produce acceptable emission levels, then owners must sell their vehicles to rural areas.
16 The gasoline and HDO pricing policy has a similar impact on NO2 levels, but only assuming a highly optimistic outcome.
17 If price increases come in small steps, people may become used to each increase without changing their behaviour. If the
prices are adjusted in large steps, the impact will be greater and people will have a strong incentive to become more efficient. Hence, the gradual price changes should be large enough to provide an incentive for people to change their behaviour.

GDP as discussed here is GDP excluding air pollution health treatment. This enables us to see clearly the impact of air pollution policies on economic output other than air pollution related health service provision.

The impact of this investment occurs after a one-year lag.

Note that household ‘incomes’ as discussed in this paper are incomes net of air pollution health costs. This enables us to see clearly the impact of pollution abatement policies on households’ command over consumption other than treatment for pollution related illnesses.

Low income households’ income elasticities are typically larger for food than for other goods and services.

See note 17.

REFERENCES


Nurrohim, A., M.S. Boedoyo and C. Malik (1994), Technological Options of Air Pollution Abatement, Cost, and Benefits, Agency for the Assessment and Application of Technology (BPPT) Internal Report, Jakarta.


Workshop on Urban Air in Jakarta, 26–27 May, Jakarta.
APPENDIX
This appendix explains the features of the CGE model for analysing the impact of air pollution abatement policies on pollution related health problems and the economy.

The model consists of six equation blocks, as follows.
- **Production Block**: represents the structure of production activities and producers’ behaviour.
- **Consumption Block**: represents the behaviour of households and government.
- **Export-Import Block**: models exports and imports of goods and services (Armington 1969).
- **Investment Block**: simulates decisions to invest as well as the demand for goods and services used in the construction of new capital.
- **Market Clearing Block**: contains market clearing conditions for labour, goods and services, and foreign exchange.
- **Intertemporal Block**: consists of dynamic equations that link future economic conditions to economic activities in the current year (Dervis, de Melo and Robinson 1982).

In the production block, a nested Constant Elasticity of Substitution (CES) function represents the production technology. At the upper level of this production function, output is defined as a CES function of composite intermediate input and value added. At the lower level, intermediate input is a Leontief function of several material inputs (see also Devarajan and Lewis 1991; Lewis 1991; and Resosudarmo 1996). Value added is a function of air pollution related illnesses and factor inputs, in which factor inputs are expressed in a CES function. The value added function is:

\[
VA_i = HE_i \cdot \alpha_i \cdot \left( \sum_f \beta_{i,f}^* \cdot FD_{i,f}^p \right)^{-\frac{1}{\rho^*}}
\]  
(A1)

where:

- \( i \) is the production sector index;
- \( f \) is the factor of production index (agricultural labourers, manual-clerical workers, professional personnel, land and capital);
- \( VA \) is composite value added;
- \( HE \) is the impact of human air pollutant related illnesses on value added; and
- \( FD \) is factor input.

The impact of air pollutant related illnesses on the value added production activity (\( HE \)) is assumed to be a function of the number of restricted activity days caused by illness. It deserves mention again that this paper limits its analysis to air pollutant related illnesses in urban areas and the impact of these illnesses on urban (non-agricultural) production sectors. The impact of air pollutant related illnesses on the value added function is then as follows:

\[
HE_i = \left(1 - \frac{RAD_i}{DA_i}\right) \quad \forall i \notin \text{agricultural sector (A2)}
\]

and

\[
HE_i = 1 \quad \forall i \in \text{agricultural sector(A3)}
\]

where:

- \( RAD \) is the number of restricted activity days caused by air pollutant related illnesses; and
- \( DA \) is the number of workdays that are available if no air pollutant related illnesses occur.

From relationships (A2) and (A3), one can see that an increase in the number of restricted activity days caused by air pol-
lutanant related illnesses reduces the productivity of all factor inputs.

Production activities are linked to ambient air quality via the fixed proportion coefficients (input–output coefficients) of oil-based fuels. Ambient air quality is thus a function of the amount of oil-based fuels used in production activities. The input–output coefficients are a function of government and/or private sector spending on technologies and services that lead to more efficient use of oil-based fuels; i.e. the higher such spending, the lower the coefficients. For example, if vehicle owners spend more to make the use of gasoline more efficient, the gasoline input–output coefficient in the transportation sector decreases.

In the consumption block, 10 different types of household groups are distinguished. The expenditures of each household group on goods and services, except for necessary health treatments for air pollutant related illnesses, are a function of prices and income. Each household group determines its expenditures by maximising utility according to a simplified version of the Linear Expenditure System, subject to the group’s budget constraint (Lewis 1991). The budget constraint of each household group equals household income minus taxes, savings, necessary health expenditures associated with air pollutant related illnesses, and net transfers among households. The following equation represents the budget constraint of each household group:

\[
\sum_{i \neq m} P_i \cdot C_{i, h} = Y_h - T_h - S_h - CH_h - TR_h
\]

(A4)

where:

- \( h \) is the household group index;
- \( m \) is the index for health services consumed by households that experience air pollutant related illnesses;
- \( P \) is the price of commodities;
- \( C \) is household consumption of commodities;
- \( Y \) is household income;
- \( T \) is income taxes;
- \( S \) is household savings;
- \( CH \) is household health costs associated with air pollutant related illnesses; and
- \( TR \) is net household transfers.

Since this paper limits its analysis to air pollutant related illnesses in urban areas, the health costs associated with these illnesses (\( CH \)) in relationship (A4) only appear in the budget constraints of urban household groups; i.e. for a non-urban household, \( CH \) is assumed to be zero. From the relationship (A4), one can see that a reduction in health costs associated with air pollutant related illnesses effectively creates extra income for urban households to spend on goods and services other than air pollution related health treatment.

Household spending on health treatment associated with air pollutant related illnesses depends on the number of these illnesses that occur. The quantity of air pollutant related illnesses is a function of the ambient level of air pollutants. The ambient level of air pollutants is a function of the quantity of oil-based fuels used in economic activities. The following equation represents the number of air pollutant related illnesses (see also Garbaccio et al. 1999):

\[
N_{p,k} = \delta_{p,k} \left( \sum_{an} \sum_{l} M_{l,p,an} \cdot Y_{l,an} \cdot IN_{an} \right) POP
\]

(A5)

where:

- \( p \) is the air pollutant index (for levels of SPM, \( NO_2 \), and lead);
- \( k \) is the air pollutant related illnesses index (for levels of lower respiratory illnesses, asthma attacks, respiratory symptoms, chronic bron-
chitis, hypertension and non-fatal heart attacks; 
\( l \) is the oil-based fuels index (for levels of coal, natural gas, gasoline, HSDO, industrial diesel oil, kerosene and fuel oil); 
\( an \) is the index for non-agricultural sectors; 
\( N \) is the number of people who contract health problems; 
\( \delta \) is the air pollutant dose–response coefficient; 
\( \mu \) is the air pollutant emission coefficient; 
\( \gamma \) is the input–output coefficient; 
\( IN \) is the composite intermediate input; and 
\( POP \) is the total population at risk of air pollutant related illnesses, i.e. the number of people in urban areas exposed to the air pollutants under consideration.

Equation (A5) is known as the dose–response function. It defines the number of people who contract health effect \( k \), given that a total population \( POP \) is exposed to a certain level of air pollutant \( p \). (The same form of equation as in relationship (A5) is also used to determine the number of restricted activity days (RAD) associated with air pollutants.) The expression \( \sum an \sum l \mu_{i,p,an} \cdot \gamma_{l,an} \cdot IN_{an} \) defines the ambient level of air pollutant \( p \). The air pollutant emission coefficient \( \mu_{p,an} \) is a function of government and private sector investment in air pollutant abatement technologies and services. For example, if the national oil company decides to reduce the lead level in gasoline, the lead emission coefficient from gasoline \( \mu_{\text{GASOLINE,LEAD,an}} \) declines.

Finally, the closure rules of this CGE model are as follows.

- The current account balance is fixed exogenously and the exchange rate is the equilibrating variable (see also Thorbecke 1992).
- Real government expenditure is fixed exogenously and government saving is determined residually.
- Land and capital are determined exogenously. The markets for agricultural, manual–clerical, and professional labour are assumed to be always in a full-employment equilibrium (Lewis 1991).