ENERGY AND ECONOMIC ADJUSTMENT

The Industrial Institute for Economic and Social Research, Stockholm

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Foreword

A major research effort of IUI and EFI in recent years has been directed towards analyzing the role of energy in the Swedish economy and ways of adjusting the economy to disturbances in the energy markets. The project - called Energy and Economic Structure - has been financed by the Energy Research Commission. B.-C. Ysander has been coordinating the project at the IUI and K.-G. Mäler has been responsible for the EFI part. The present book is part of the ongoing documentation of this work.

The two papers collected in this volume are both concerned with the problems raised by the instability and uncertainty of energy prices and with the alternative Swedish policy options available for dealing with these problems. Both papers report on simulation experiments carried out on macro-models for the Swedish economy, specially designed for this purpose at IUI and EFI respectively. These simulations, covering the period up to the turn of the century, exemplify the impact of changing international energy prices with present Swedish policies, as well as the differential effects of alternative policies aimed at easing the domestic adjustment. Apart from the particular insights and policy recommendations to be drawn from these simulations, their integration of energy policies within the wider problem of macro-economic stabilization should prove instructive and should help in avoiding many of the pitfalls encountered in more specialized energy studies.

Stockholm in September, 1983

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Contents

Page

OIL PRICE INSTABILITY AND ECONOMIC FLEXIBILITY
An Introduction

The oil price hikes and the stagflation experience of the 70s demonstrated how inflation-prone and how vulnerable to supply shocks the industrialized economies had become. Attention became increasingly focussed on questions of supply elasticity and price stabilization in general and energy policy in particular.

The problem of adjusting to changing energy prices is especially crucial for a small open economy like the Swedish, where imported oil makes up a major part of total fuel supply. Tracing the impact of changing energy prices on the Swedish economy is therefore a primary concern for economic research. The lessons learned from such analysis should help in the task of devising ways for national energy policy of reducing or accomodating the impact of future sudden changes in the oil price.

The two studies assembled in this volume are both preliminary attempts to meet this double challenge to empirical research and policy analysis. Although they start with a common problem - and indeed use common or similar data and assumptions about the future - their conceptual frameworks differ enough to allow them to treat different aspects and to arrive at different but complementary results.

The Instability of the Oil Market

The emergence of the OPEC cartel and the resulting oil price hikes in the 70s may not have fundamentally changed the long-run real price trend for oil. Short-run price expectations and market stability did however change radically.

In the very long run the real oil price should continue to increase. If we had, i.a., a given volume of proven reserves, given small and constant extraction costs and could assume the same risk-scenario for oil as for other lines of business, the celebrated 'Hotelling's rule' would hold. The annual rate of price increase should then tend to be close to the rate of interest, giving the owners the same rate of return on oil in the ground as on other capital assets. The existence of secondary deposits with higher extraction costs, being successively taken into use as the price goes up, does not in principle change this rationale. The discovery of new reserves and the development of new extraction technologies do however tend to make the rule at best an imprecise and fallible guide to long-run price trends in oil. By accelerating the search both for oil and for ways of saving oil, the oil price hikes, if anything, contributed to an increased consciousness of the uncertainties involved in any long-run oil forecasting.

The international oil market has always had certain characteristics which tend to make it potentially instable. Relatively small consumer stocks and a low short-run price elasticity combined with a freely fluctuating spot market pricing and a lack of substantial forward oil markets make wide price fluctuations possible.

Oil price changes, moreover, undoubtedly affect income levels while oil usage is a function both of income and oil price. The income elasticity seems to be close to unity in the short-run and the long-run price elasticity may well - as the experience of the last decade seems to indicate - be rather high. Drastic changes in the oil price could thus tend to be countered by demand shifts in the medium term, possibly giving rise to price cycles.

When the hegemony of the "seven sisters" was broken by the emergence of the OPEC cartel, this potential instability became a reality. The two oil price hikes demonstrated the risk for OPEC pricing to "overshoot", setting off cyclical changes in world economic activity and energy demand. The increasing instability could also to a large extent be looked upon as a case of uncertainty breeding on uncertainty. A tendency towards shortened contract times, a convergence of contract prices between consumer groups and between countries, an increased sensitivity to changes in spot prices and a growing propensity to inventory speculations, all contribute to this impression. This inherent market instability is further accentuated by the instable structure of the OPEC itself and by the political instabilities of some oil producing countries creating risks of major supply disturbances.

Unfortunately there seems to be no reason to expect these uncertainties and stability problems to become resolved in the near future. In the years to come we may well have to cope again with supply disturbances or with sudden price jumps being caused by shifts in expectations acting on supply strategies and on inventory speculations.

In both the simulation studies reported in this volume, the standard representation of these price risks is a 60 percent oil price hike occurring in 91, after a decade of stagnant or slowly increasing real oil prices.

The costs of inflexibility

In a perfectly flexible world economy, with all factors easily mobile and prices flexible enough to assure instantaneous clearing of all markets, even shifts in relative prices of the order of the oil price hikes would probably be accomodated without any great losses in real income. Since we cannot have cartels in this kind of world the oil price increase could instead be thought of as e.g. the result of unexpected problems in extraction technology leading to a jump up in marginal extraction costs. This would be followed by a consequential shift in relative prices and in the pattern of demand and trade in an energy-saving direction and a redistribution of the gains of trade in favor of the oil exporting countries. As long as the increased rent accruing to the oil producers almost covered the increased costs of the oil consumers there would, however, not necessarily be any substantial change in world real income. Even if the extraction cost went up for all oil, the expected loss in real income would probably be marginal.

Oil and its substitutes do after all only account for a very minor part of the total bill for companies and households.

The simple lesson to be drawn from this parable is that most of the problems and welfare losses we associate with oil price hikes - in the past and in the future - are really due to adjustment difficulties, to various kinds of inflexibilities in the economy. For our purposes here it is sufficient to distinguish three main groups of adjustment obstacles: technological inflexibilities, price or market inflexibilities and (government) policy inflexibilities.

By technological inflexibilities we refer to the fact that technological choices of the past are reflected in today's capital equipment and labor training. Shifts in relative prices can make these equipments inoptimal. Adjustment to a new price structure may however be costly and time-consuming. In the extreme case of total inflexibility, factor substitution can only be realized by scrapping the old equipment and installing new capital equipment.

An oil price hike can therefore be expected to render part of the capital equipment inoptimal or even economically obsolete[1]. The more inflexible the capital equipment is - the smaller the elasticities of substitution in the ex post production functions are - the bigger will be this "capital loss".

Both the studies reported in the following use models, incorporating technological inflexibilities by way of a vintage capital approach. Each vintage of capital in a manufacturing sector, once invested, reflects the technological choice of that year based on the then current factor prices. In most cases considered the main factor proportions will be fixed by this choice although there are possibilities for ex post substitution between types of primary energy or at least between fuels.

In the study by Bergman-Mäler (in the following referred to as BM) the problem of technological inflexibility is discussed in some detail, both theoretically and by numerical examples. In their analysis the authors develop the notion of a trade-off between efficiency on the one hand and ex post substitution on the other. By sacrificing some efficiency - and thus accepting a higher cost - one could achieve a technical design that allowed for greater substitution possiblities and thus enhanced the opportunity of adjusting to unexpected shifts in relative factor prices. They also exemplify numerically how such a "flexible" design could significantly modify the real income loss associated with a future oil price hike.

Probably more important, and certainly more extensively treated in economic theory, is the inflexibility of prices and markets. Instead of the price structure adjusting to new equilibrium levels after a sudden price change like an oil price hike, we may, as the experience in the 70s shows, get into a domestic inflationary spiral. Compensatory wage claims may be successively unloaded onto foreign customers resulting in a drop in sales abroad and a rising unemployment at home. Immobility in factor markets, institutional regidities in the wage- and price-setting process and monopolistic behavior of firms and unions may together prevent adjustment long enough to create stability problems in the form of inflationary expectations, market share losses and increased unemployment that can take a long time to overcome.

In the BM study an equilibrium model is used. The authors however have tried to measure how the real income loss, associated with an oil price hike, would grow if some of the equilibrating price mechanisms were prevented from functioning. From their simulation experiments they conclude, not surprisingly, that economic flexibility is of overriding importance, and i.a. helps to compensate for the lack of technological flexibility.

In the study by Nordström-Ysander (henceforth referred to as NY) a dynamic disequilibrium model is used, incorporating beside technological inflexibility, various kinds of obstacles for market adjustment, like sticky wages and prices, regulated prices, cash-flow restrictions on investment and the inertia and lags observed in both private and local government consumption. With these market inflexibilities built into the model, the adjustment after an oil price hike will not only be drawn-out but will also tend to be aggravated by unemployment and inflation problems. As a consequence NY have felt the need for modeling and exercising more explicitly some instruments for a government stabilization policy, varying from the control of aggregate demand by way of taxes and government consumption to wage policies and exchange rate decisions. In their simulations they assume that the Swedish government tries, after an oil price hike, to regain full employment, external balance and price stability within three years. Whether these attempts succeed, and how costly the compensatory policies will prove to be in terms of real income losses and temporary unemployment will to a large extent be determined by the degree of policy flexibility the government enjoys. The NY simulations exemplify what already the Swedish experience in the 70s seemed to show, viz. that restrictions on policies - say narrow limits for the use of wage policy or for changes in public consumption, arising out of general political considerations or a concern for special interest groups - may multiply the cost of adjustment and even make stabilization goals unattainable. This result is at least consistent with the not uncommon view, assigning a major part of the blame for the protracted stagflation problems in Sweden to the lack of a concerted and well-timed stabilization policy in the Western countries in general and in Sweden in particular.

For a small open economy like Sweden, the direct impact of an oil price hike is only half the story. Of sometimes equal importance is the indirect effect by way of changes in prices and demand conditions in the world markets. These changes in their turn can probably be traced back, to a large extent, to the various inflexibilities in the economies concerned. NY have tried to measure the possible relative importance for Sweden of the indirect effects, given a similar world economic scenario as in 1973. They conclude that these may add as much as 50 percent to the adjustment costs after an oil price hike. BM have made some similar calculation of the effect of international price changes, given that these prices develop analogously with the relative prices in Sweden.

Increasing Flexibility

The economist's analytical tools will always to some extent guide his choice of problem, his way of reasoning and the answers he comes up with. The two studies assembled here are no exception. Applying different conceptual frameworks to the same data, they formulate their questions in different ways and sometimes get widely - but not necessarily inconsistent - answers. By publishing them jointly the reader is thus given a good chance to see how different energy problems may look when you change the angle of approach.

This ways already exemplified above where we described how the two studies focused on different kinds of inflexibilities in tracing and analyzing the impact of an oil price hike on the Swedish economy. Their analyses of different policies for dealing with the oil price uncertainty are equally shaped by the analytical tools provided by their different models. Three main types of policy measures are discussed: increasing flexibility, pooling price risks and reducing oil dependence.

Even if you cannot do anything about reducing the price uncertainty you can always try to lessen the cost of adjusting to unexpected changes by increasing the flexibility in the economy.

For BM, with a model built around the concept of a competitive equilibrium, with firms and households as main actors, the interest is naturally focussed on attempts to improve the efficiency of the equilibrating mechanisms by increased technological and price flexibility. They thus stress the importance of factor mobility and competitive pricing for easing the adjustment to new relative prices. Particular attention is paid to the possibilities of stimulating flexible designs of production plants and the moral hazard involved in any demand stabilization scheme, which tends to diminish the incentive for such built-in flexibility.

With their disequilibrium model, incorporating various kinds of "inflexibilities" in the form of institutional inertia, time-lags and feed-back effects of market disequilibria, NY tend to treat the dynamic performance, or non-performance, of the market economy as given. Instead their interest is focussed on the possibilities of compensating for these inflexibilities by way of government stabilization policies. They therefore underline, and illustrate numerically, the importance of policy flexibility - of having enough political room for maneuver - and suitable policy instruments - to enforce a necessary rapid adjustment after a major oil price change.

Sharing Price Risks

Instead of just easing the adjustment to unexpected price changes one may want to deal directly with the uncertainty arising from an instable oil market.

One way to do this could be for the government to offer a limited insurance against sudden major changes of the oil price. The offer could e.g. take the form of guaranteeing that the annual change in domestic real oil price would never exceed say 5 percent. By taxes and subsidies, respectively, the central government would thus provide a hedge against too abrupt changes without, however, trying to impose a long-term price trend. The arrangement could be regarded as a simple scheme of risk pooling with a certain limited individual liability.

The general argument for such a risk pooling is well known. Under certain general conditions the total cost of riskbearing goes down when shared by many individuals (cf. Arrow-Lind, 1970).

The oil price risks are very unevenly distributed in the economy.

Some investors e.g. in oil substitutes stand to loose considerably in the event of an oil price slump - while the opposite is true of heavy oil users and their customers, etc. Given a certain degree of relative risk-aversion the economy as a whole then stands to gain by having some kind of risk-pooling arrangement. By letting the less risk averse government shoulder a major part of short-term price risks there will i.a. be less danger of the price uncertainty impeding otherwise desirable investments, etc.

Two types of costs for such a risk-pooling should be mentioned. If the sudden shift in oil price level proves to be permanent, the government guarantee will tend to slow up the necessary adjustment, giving an edge to foreign competition. The second disadvantage, discussed in depth by BM, is that the incentive to design flexible plants is correspondingly diminished. If flexibility to adapt to temporary fluctuations is of limited importance, this "moral hazard" argument may however not carry the same weight in relation to a pure risk-pooling arrangement as it would in connection with a long-term price guarantee.

Reducing Oil Dependence

In the simulation experiments reported in the two studies, the policies studied go beyond a mere risk-pooling and take the form of a long-term price guarantee. In the BM study the guaranteed price is immediately fixed at a very high level, making it possible to compensate for future oil price hikes by lifting off a corresponding part of the oil tax. NY use instead a steadily rising oil tax, but again with the aim of being able to compensate any abrupt price increases with tax cuts.

One major result of any such oil tax scheme will be a forced acceleration of oil saving in the economy.

The simplest way to argue for this extension from pure risk pooling to long-term price guarantee would be to assert that central government knows better, having more foresight and a longer horizon than the individual agents in the economy. However, the "track record" of central government forecasting and action in the energy field is not particularly convincing at least not when compared with that of big companies. It could however still be the case that e.g. households and local governments tend to be even more biased or myopic than central government.

Leaving aside these questions of informational assymetries there are other ways of arguing for and against a price guarantee.

The BM simulation study of this policy alternative exemplifies two kinds of disadvantages. One is the moral hazard already mentioned above, which becomes much more troublesome in connection with long-term price guarantees. The second type of "cost" has to do with the risk of adjusting to the "wrong" price structure. Forcing the agents to adjust to a high oil price with other international prices being kept unchanged, means that if and when the international oil price goes up and causes a realignment of other world market prices, the Swedish investor may find himself badly out of tune with the then current international price structure. The BM simulation shows that the real income effects of such a misallocation may be quite substantial.

In interpreting the BM measurement of these relative "price distortion" effects one should however keep in mind that their experiment was based on the assumption of a rather extreme government oil tax policy, trebling the 1979 price level and then keeping this level unchanged.

Both these arguments dealing with moral hazard and relative price distortion, respectively, hold true even if the government turns out to be right about the direction and size of the long-run change in the oil price. If no oil price hikes occur and the price trend, up to the turn of the century, does not develop according to government expectations, there will be another and substantial cost of the price guarantee due to the "misguided" investments in an oil-saving direction. Within the framework of the BM analysis the benefits are to low to offset the costs of extending the risk-pooling into a full-fledged long-term price guarantee. Apart from the possibly beneficial effects of further reducing the price uncertainty of private agents in the economy, the main argument for a price guarantee hinges on the probability that government fears about sudden huge price increases turn out to be well founded. In that case Swedish producers and consumers will profit from having had, as it were, advance notice. The profit could however be significantly reduced by the relative price distortion discussed above. The BM evaluation of oil price guarantees by way of energy taxation for these reasons ends on a sceptical note, the negative conclusions being underlined by the way their simulation experiment was set up.

NY, in their study, arrive at a more positive evaluation, not only by using another experimental design but primarily by looking at the price stability problem from another conceptual angle and with a different focus of interest.

In their simulation they add a cumulative oil tax during the 80s, so that by '91 - if a 60 percent oil crises occurs - they can just offset the price hike by lifting off the tax. If there is no price hike the tax level is either kept unchanged or reduced successively so as to stabilize or lower oil prices in the 90s. Compared to the BM experiment, this design could obviously in itself be expected to present the argument for a price guarantee in a kinder light.

Moreover, the characteristics of their model make it natural for them to trace closely the disequilibrium developments during the 80s and to focus attention on the efficiency of government stabilization policies.

The external payment deficit problem that may well continue to be a primary concern of Swedish economic policy for the rest of the decade, could provide an independent reason for concentrating a necessary oil saving to the 80s instead of spreading it out over both the 80s and the 90s. A "tariff" on imported oil implies - at least in the short run - a certain terms-of-trade gain, which will be the greater the more price sensitive Swedish oil consumers are and the less price sensitive our foreign customers are. In as far as our deficit problems will force the Swedish government to adhere to a very hard-fisted domestic demand policy over the next few years in order to support an export-offensive, a "forced" oil saving may help to ease this adjustment.

A corresponding concern about macro-economic adjustment provides the basis also for the main NY argument in favor of a price guarantee.

Given not only various kinds of technological and economic inflexibilities but also restriction and/or inertia in the decision making of stabilization policy, reducing the stabilization threat by a "forced" oil-saving could substantially increase the probability of a successful macro-economic adjustment after an oil price hike.

This is one of the major conclusions of the NY discussion on price guarantees. The fact that it more or less falls outside the framework of the BM analysis helps to explain the different evaluation results of the two studies. Instead of looking, as the BM study primarily does, for first-best solutions by way of restoring technological and economic flexibility, the more pessimistic NY study is searching for second-best solutions for the case where these rigidities remain and are reinforced by inflexibility in government policy.

Economic Research and Energy Policy

That the treatment of price uncertainty is a major problem for energy policy may not be a very controversial proposition. The two studies in this volume however illustrate that there are many different ways of tracing the impact of price changes and of designing counteracting policies. Different choices of analytical tools may lead you to highlight different economic mechanisms and different policy options.

If the only lesson of the studies was a further proof of the relativity of economic policy analysis the reader would have reason to feel frustrated, when faced with imminent policy decisions.

There is, however, another and more fruitful way of interpreting the results. The two studies to a large extent complement each other in focussing on different, although connected, problems and in evaluating policy options under different assumptions. It is rightly left for the policy-maker to decide what types of problems and risks, that are most probable to arise and that should be given priority and what political solutions are feasible within the Swedish political context. Are the various forms of economic and technological inflexibility not only more important than "policy inflexibility" but also easier to modify by political action? How much credit should be given to statements about long-term price trends? How well have the governments learned the lesson of the 70s and how much better can they be expected to manage the necessary macro-economic adjustment and ward against grave disturbances in world trade after another oil price hike?

These are the type of questions the policy-oriented reader must answer, before being able to pick out the most relevant arguments and results from the selected research menue presented in the following papers.

NOTE

[1] Since different types of production capital are aggregated in economic accounts by using some profitability indicator like capital value as weight, one important effect of an unanticipated oil price hike is that part of the aggregate production capital as usually measured is "destroyed" or "lost". For a stringent discussion of this measurement problem cf. Berndt-Wood (1983).

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Oil Price Uncertainty and National Energy Strategies

by Lars Bergman and Karl-Göran Mäler

1 THE NATURE OF OIL PRICE UNCERTAINTY

Since 1973 the world market real price of oil has increased very substantially. Moreover, the much higher real oil price level has been attained by means of two quite dramatic "jumps", one in 1973/74 and one in 1979. These events have very much changed the perceptions about the international oil market as well as about national energy policies. To begin with there seemed to be a very firm belief that real oil prices would continue to increase in the future. In view of recent developments on the international oil market, the opinions about the medium term outlook are a little more mixed. Yet prominent studies of the field seem to indicate that there is an increasing long term trend in the development of real oil prices.[1] The details of the future oil price developments, however, are generally regarded as very uncertain.

Many economic arguments can be put behind these beliefs. Thus, since oil is an exhaustible resource, its real price should increase in the long run. Under certain idealized conditions the annual rate of increase should be close to the real rate of interest. This is the celebrated "Hotelling's rule". Its rationale is very simple: Being an exhaustible resource, oil in the ground can be looked upon as a capital asset. The owners should expect, or demand, the same rate of return on oil in the ground as they can get from other capital assets. But oil in the ground gives no annual dividends, so the entire rate of return has to take the form of capital gains, i.e. increases in the market price of oil. These price increases, then, can be attained by means of a suitable supply policy.

From the logical point of view, Hotelling's rule offers a very nice rationale for the notion of ever increasing real prices of oil. Its explanatory power in empirical analyses, however, has so far turned out to be rather limited. (See for instance Pindyck, 1982). But this failure of the rule can partly be explained in terms of the economics of the international oil market.

One characteristic feature of the demand for oil is that, in the short run, the income elasticity is close to unity while the own price elasticity is very small. This means that supply interruptions at given income levels, as well as a recovery in the world economy at more or less given oil supply levels, can produce quite significant oil price increases in the short run. But the increasing evidence about relatively high long run price elasticities in the demand for oil (see for instance Pindyck 1980 and Bohi 1981) suggests that significant oil price increases might be counterproductive in the long-run from the oil producers' point of view.

Lacking organized future (in he form of actual markets or vertically integrated firms) and contingency[2] markets for oil the oil, producers have great difficulties in finding a supply strategy which would maximize the value of their oil resources. Essentially all supply decisions have to be based on expectations about future income levels in the oil consuming areas, incomplete evidence on short- and long-run price elasticities of the demand for oil as well as about the behavior of other oil suppliers. In addition the "uninsurable" uncertainty about the outcome of activities such as technological change, exploration etc. has to be taken into account by the decision makers both on the supply and the demand side.

Under these conditions the future development of oil prices to a very large extent depends on how expectations about future oil prices are formed. Thus, if a drop in oil prices is taken as a sign of a long-run reduction in the oil price level, oil producers might want to increase their current supply in order to benefit from the current, relatively high, price level. But if such reactions are quantitatively significant, they are likely to produce additional drops in the market price of oil. A similar argument can be made in the case of an initial increase in the price of oil; the reactions of the producers, and perhaps the consumers, might induce additional price increases.

In other words, depending on the nature of expectations, a lack of future markets can lead to a very unstable development of the international oil market. Moreover, in a short or medium term perspective, price fluctuations might be a much more important aspect of the international oil market than a possible tendency towards ever increasing price levels. In other words, oil price uncertainty is not only uncertainty about how much and when the price of oil will increase, but uncertainty about the magnitude and direction of future oil price changes. Consequently it can be argued that the main task of national oil policy is to cope with oil price fluctuations rather than with gradually increasing oil prices. That is the basic point of departure in this study.

The purpose of the study thus is to explore some of the economic consequences and policy implications of oil price uncertainty. Although the analytical approach is fairly general, it is the consequences for the Swedish economy and the implications for Swedish energy policy we have in mind. Needless to say, our choice of focus does not imply that oil price uncertainty is the only factor of relevance for the formation of Sweden's energy policy. For the moment being, and in this particular study, however, our attention is entirely focused on the economics of oil price uncertainty.

Our analysis of the economics of oil price uncertainty is focused on three particular, and interrelated, aspects of the problem. The first is the economic impact of unexpected oil price increases. Here, like in most of the other parts of the study, the analysis is carried out on a fairly aggregated level. Much of the analysis deals with the relation between aggregated real income measures and the oil price level. In particular this relation is studied under various assumptions about domestic energy policy strategies, the substitutability of oil and other factors of production and the flexibility in the economy's resource allocation mechanism. Most of this analysis is presented in Chapter 2 and Chapter 3.

The analysis in these chapters to a large extent is carried out in terms of numerical illustrations based on model simulations. The results clearly indicate that oil price level indeed matters for the domestic real income level. One can say that the real income level in Sweden exhibits a considerable oil price vulnerability. Once this, not very surprising, result has been established, there is reason to look for a strategy which, given the oil price uncertainty, would lead to the most desirable development of the economy. The analysis of this issue, which involves the introduction of the concepts "economic flexibility" and "technological flexibility", is presented in Chapter 4.

One of the main findings in Chapter 4 is the importance of economic flexibility, i.e., the ability of the economy to reallocate resources in response to changes in the economic environment. Another important result is the need to let individual decision makers be faced with the real uncertainty in order to induce them to include technical possibilities of substitution in their oil consuming plans.

The analysis in Chapter 4 is, however, based on the assumption of risk neutral decision makers. In Chapter 5, the opposite case is studied, namely the case when individual decision makers are risk averse and have no means of designing plants more flexible. In this case, we show that society should be more risk neutral than the individuals, and in order to induce a more risk neutral behavior, some, but less than complete, stabilization of the oil price level might be an appropriate policy strategy.

The next step in the analysis is, concerned with the policy implications of oil price uncertainty. More specifically the question is whether or not an unregulated market economy tends to produce optimal resource allocation patterns when there is oil price uncertainty, and, if a need for government intervention can be established, how an efficient energy policy strategy should be designed. These issues are dealt with in Chapter 5 and Chapter 6. In Chapter 6 we also draw the conclusions of our analysis.

NOTE

[1] This result came out from all the 10 models used by the Energy Modeling Forum (EMF, 1982) for oil price simulations over the period 1980-2000.

[2] I.e. an institutional arrangement which makes it possible for the agents to make the specific features of their agreements contingent on the actual outcome of uncertain events, such as exploration, technololgical development and so forth.

2 REAL INCOME AND THE OIL PRICE LEVEL

2.1 Introduction

Before approaching the problem of energy policy under conditions of oil price uncertainty in more general terms, the results of some numerical comparative statics experiments are presented in this section. The purpose of these experiments is to indicate the relation beween the real income level in the Swedish economy and the real oil price level under different energy policy assumptions.

Needless to say, the results presented below are just numerical illustrations; the definition of energy policy strategies as well as oil price scenarios are chosen for illustrative purposes and thus are not regarded as the most probable future outcomes. Both the energy policy strategies and the oil price scenarios chosen, however, seem to be well within the feasible set of future outcomes.

2.2 Energy Strategies and Oil Price Realizations

The analysis is designed in the following way. At each point in time there is an (unspecified) probability distribution for the world market price of oil. The mean value of this distribution, i.e. the expected price of oil, is assumed to increase by 2 percent per annum in real terms. In our comparative statics experiments, we are concerned with the situation 1991, and we consider two particular realizations of the world market price of oil that particular year. That is, in order to get a first hand feeling for the relation between oil prices and domestic real income levels, the numerical experiments are confined to two points on the probability distribution for oil prices. One investigated oil price realization is that the price of oil attains its expected value in 1991, while the other implies an oil price level 60 percent above the expected level that year.

Obviously the analysis has to be based on some projections of the state of the Swedish economy in 1991. These projections, as well as the comparative statics, are generated by means of a multiperiod, multisectoral numerical general equilibrium type of model. (This model belongs to a system of computable models developed within this project. The model system is fully described in the appendix, as well as in Bergman 1982). The projections are based on three sets of assumptions, differing only with respect to the assumption about national energy policies. Thus, for convenience we can refer to the sets of assumptions as "energy policy strategies".

One of these strategies, Strategy 0, is taken as the "reference case" and denoted "passive". That is, no particular changes in domestic energy policies are assumed. The other two strategies both represent a particular type of oil conservation policy, Strategy 1 being a case where conservation efforts are "modest", while these efforts are "vigorous" in Strategy 2. In view of the specification of the computation model, the energy policy strategies can be described in terms of their implications for the oil-price expectations held by the producers in the economy. The reason for that is as follows.

The basic assumption about technology in the model is that it exhibits the so-called putty-clay property in terms of capital use and energy input coefficients. Moreover, technical change is assumed to be entirely embodied. This means that decisions about investment and technical coefficients in new production units have to be based on the producers' (and investors') expectations about future input and output prices. Consequently the sectoral allocation of real capital and the **ex post** (fixed) energy input coefficients at a given point in time reflect the price expectations held at various previous points in time.

In the reference case, i.e. "Strategy 0", producers are assumed to have static expectations. That is, currently observed relative prices are expected to prevail also in the future. Energy policy is assumed to improve the producers' foresight about future oil prices and thus the design of new production units. For the moment being we are not concerned about whether some government agency could, or should try to, accomplish such a task. To give a flavor of reality to the strategy definitions, however, the "active" policy strategies could be regarded as a set of regulations of oil input coefficients in new plants. The prescribed coefficients are defined as the cost-minimizing oil input coefficients at a specific oil price level (and current prices of outputs and other inputs). Throughout it is assumed that the regulation of oil input coefficients is efficient, i.e.

that the oil use restrictions imposed in various sectors of the economy all reflect the same implicit oil price level.[1]

As mentioned above Strategy 1 can be regarded as a "modest" conservation strategy. More specifically this means that the regulations are consistent with an assumption about a gradual increase by 2 percent per annum of real oil prices.[2] Strategy 2, on the other hand, represents a "vigorous" conservation effort. Thus, the regulations of oil input coefficients in new production units reflect an oil price level which is 300 percent higher than the one implicitly assumed in Strategy 1.

To sum up we have three energy policy strategies and two oil price realizations in 1991. Thus we can depict six alternatives for the state of the Swedish economy in 1991. There is, however, no reason to compare these alternatives on a full scale. Instead we limit ourselves to a comparison of the real income levels attained in the six cases. Moreover, in order to simplify the exposition, the real income level attained under Strategy 0 and oil price realization 1 is taken as the basis for comparison, i.e., as a reference case.

Real income differences between the cases are expressed in terms of equivalent variations (EV). That is, each case, or constellation of energy policy strategy and oil price realization 1991, is characterized by the income change which, from the individuals' point of view, would make the case in question equivalent to the reference case. The approach can be described by the following matrix.

Energy policy strategy, i \ Oil price realization, j	1 Mathematical expectation	2 Mathematical expectation + 60 percent	Conditional per unit cost of an oil price deviation* $(EV_{i2}-EV_{i1})/60$
0: Passive	$EV_{01} \equiv 0$	EV_{02}	$EV_{02}/60$
1: Modest conservation	EV_{11}	EV_{12}	$(EV_{12}-EV_{11})/60$
2: Vigorolus conservation	EV_{21}	EV_{22}	$(jEV_{22}-EV_{21})/60$

[a] I.e. percentage point upward deviation from the mathematical expectation for the oil price level, given the energy policy strategy.

The measure "Conditional per unit cost per an oil price deviation" indicates the sensitivity of the real income level with respect to the oil price level, given that a specific energy policy strategy is adopted. Clearly this is a measure of the economy's vulnerability to oil price changes. In general one should expect that conservation efforts should reduce the absolute value of that measure. Also, one should expect that the higher the oil price level is, the lower is the real income level. Thus, all $EV_{i1} - EV_{i2}$ should be negative.

As neither of the three strategies imply a long run equilibrium allocation of the economy's resources in 1991, however, the signs of EV_{11} and EV_{21} cannot be determined on a priori grounds. Nevertheless there is a strong presumption that EV_{21} is negative. The reason for that is the significant difference between the actual 1991 oil prices in each of the two oil price realizations we investigate and the oil prices underlying the choice of technology in Stragegy 2.

With this approach the projected development of the economy under "reference case" conditions is not very crucial for the results of the analysis. Yet a brief description of the reference case is appropriate.

2.3 The Reference Case

Essentially the reference case is based on the same assumptions about aggregate capital formation, labor supply and world market conditions as a long-term survey of the Swedish economy recently published by the Ministry of Economic Affairs. (See SOU 1982:14). Several alternatives are discussed in that survey, but we have chosen to base our assumptions on the alternative which is described as a "route towards balance". This means that goods and factor prices are assumed flexible enough to clear the corresponding markets, and that the domestic savings ratio increases enough to allow for a simultaneous increase of the rate of real capital formation and a significant improvement in the current account.

On the basis of the chosen assumptions and the so called dynamic model (DYN) described in the Appendix, the projected development of the Swedish economy from 1979, the initial year of the model's data base, to 1991 can be summarized in the following way:

Table 2.1 The projected "reference case" development of selected macroeconomic indicators in the Swedish economy 1979-91

	Annual rate of change (%)
Private consumption	1.3
Public consumption	0.9
Gross investments	3.0
Export	3.9
Import	1.6
GDP	2.3
Terms of trade	-1.1
Oil consumption	0.9

It should be pointed out that the reference case gives an overly optimistic picture of the Swedish economy. In view of the actual development 1979-82, a realization of the reference case trends for the entire 12 year period seems to be a highly unlikely outcome.

Except for the world market prices of oil and the parameters defining the energy policy strategies, the reference case values of the model's exogenous variables are not varied across the cases. For most of the exogenous variables this is hardly questionable. In some cases, however, our approach implies rather strong assumptions.

One such case is that real income levels and relative goods prices in the rest of the world are kept constant across oil price realizations. Later on (in ch 5) we will partly relax this assumption, and in chapter 3 we will, at some length, discuss the relation between international oil prices, relative prices and traded goods and real income and spending patterns in the rest of the world. As there is no obvious way to take these factors into account, we have chosen to disregard the problem at this stage of our analysis.

We have also chosen to disregard the relation between the oil price level and the deficit on Sweden's current account. In an analysis of the intertemporal allocation of the cost of higher oil prices, this is of course a highly unreasonable assumption. Our analysis, however, primarily is concerned with the total change of the real income level resulting from higher oil prices. By assuming a constant current account deficit across oil price realizations, that particular issue can reasonably well be elucidated within a one-period framework.

2.4 Numerical Results

The results of the model simulations are presented in Tables 2.2 and 2.3 below. Several observations can be made on the basis of these results. Perhaps the most striking result is the quite significant negative values in the second column. These figures indicate that the oil price realization clearly matters for the real income level in the Swedish economy. Thus it seems to be a worthwhile task to look for an energy policy strategy which could help to reduce the impact of changing oil prices on the real income level in Sweden.

Another observation can be based on the third column in Table 2.2. As can be seen from these results, an energy conservation strategy carried out over a twelve-year period (1979-1991) signifi-

Table 2.2 Computed values of equivalent variations 1991
Millions SEK in the 1979 price level

Energy policy strategy, i \ Oil price realization, j	1 Mathematical expectation	2 Mathematical expectation + 60 percent	Conditional per unit cost of an oil price deviation* $(EV_{i2}-EV_{i1})/60$
0: Passive	0	-23 470	390
1: Modest conservation	- 520	-20 480	330
2: Vigorous conservation	-10 500	-27 340	280

* I.e. per percentage point upward deviation from the mathematical expectation for the oil price level, given the energy policy strategy.

Table 2.3 Computed values of equivalent variations 1991
Percent of the reference case GNI

Energy policy strategy, i \ Oil price realization, j	Mathematical expectation	Mathematical expectation + 60 percent
0: Passive	0	-3.8
1: "Conservation"	-0.1	-3.4
2: "Unexpected"	-1.7	-4.5

cantly reduces the sensitivity of the real income level with respect to the oil price level. Under the particular conditions behind these experiments, however, it turns out that the strategy which leads to the lowest vulnerability, i.e., Strategy 2, also leads to the lowest real income level. A rough calculation (assuming linearity) based on the results in Table 2.2 shows that, compared to Strategy 2, Strategy 0 would imply a higher real income level in 1991 unless the upward oil price deviation that year is at least 95 percent. The corresponding figure in a comparison between Strategy 1 and Strategy 2 is 197 percent.

Obviously these numbers should not be taken too seriously. Yet they clearly demonstrate that reduced oil price vulnerability, for instance through active oil conservation efforts, is not a free good, and that the value of reduced oil price vulnerability critically depends on the cost of attaining such a reduction as well as on the probability distribution for the oil price level. But the value of reduced oil price vulnerability also depends on the attitudes towards risk.

Thus, if households are so called risk avoiders, a comparison between two feasible, mutually exclusive, uncertain income streams with the same expected value, would turn out in favor of the most "even" income stream. That is, under these conditions, households tend to avoid income streams where there is a possibility that the income level attains values representing "extreme" deviations from the trend value. If risk aversion is an important aspect of reality, the comparison of energy policy strategies involves a trade-off between, on the one hand, the expected value of the real income level and, on the other hand, the dispersion of possible annual real income levels.

The results in Table 2.2 and Table 2.3 also highlights another aspect of energy policy under oil price uncertainty, namely that errors in widely accepted oil price predictions can be quite costly. Thus, in relation to both oil price realizations in our simulations, the oil price prediction underlying Strategy 2 represents a significant "overshooting". Each year the actual oil price level is in the range 100 - 160 percent of the expected value of the "true" oil price distribution, the cost of the Strategy 2 oil price prediction is in the range 1.1 - 1.6 percent of GNI (see Table 2.3). This means that the profitability of Strategy 2 critically depends on extremely high oil price realizations, and if the probability of such realizations has been overestimated, the cost of that prediction error can be significant.

It is obvious that our simulation experiments raises more questions than they answer. Yet it seems reasonable to conclude that the real income level depends on the oil price level in a quantitatively important way. Moreover, it seems that well chosen and efficiently designed energy policy strategies could help to reduce the economy's oil price vulnerability. In the following exposition we will investigate, in more general terms, the conditions for efficient adjustment of the economy to oil price uncertainty, as well as the role of national energy policy in this particular context.

NOTES

In practice the implementation of such an energy policy probably would be very costly because of the quite significant amount of information it would require. For the moment, however, we disregard this point.

Technically this means that plants are designed to be cost-efficient at an oil price level which is the weighted average of the oil prices which are assumed to prevail over the life-time of the plant.

However, the so called Armington export demand functions incorporated in the computation model give an upward bias to our estimates of the oil price sensitivity of the real income level.

It might be surprising that Strategy 1 implies a lower real income level than Strategy 0 under Oil price realization 1; after all the design of plants in Strategy 1 is based on the assumption that the oil price level attains its expected value. However, it is only the oil prices that are well predicted in Strategy 1. Like in Strategy 0 the expectations about all other input and output prices are static in Strategy 1. Moreover, our comparison only refers to one single year. In the long run Strategy 1 might be better than Strategy 0.

3 A SLIGHTLY MORE GENERAL APPROACH

3.1 Introduction

The purpose of this chapter is to carry the analysis of the preceding section one step further by developing a slightly more general analytical framework. To begin with, a simple diagrammatic representation of the relation between oil price uncertainty and real income uncertainty in a natioal economy is presented. Then the key parameters of this relation are discussed, as well as the role of energy policy. Finally some numerical illustrations are presented.

3.2 A Conceptual Framework

The conceptual framework suggested here has two essential building blocks: A representation of the international oil market, and a functional relation between the price of imported oil and the aggregate real income in the oil-importing economy. The international oil market is simply represented by a density function, $\Theta_t(P_0)$, defining the probability of various realizations of the world market price of oil, P_0, at time t. In general the density function $\Theta_t(P_0)$ should depend on the relevant information about the oil market available in period t. It is assumed that the world market price of oil is independent of the actions of the agents of the Swedish economy.

The relation between the real national income at time t, Y(t), and the world market price of oil at that time, $P_0(t)$, can be written

$$Y(t) = \Psi\left[P_0(t),\ X(P_0(t)),\ H(t)\right] \ ; \qquad (3.1)$$

In this expression $X(P_0(t))$ is a vector of world market prices (other than the price of oil) and the level of real income in the rest of the world, expressed as functions of the world market price of oil. H(t) is another vector, where the components represent the supply of labor, the availability of capital and technology in various sectors of the economy as well as the values given to various policy parameters. It is assumed that the last set of variables all are fixed at the beginning of period t, and that they remain constant throughout that period.[1] Thus it is assumed that

$$H(t) = \bar{H}(t) \ ; \qquad (3.2)$$

which means that eq. 3.1 expresses the level of real national income as a function of the real price of oil only.

Within this framework the impact of an oil price increase on the real national income becomes

$$dY = \left\{\frac{\partial\Psi}{\partial P_0} + \sum_{j=1}^{n} \frac{\partial\Psi}{X_j}\frac{dX_j}{dP_0} \quad dP_0 \ ;\right\} \qquad (3.3)$$

where the first term in the parenthesis will be denoted the "direct effect" and the second the "indirect effect" of an oil price increase.

The direct effect of an oil price increase works through the cost of domestically consumed oil. Under reasonable assumptions, this effect clearly is negative. Its magnitude depends positively on the initial level of oil consumption, and negatively on the substitutability of oil and other factors of production.[2] That substitutability can be subdivided into two parts; one representing the substitutability of oil and other fuels in the production of secondary energy, and the other the substitutability of energy and other inputs in industrial and household production processes.

Moreover, rigidities in the adjustment of relative prices to new equilibrium values after an oil price increase can cause unemployment of resources, during the period of adjustment which leads to additional real income losses.

The indirect effects of an oil price increase work through the world market prices of other goods than oil, as well as through the real income levels in the "home" country's trading partners. In the case of a price taking small open economy, the indirect effects of an oil price increase solely work through changes in world market prices (provided these prices immediately attain their new equilibrium values). Whether the changes in world market prices (other than the price of oil) tend to improve or deteriorate the "home" country's terms of trade depends, among other factors, on its pattern of specialization.

In our calculations, however, we have assumed that Swedish producers are faced with export demand functions, i.e. the demand for Swedish exports is assumed to depend (positively) on the real income level in the rest of the world and (negatively) on the relation between Swedish export prices and the corresponding world market prices. Thus our approach is not entirely consistent with the so called "small economy" assumptions, but well in line with the position taken in the long term surveys published by the Ministry of Economic Affairs. (This is further elaborated in the Appendix where the model used in the calculations is presented.) Under these conditions the sign of the indirect effect of an oil price increase not only depends on how relative prices of traded goods are affected. It also to a very large extent depends on how the oil price increase affects the real income level in the "home" country's main export markets; ceteris paribus the "home" country's terms of trade depend positively on the real income level of the main buyers of its exports. In the short run the relation between real income changes and changes in spending patterns perhaps is an even more important factor.

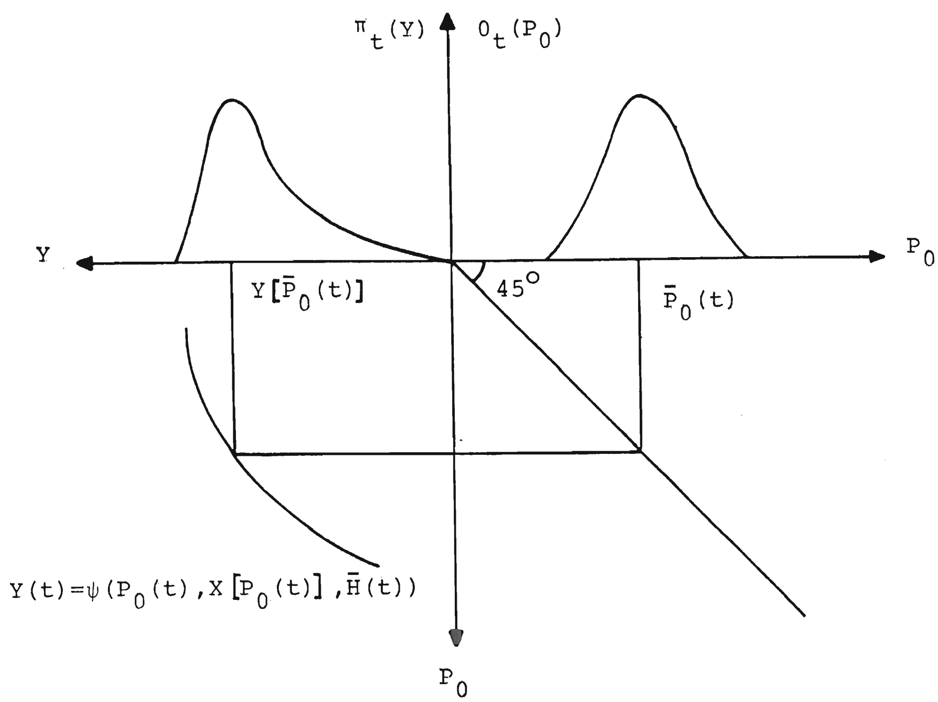
At the beginning of the 70s most of the Swedish exports were bought by countries which were net importers of oil. Thus, most of the "old" buyers of Swedish exports suffered a real income loss when the price of oil went up in 1973. This effect was amplified by rigidities in the adjustment to the new oil price level as well as by policy reactions in the Western countries. Moreover, the OPEC countries only to a very small extent spent their real income gains on imports. Consequently the indirect effect of the 1973 oil price increase experienced by the Swedish economy was strongly negative.

Ten years later, however, the situation is slightly different. Two of Sweden's main trading partners, Norway and UK, are now net exporters of oil and would thus experience a real income gain from an oil price increase. In addition the oil exporting countries, looked upon as a group, might be more inclined than the OPEC countries in 1973 to spend income gains on goods and services. It follows that the indirect effect of an oil price increase should be less negative 1983 than it was 1973. Whether or not it is still negative depends on how the relative prices on international markets for Sweden's tradables are affected by oil price increases. The graph of $\Psi(\cdot)$ in the P_0, Y-space can be either convex or concave to the origin. The latter case can occur if there are rigidities in the economy's adjustment to higher oil prices, and the economic significance of these rigidities increases with the level of P_0.

In Figure 3.1 below our two building blocks, the density function $\Theta_t(P_0)$ and the function $\Psi(\cdot)$, are combined into a complete analytical framework. As long as the vector H(t) is kept fixed at $\bar{H}(t)$, uncertainty about the oil price level obviously leads to uncertainty about the real income level. This uncertainty is represented by the density function $\pi_t(Y)$. In the figure $\bar{P}_0$ denotes the expected value of the oil price level at time t, while $Y(\bar{P}_0(t))$ is the real income level, which, for the given H(t), can be realized at the oil price level $\bar{P}_0(t)$. Clearly $Y(\bar{P}_0(t))$ does not necessarily coincide with the expected value of the real income level, $\bar{Y}(t)$.

It should be noted that the shape of the function

Figure 3.1 Hypothetical relation between international oil prices and the domestic real national income



$\Psi(\cdot)$ depends on $\bar{H}(t)$, i.e. on, among other factors, the energy policies carried out in the previous periods. Thus, for each configuration of capital accumulation, technical change and economic policy in the periods preceding period t, there is a specific shape of $\Psi(\cdot)$. This means that, in principle, there is a (possibly not unique) set of optimum energy policies, i.e. policies which would lead to a welfare maximizing sequence of density functions $\pi_t(Y)$ for t = 1, 2, ... T, where T represents the relevant planning horizon.

Disregarding distributional considerations and assuming risk neutrality the social welfare in period t only depends on $\bar{Y}(t)$. If there is some degree of risk aversion, however, social welfare depends on the shape of the entire density function $\pi_t(Y)$ and thus, for any given $\Theta_t(P_0)$, on the shape of $\Psi(\cdot)$. Under the specific assumption that the welfare function is quadratic (and concave), there is a trade-off between the mean and the variance of $\pi_t(Y)$ in the case of risk aversion. Thus, if households in general are risk avoiders, they are willing to accept a somewhat lower level of expected real income provided that would make their future real income levels less sensitive to the uncertain oil price level. In any case social welfare crucially depends on the location (in the P_0, Y-space) and shape of the function $\Psi(\cdot)$.

Ideally we would like to estimate the functions $\Psi(\cdot)$ and $\Theta_t(P_0)$. However, lacking empirical evidence on the indirect effect of an oil price increase, as well as of the density function $\Theta_t(P_0)$, the analysis has to be confined to the properties of $\Psi(\cdot)$ at given values of all the components of the vectors $X(P_0(t))$ and $H(t)$. (In Chapter 5 some simulations, where estimated indirect effects are taken into account, are presented.) The resulting relation between oil prices and the real national income then reflects direct effects only. It will be denoted $\Psi(P_0)$. In the next subsection the properties of $\Psi_t(P_0)$ is explored.

3.3 Real Income and the Price of Oil

On the basis of the discussion above, it is reasonable to expect the derivative of $\Psi(P_0)$ to be non-positive over the entire range of positive P_0. In general the graph of $\Psi_t(P_0)$ is steeper in the P_0, Y-space the lower the consumption of oil per unit of income is. If there is no possibility to substitute away from oil, i.e. the oil consumption level is fixed, the graph of $\Psi(P_0)$ is a straight line. That is, an oil price increase of a given absolute magnitude leads to the same absolute income loss at all oil price levels. In normal cases, however, there is some substitutability between oil and other inputs in the production of final goods and services. This means that oil price increases, ceteris paribus, induce substitution away from oil. Consequently, assuming risk neutrality and that all goods and factor markets immediately clear after an oil price increase, the absolute real income loss due to an oil price increase of a given magnitude is a decreasing function of the oil price level. This means that the graph of $\Psi(P_0)$ is strictly convex to the origin, and the "degree of convexity" depends on the substitutability of oil and other inputs.

Changes in economic variables, however, often are expressed in relative terms. Thus, it might be natural to analyze the percentage change of the real national income, resulting from a given percentage change in the price of oil. In this subsection, therefore, we will be concerned with the elasticity of the real national income with respect to the price of oil, i.e. with the elasticity of $\Psi_t(P_0)$. The objective is to derive some quantitative estimates of that elasticity under various assumptions about the flexibility of the technology in terms of the substitutability of oil and other inputs.

However, in doing this it is important to note, that the flexibility of the technology is not the only factor that matters. If goods and factor markets do not clear, the real income loss due to an oil price increase also depends on how much, and which, resources that will be left idle. An obviously important empirical issue then is to estimate the relative importance of technology flexibility and the flexibility of the economic system. To explore this issue, a few model calculations have been carried out. (Here the one-period versions of the model described in Appendix are used.) They are designed on the following way.

Three cases, differing in terms of the assumptions about "economic" and "technological" flexibility, are defined. These cases are:

I Flexible technology (unitary elasticity of substitution between oil and electricity as well as between energy and other inputs) and prices which clear all markets. (Calculations based on the LRS version with fixed capital stocks.)

II Rigid technology (zero elasticity of substitution between oil and electricity as well as between energy and other inputs) and prices which clear all markets. (Calculations based on the SRS version with flexible real wage rate.)

III Rigid technology and rigid prices (i.e. the real wage rate is completely rigid downwards but flexible upwards, and all other prices are flexible). (Calculations based on the SRS version with fixed real wage rate.)

For each one of these cases, the real national income level is computed for a number of oil price levels. Using the results of these computations, the elasticity of the real national income, with respect to the price of oil in various oil price intervals, is computed. Before presenting the results, a few remarks should be made about the nature of the computed equilibria, as well as about the appropriate choice of real income measure.

The computed equilibria all are of a short-run nature, i.e. the sectoral capital stocks are fixed. By the design of the data-base (see the description of the data-bases in the Appendix), however, the fixed capital stocks and the fixed energy input coefficients (in Case II and Case III) would coincide with the corresponding long-run values, provided the long-run (or **ex ante**) technology is of the Cobb-Douglas type (that is, the elasticity of substitution between oil and electricity as well as between energy and other inputs is unity), and the price of oil is unity (in terms of the units used in the model calculations). Thus, by definition the real income level does not differ across the cases when $P_0 = 1.0$. Moreover, the computed impact of oil price deviations can be regarded as real income deviations from the long run equilibrium (as is clear from the Appendix, however, this statement is subject to some qualifications). The "reference case" of the numerical experiments presented in Chapter 2 was a short-run equilibrium with, for instance, significant differences across sectors in terms of the rates of return on real capital.

As in the computations presented in Chapter 2, the current account deficit is taken to be exogenously determined and independent of the oil price level. Due to the specification of the model (see the discussion in subsection 3.1 and the description of the model in the Appendix), this means that an oil price increase induces a further deterioration of the terms of trade. That is, the terms of trade deteriorate partly as a result of the import price increase, partly as a result of the export price decrease which is necessary in order to increase the export volume enough to maintain the current account deficit, at the exogenously given level.

It turns out that changes in the oil price level have quite strong effects on the terms of trade under the conditions implied by the specification of the model. (In Bergman 1982 an alternative specification of the model, without this property, is presented.) This means that the magnitude of the real income effects quite strongly depends on the composition of the numeraire good in which the real value of the total factor incomes is evaluated. Thus, if the numeraire good is a basket of imports, the real income deviations due to oil price deviations tend to be relatively strong. If, on the other hand, the numeraire good is a basket of domestically produced goods, the relation between the real income level and the oil price level tend to be much smaller.

From the theoretical point of view, the natural way to proceed is to define real national income on the basis of the postulated utility function of the model's aggregated household sector. As can be seen in the model description (in the Appendix), however, neither savings nor consumption of public services are included in the utility function of the household sector. The same applies to the "disutility" of unemployment, which can occur in Case III. Thus, there is no theoretically obvious way to define real national income in the computation model. In view of this, we have defined "real national income" in three alternative ways.

According to the first measure, real national income is defined as the value of total factor incomes in terms of an aggregate of household consumption goods (around 50 percent), public services (around 25 percent) and investment goods (around 25 percent). In other words, real national income is defined in terms of an aggregate of goods and services actually used for domestic consumption and investment purposes. This is our main alternative in terms of the specification of real national income.

The second measure defines real national income in terms of imported manufactures (which happens to be the numeraire good of the computation model). With this definition, real national income should be relatively sensitive to terms of trade changes. That, however is not the case for the third measure. According to this definition, real national income namely is defined in terms of domestically produced public services. The results of the computations are presented in Tables 3.1-3.3 below.

First of all it should be noted that the results are derived from assumed oil price variations around the 1975 oil price level. Since the current real oil price level is roughly twice as high, the

Table 3.1 **The estimated elasticity of real national income* with respect to the price of oil**
Main alternative

Oil price** interval	Computed elasticity*** of real national income Case I[a]	Case II[a]	Case III[a]
0.2 - 0.6	-0.018	-0.015	-0.015
0.6 - 1.0	-0.026	-0.026	-0.026
1.0 - 1.4	-0.037	-0.040	-0.083
1.4 - 1.8	-0.039	-0.053	-0.109
1.8 - 2.2	-0.041	-0.067	-0.134
2.2 - 2.6	-0.043	-0.090	-0.162
2.6 - 3.0	-0.045	-0.083	-0.194

Table 3.2 **The estimated elasticity of real national income* with respect to the price of oil**
Second alternative

Oil price** interval	Computed elasticity*** of real national income Case I[a]	Case II[a]	Case III[a]
0.2 - 0.6	-0.031	-0.019	-0.019
0.6 - 1.0	-0.038	-0.036	-0.036
1.0 - 1.4	-0.044	-0.055	-0.080
1.4 - 1.8	-0.046	-0.074	-0.104
1.8 - 2.2	-0.047	-0.094	-0.128
2.2 - 2.6	-0.049	-0.107	-0.148
2.6 - 3.0	-0.053	-0.116	-0.176

* Total domestic factor in terms of imported manufactures.

** The oil price level 1.00 is equal to the actual real oil price level in 1975.

*** Arc elasticities in various oil price intervals.

a See p. 51 ff.

Table 3.3 The estimated elasticity of real national income* with respect to the price of oil
Third alternative

Oil price** interval	Computed elasticity*** of real national income Case I[a]	Case II[a]	Case III[a]
0.2 - 0.6	-0.008	-0.004	-0.004
0.6 - 1.0	-0.012	-0.008	-0.008
1.0 - 1.4	-0.015	-0.012	-0.086
1.4 - 1.8	-0.016	-0.016	-0.109
1.8 - 2.2	-0.016	-0.017	-0.134
2.2 - 2.6	-0.017	-0.018	-0.155
2.6 - 3.0	-0.018	-0.022	-0.186

* Total domestic factor incomes in terms of public services.

** The oil price level 1.00 is equal to the actual real oil price level in 1975.

*** Arc elasticities in various oil price intervals.

a See p. 51 ff.

results in Tables 3.1 - 3.3 multiplied by a factor close to two should give an approximate estimate of the current values of the computed elasticities.

Several observations can be made on the basis of the above presented results. One is that the nature of the economy's foreign trade functions, in conjunction with the assumed effects of the oil price changes on real incomes and spending patterns in the rest of the world, clearly matters for the relation between the real income level and the oil price level. This is shown by the quite significant terms of trade effects which show up in the differences between our three measures of real national income.

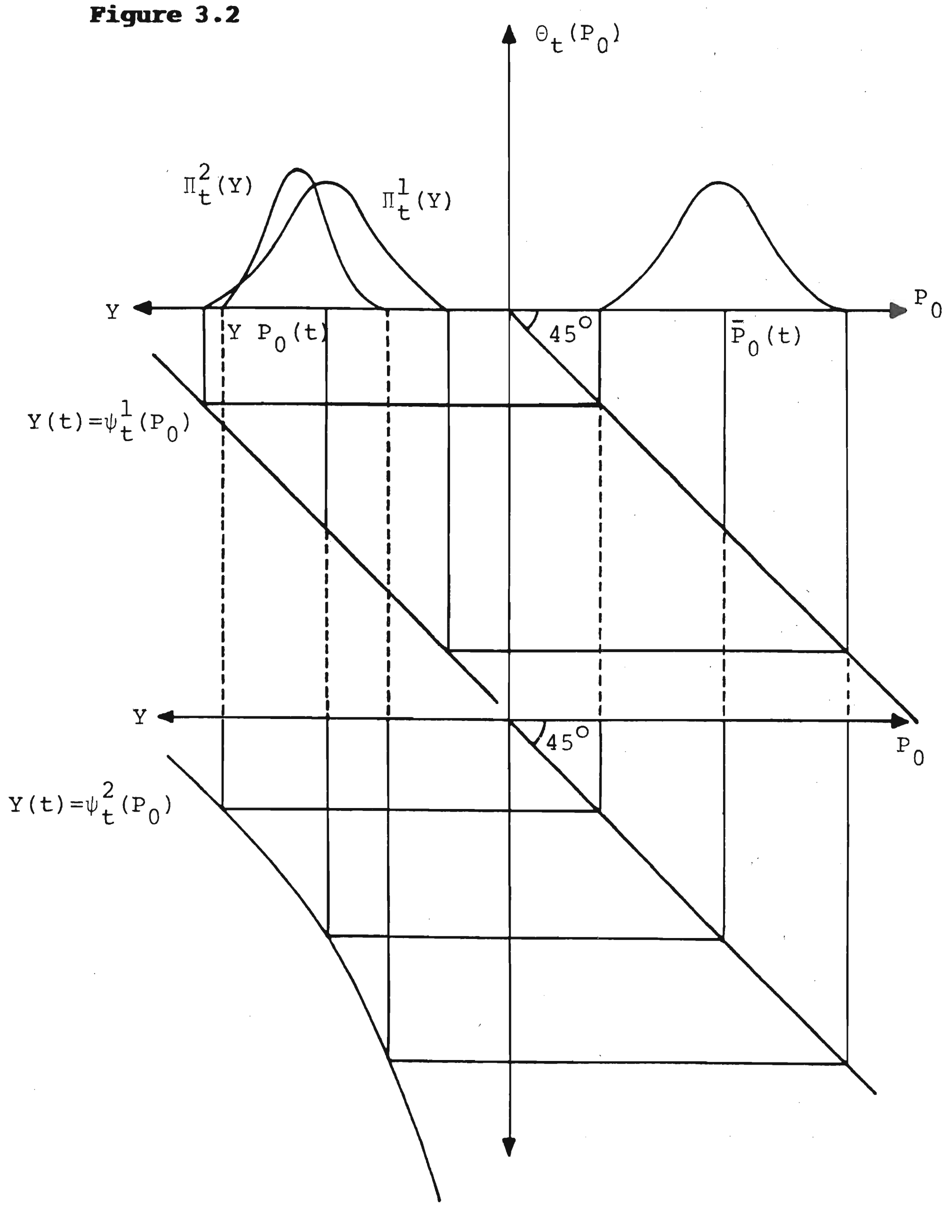
Another observation is that the difference between Case I and Case II generally seems to be much smaller than the difference between Case II and Case III. This suggests that "economic flexibility" relaxes the domestic real income level from the international oil price level much more efficiently than "technological flexibility" does. This is an interesting result, but it is subject of qualifications. First, "economic flexibility" and "technological flexibility" are by no means well-defined concepts. Thus, another specification of economic flexibility could have lead to significantly different results. Second, there is no trade-off between "economic flexibility" and "technological flexibility"; to achieve an increase in the first type of flexibility, one does not necessarily have to reduce the other type of flexibility.

A third observation is, however, that the degree "technological flexibility" definitely matters, especially when the unexpected oil price deviation is very large. Thus, provided a "flexible technology" does not cost more than less flexible feasible alternatives, such a technology should always be chosen. This argument can be demonstrated by means of Figure 3.2.

We assume that all goods and factor markets immediately clear after a change in some exogenous variable. In accordance with the discussion above, this means that $\Psi_t(P_0)$ is convex to the origin in the P_0, Y-space. We consider two technologies, 1 and 2, leading to $\Psi_t^1(P_0)$ and $\Psi_t^2(P_0)$ respectively. By assumption Technology 1 is characterized by fixed coefficients, while Technology 2 exhibits a higher degree of technological flexibility. Also by assumption it holds that

$$Y(\bar{P}_0(t)) = \Psi_t^1(\bar{P}_0(t)) = \Psi_t^2(\bar{P}_0(t)) \tag{3.4}$$

Figure 3.2



where $\bar{P}_0(t)$ is the mathematical expectation for the oil price level, i.e.

$$\bar{P}_0(t) = E[P_0(t)] \tag{3.5}$$

In other words, when the price of oil attains its expected value, the two technologies generate the same real income level. It is in this sense that the flexible technology does not cost more than the less flexible one.

However, as can be seen in Figure 3.2, it also holds that

$$E^2[Y(t)] > E^1[Y(t)] \tag{3.6}$$

$$Var^2[Y(t)] < Var^1[Y(t)] \tag{3.7}$$

That is, the more flexible technology generates a higher value of the expected real income level. In addition, Technology 2 implies a lower variance of the real income level. On the basis of these results, we conclude that if two technologies are equally costly, the more flexible alternative should be chosen.

Moreover, it might very well be the case that the technology which generates the highest expected value of the real income level is inferior to some other, less flexible, technology at the specific oil price level $\bar{P}_0(t)$. In the next chapter we will develop the notion of technology flexibility and show, that a technology which is designed to be optimal in view of the entire probability distribution for the oil price, is more flexible than a technology which is designed to be optimal at a specific oil price level. But a technology, which is designed to be optimal at the specific oil price level $\bar{P}_0(t)$, turns out to be more efficient than a technology, which is optimal with respect to the entire oil price distribution at that particular oil price level. Thus, there is a trade-off between efficiency and flexibility.

4 OIL PRICE UNCERTAINTY AND NOTIONS OF FLEXIBILITY

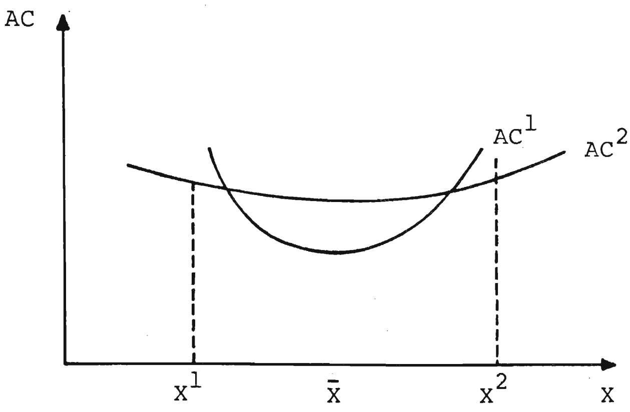
4.1 Technological Flexibility

Our approach starts from the notion that the properties of technology at the **ex ante** stage differ from the properties **ex post**, and in particular, that there is a trade-off between static **ex ante** efficiency and **ex post** flexibility. The basic idea is that plants designed for a single input price constellation can be made more efficient than those designed for a spectrum of input price constellations.

Another way of describing the situation we are studying is the following. By designing a plant with a given capacity from a given static efficiency point of view, the average cost curve will show the least cost for producing different quantities (given the capacity). The average cost curve is in general assumed to be U-shaped, which means that deviations from the "optimal" production volume increase the average cost. However, by designing the plant somewhat differently, it may be possible to achieve an average cost curve, which is flatter but with a higher minimum average cost than the former.

In Figure 4.1 the cost curves are drawn. It is clear that if the entrepreneur is completely certain that the production volume will be $\bar{X}$, it is optimal to choose the design corresponding to the curve AC^1. If, on the other hand, he is uncertain about the future production volumes he may prefer

Figure 4.1



the inefficient design corresponding to AC^2. In particular, if he believes X^1 with probability 1/2 and X^2 with the same probability, the expected production volume is $\bar{X}$, but it is obvious that the design corresponding to AC^2 is the optimal choice. (In Figure 4.1 we have looked at cost as a function of output. In our later analysis we will, however, consider cost as a function of factor prices and accordingly look into the flexibility with respect to variations in factor prices.)

This idea of including flexibility into the design of new plants is not new. As early as in Stigler (1939) this form of flexibility was discussed (by using an identical diagram to that in Figure 4.1). In Baumol (1959) the same type of diagram is used. A neat summary of this and related ideas is given in Tisdell (1968). In spite of these important contributions, the idea of flexibility does not seen to have hooked on to the main stream of microeconomic ideas. One exception is McFadden and Fuss (1979) where econometric methods to estimate this trade off are developed.

The analysis of flexibility and oilprice uncertainty to be presented here follows quite closely Bergman and Mäler (1981).

4.2 The Theoretical Argument

Although the quantitative results presented later are derived from simulations with a computable general equilibrium model, we will in our theoretical analysis restrict the discussion to a one plant model. In order not to overburden the presentation we will also assume that there is only one energy input E with uncertain price Q. In addition to E, labor L, is the only variable input with price W, assumed to be known with certainty. The third input is capital, K, where the user cost is equal to the real interest rate, R (thus, for simplicity, we disregard depreciation and the possibility of capital goods prices differing from the price of output in the sector under study), also assumed to be known with certainty. We assume that the amount of capital cannot be changed after the plant has been built. K should be interpreted as an aggregate of different capital goods; there are in general several different ways of combining these goods to yield the same K. A design variable, D, is assumed to reflect this diversity of K. It is assumed that D has to be determined prior to the actual construction of the plant. The output from the plant is denoted X.

The plant is completely characterized by the vector Y = (X,Z,D), where Z = (L,E,K) is the input vector. In order to be technically feasible, Y must belong to the feasibility set T, that is $Y \subset T$. It is assumed that T is a convex, closed cone, i.e. in the long run there are constant returns to scale.

The long-run production function is given by

$$F(L,E,K) = \sup\{X; \exists D, \text{ such that } (X,L,E,K,D) \in T\} \quad (4.1)$$

As T is a cone, it follows that F is linearly homogenous in Z. Since T is closed, the supremum will be attained. The set of D that maximizes (4.1) is denoted $D(Z)$. We can now define the production set $\bar{T}$ as the technically efficient set

$$\bar{T} = \{(X,L,E,K); (X,L,E,K,D(Z)) \in T\} \quad (4.2)$$

When complete adjustment is possible, the cost function is given by

$$TC(X,W,Q,R) = \inf\{WL+QE+RK; (X,L,E,K,D) \in T\} \quad (4.3)$$

As T is closed, the infimum is attained. Since T is a cone, it follows that TC is linear in X, so that the unit cost can be defined as

$$(1/X)TC(X,W,Q,R) = \kappa(W,Q,R), \quad (4.4)$$

which is independent of X.

Let us now consider the case where neither K nor D can be changed after the plant has been completed. The short-run total cost is defined by

$$SC(X,W,Q,K,D) = \inf\{WL+QE; Y \in T\}, \quad (4.5)$$

where once again the infimum is actually a minimum.

It is easily shown that SC is concave in (W,Q) and convex i (X,K,D). The following relations are also easy to prove:

$$\partial SC/\partial W = L(X,W,Q,K,D), \ \partial SC/\partial Q = E(X,W,Q,K,D), \quad (4.6)$$

where L(•) and E(•) are the short-run demand functions for labor and energy, respectively. Moreover, the short-run supply of production is given by

$$\partial SC/\partial X = P, \quad (4.7)$$

where P is the output price. The relation between the short-run and long-run cost functions is given by

$$\inf_{K,D} \left(SC(X,W,Q,K,D)+RK \right) = TC(X,W,Q,R). \quad (4.8)$$

Let us now introduce uncertainty by assuming that Q is a random variable. As Q changes, so will the unit and marginal costs and therefore also the price of the output (unless demand is completely elastic). But as the price of output changes, so will the output itself. Thus X should also be treated as a random variable. Of course, X and Q are not independently distributed, so let their joint probability measure be $\mu(X,Q)$. The expectations of the two variables are denoted by $\bar{X}$ and $\bar{Q}$, respectively.

The problem of designing the plant can now be formulated as finding

$$\inf \int SC(X,W,Q,K,D)d\mu(X,Q)+RK, \tag{4.9}$$

where it is implicitly assumed that the plant manager is risk neutral. The solution to this problem yields the following planning functions (for simplicity we assume they are single valued):

$$K = K^u(W,R) \tag{4.10}$$

$$D = D^u(W,R). \tag{4.11}$$

These planning functions give the optimal capital stock and its optimal design as functions of the wage rate and the cost of capital, when energy cost and output volume are random variables.

A very common rule of thumb when dealing with uncertainty is to replace uncertain variables with their expected values. The problem of risk then becomes deterministic. Such a replacement in this particular problem would imply that the design of the plant could be determined by

$$\inf\ SC(\bar{X},W,\bar{Q},K,D)+RK. \tag{4.12}$$

The solution to this deterministic problem is given by

$$K = K^c(\bar{X},W,\bar{Q},R) = \partial TC(\bar{X},W,\bar{Q},R)/\partial R \tag{4.13}$$

$$D = D^c(\bar{X},W,\bar{Q},R). \tag{4.14}$$

It is clear that (4.13) and (4.14) will provide a technically efficient plant design in the sense that the corresponding vector $(\bar{X},L,E,K^c,D^c)$ will belong to $\bar{T}$. This is also the procedure we follow when using the simulation model.

However, it is by no means certain that the design corresponding to (4.10) and (4.11) will be technically efficient. All technically efficient points, i.e. all elements in $\bar{T}$, can be generated by parametric variation of $(\bar{X},W,\bar{Q},R)$ in (4.13) and (4.14). However, unless SC is linear in X and Q, (4.10) and (4.11) cannot be generated from (4.13) and (4.14), i.e. the solution to the uncertainty problem will not in general be technically efficient. The intuitive reason is obvious. By choosing an inefficient design, it is usually possible to obtain increase flexibility and elasticity with respect to changes in energy prices.

By definition then:

$$SC(\bar{X},W,\bar{Q},K^c,D^c)+RK^c<SC(\bar{X},W,\bar{Q},K^u,D^u) + RK^u \qquad (4.15)$$

and

$$\int SC(X,W,Q,K^c,D^c)d\mu(X,Q) + RK^c > \int SC(X,W,Q,K^u,D^c)d\mu(X,Q) + RK^u. \qquad (4.16)$$

Figure 4.2

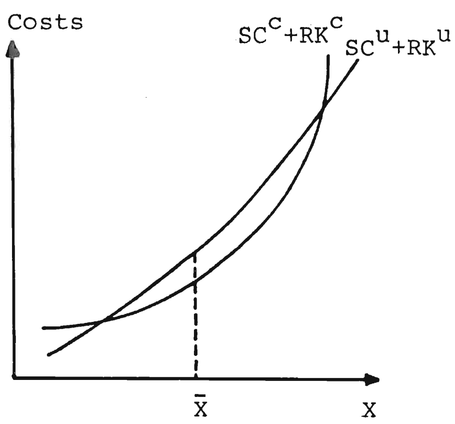
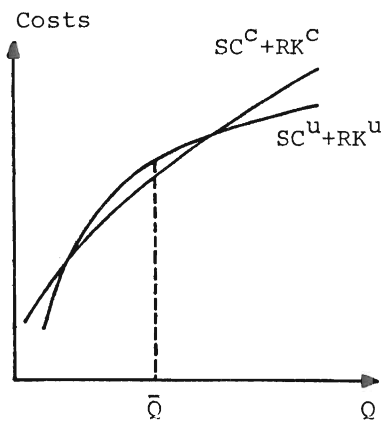


Figure 4.3



As SC is concave in Q and convex in X, it follows that unless the distribution of (X,Q) is quite odd, the relation between the solution to the certainty and risk problems may be described as shown in Figures 4.1 and 4.2. These two figures indicate that for small deviations from the expected values of Q and X, the choices of K and D in the certainty case will yield smaller total expected costs than the optimal strategy for the uncertainty case, while large deviations will improve the optimal solution for the uncertainty case more **ex post** than the corresponding solutions for the certainty case. As the demand for energy will fall along with increases in its price, it follows that the solution to the uncertainty case will yield a more elastic demand for energy and a more elastic supply of output than the corresponding solutions for the certainty case.

One major conclusion that follows is that given the assumption about risk neutrality, it is always better to design the plant with regard to the whole probability distribution of future prices than to design the plant for any fixed price.

This conclusion has important consequences for energy policy formulations. No matter how good a point estimate of the future price we have, there is always a positive probability the realization will be different and the design of the plant should take that into account.

In particular, it means that stabilization of the domestic price will be inefficient. This is because entrepreneurs will have no incentives to design their plants flexible enough to accomodate future price variations. Moreover, as we have seen in previous chapters, if the domestic price level turns out to be badly choosen with respect to the actual distribution of world market prices, the domestic cost of such a policy may be substantial.

However, the existence of risk aversion may change these conclusions. Therefore we will come back to the problem of risk aversion in the next chapter.

4.3 The Simulation Experiment

Thus the initial choice of capital stock and its design may be important in influencing the social cost of changes in energy prices. If the capital stock of society is designed as cost minimizing for a particular set of prices, the cost deviations in prices from this set may be much higher than if the stock was designed to accomodate price uncertainty. The primary purpose with the following discussion is to give some numerical indications of the importance of these possibilities. For this we use the long-run static (LRS) version (with fixed capital stocks) of the simulation model. The model version used is thus very similar to one used in the previous sections except that it contains only one time period and thus no vintage capital. Although the complete model is described in Appendix, a brief discussion of the model's production function is warranted here.

The production in each sector j is specified by a nested Cobb-Douglas-CES production function

$$X_j = A_j \left[a_j F_j^{\rho_j} + b_j H_j^{\rho_j} \right]^{1/\rho_j} e^{\lambda_j} \tag{4.17}$$

$$F_j = K_j^{\alpha_j} L_\gamma^{1-\alpha_j} \tag{4.18}$$

$$H_j = \left[{}_j X_{1j}^{\gamma_j} + d_j X_{2j}^{\gamma_j} \right]^{1/\gamma_j} \tag{4.19}$$

where X_j is output, K_j is the capital stock, L_j labor input and X_{ij} $(i=1,2)$ energy input in the j'th sector. This production structure has three design parameters, i.e. the substitution parameters ρ_j and γ_j and the efficiency parameter λ_j. We now assume that **ex ante** there is a trade-off between these parameters. This trade-off can be represented by

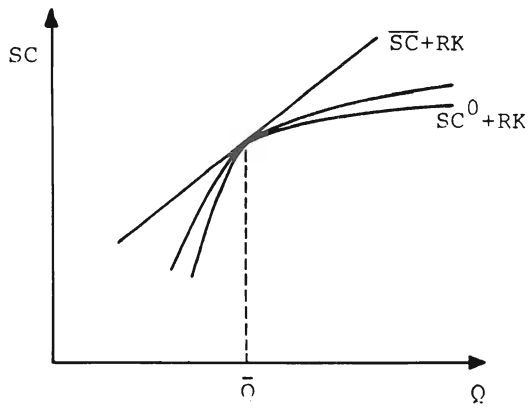
$$\lambda_j = \varphi_j(\rho_j, \gamma_j) \tag{4.20}$$

Thus **ex ante** there is a trade-off between flexibility and efficiency; higher flexibility (i.e. lower absolute values of ρ_j and γ_j) can be achieved at the expense of lower efficiency (i.e. lower λ_j).

If we had a way of estimating the φ-function it would have been possible to carry out cost-benefit analysis of designing the production structures for different probability distributions of the oil price. Due to lack of data, however, this has not been possible to achieve. Therefore, we are forced to accept a much less ambitious goal for the analysis. We will thus concentrate on the benefits from increases in substitution elasticities (i.e. decreases in the substitution parameters).

The situation can most easily be explained by Figure 4.4, where for simplicity only fuels are

Figure 4.4



considered. The figure contains three cost curves tangent to each other at the price $\bar{Q}$. The curve $\bar{S}\bar{C}$ corresponds to the case where the production structure is completely rigid **ex post**, i.e. where input coefficients are fixed (i.e. substitution elasticities equal to zero). SC^o, on the other hand, corresponds to the case where the **ex post** substitutability corresponds to a Cobb-Douglas production function (i.e. substitution elasticities equal to unity). This is the most "flexible" case we consider. The efficiency parameter would in general vary among these different sets of substitution parameters according to the function φ. As it has not been possible to estimate this function, we have chosen λ_j so that each cost curve is tangent to the **ex ante** cost curve at the expected price $\bar{Q}$. (That is, we have made the same type of assumption as in the construction of Figure 3.2.)

In order to get a first hand feeling of the importance of flexibility we will postpone the calculations of the expected gain from having a more flexible technology and instead look at the gains from a specific outcome. Thus we consider a case where the price of oil deviates by 80 percent from its expected value. This simply means that we calculated the vertical differences between the various curves in Figure 4.4 for a price 80 percent higher than the expected.

As was mentioned above, this part of the study was made with a version of the so called long run static model presented in the Appendix. Throughout in the calculations, sectoral capital stocks were fixed. The main data source was an input-output table for 1975. The actual energy resource price in 1975 were taken to be equal to expected energy resource prices. For given values of the efficiency parameters λ_j, the sectoral **ex ante** production functions, the expected values of energy resource prices and the actual 1975 values of other exogenous variables, a full equilibrium was computed.

In accordance with the discussion at the end of the preceding section we assume, in effect, that all the **ex post** production functions considered exhibit the same efficiency when energy resources prices attain their expected values. Thus, regardless of the design of the **ex post** technology, the "short-run" equilibria consistent with each of the **ex post** technologies coincide at these energy resource prices. The utility level (approximated by the consumption vector) attained at this equilibrium is taken as the standard of comparison.

Four different **ex post** technology designs are considered. None of them contain any differentiation between sectors in terms of the substitution para-

Table 4.1 The ex post designs

h	$(1-\rho(h))^{-1}$	$(1-x(h))^{-1}$
1	~0	~0
2	0.6	0.2
3	0.2	0.6
4	~1.0	~1.0

meters ρ_j and γ_j. Accordingly, the sector indices on these parameters can be dropped, and each design D(h) is characterized fully by $\rho(h)$, $\gamma(h)$. The characteristics of the four **ex post** designs in terms of the implied elasticities of substitution are summarized in Table 4.1.

Thus, D(1) implies an **ex post** technology which is rigid in terms of energy use per unit of output in each sector. D(4), on the other hand, implies unitary substitutability between energy and other factors of production, as well as between energy and other factors of production, as well as between fuels and electricity. Design D(2) is relatively flexible in terms of aggregate energy use, although less so D(4), and relatively rigid in terms of the composition of aggregated energy, but less so than D(1). As compared to D(2), design D(3) has the opposite properties.

Under the assumption that the four designs are equally efficient when energy resource prices attain their expected values, D(1) is clearly an inferior design, while D(4) is superior to the others. Obviously D(1) represents an extremely rigid technology. Whether D(4) is unrealistically flexible is an empirical question which cannot be settled on **a priori** grounds.

Designs D(2) and D(3) represent cases where uncertainty about future prices leads to a choice of design which allows for some flexibility **ex post**. However, in order to represent an optimum choice of **ex post** technology, these two designs reflect different expectations about future energy prices. Thus, D(2) reflects expectations about rather uniform future energy price changes, while D(3) reflects expectations about changes in the price relations between fuels and electricity. The ranking of D(2) and D(3) obviously depends on the actual development of energy prices.

The analysis was focused on a case where the world market price of crude oil, i.e. the variable Q_1 in the simulation model, attains a level which is 80 percent higher than the expected level. All prices are assumed to attain their new equilibrium values

Table 4.2 Estimated values of equivalent variations (EV) at a 80 percent deviation of the crude oil price level from its expected value.
Full short-run adjustment

h	EV(h)[a]	(EV(h)/EV(1))100	EV(h)-EV(1)[b]
1	-7 590	100	0
2	-7 020	92.5	570
3	-6 920	91.2	670
4	-5 260	80.7	2 330

[a] Expressed in 10^6 SEK at the 1975 price level. In order to make these numbers comparable to those in Table 2.2, they should be multiplied by 1.45.

[b] This is a measure of the benefit of higher flexibility (in h=1,...,4).

instantaneously and aggregate demand in the "rest of the world" is assumed to be kept at the full employment level. Estimates of the corresponding equivalent variations (EV) are presented in Table 4.2.

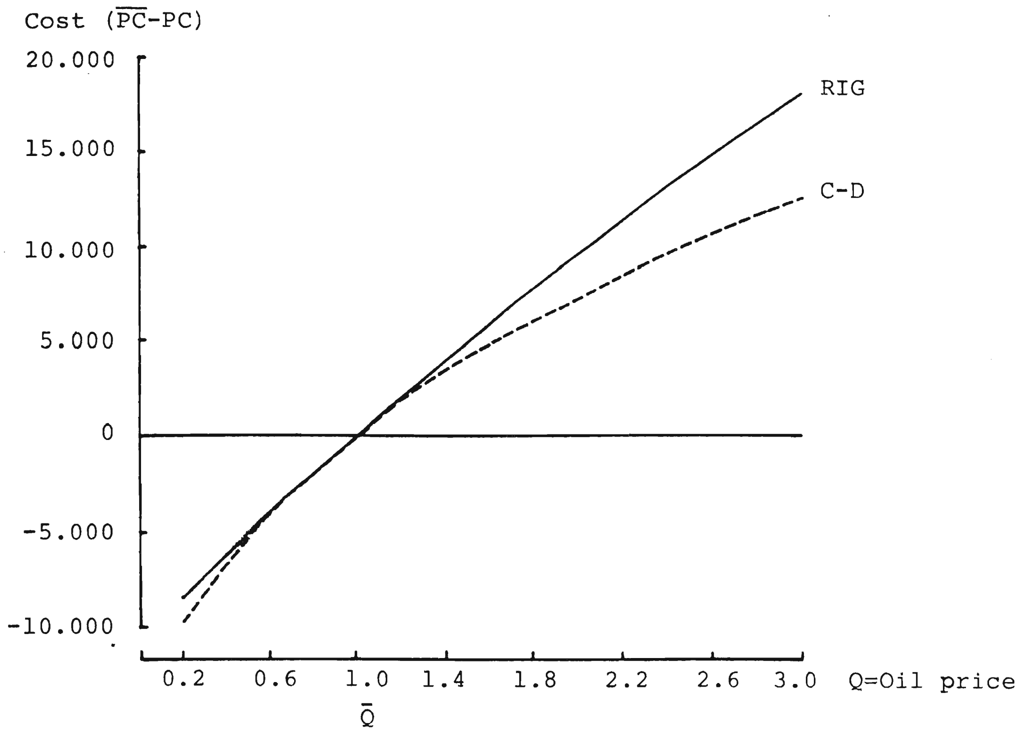
Clearly, the real income deviation of the magnitude is significant, even when the technology is as flexible as in D(4) and a new equilibrium is instantaneously attained. However, the degree of flexibility certainly matters; as compared to the rigid design D(1), flexible **ex post** technologies such as D(2) or D(3) reduce the real income deviation by about 8 percent. Accordingly, society benefits from flexible technology if the price of oil attains an unexpectedly high value.

4.4 Expected Gains

Up till now, we have looked at the gains from increased ex post flexibility given that the "unexpected" oil price increase was 80 percent. By doing the same calculations for a spectrum of oil price changes it is possible to get a better picture of the importance of **ex post** flexibility. In order to simplify the presentation we have limited ourselves to a comparison between unitary substitution elasticities **ex post** and zero elasticities **ex post**, i.e. between a case with the same **ex ante** and **ex post** substitution possibilities and a case with completely rigid technology **ex post**.

The result is given in Figure 4.5. The curve RIG corresponds to the curve SC^O in Figure 4.4 and thus corresponds to the case with fixed production

Figure 4.5



coefficients **ex post**. The curve C-D corresponds to the curve SC and stands for the case with a Cobb-Douglas **ex post** technology.

By using the results illustrated in the figure below it is possible to give some indications of the expected gains from going from a situation with completely rigid **ex post** technology to a situation with a Cobb-Douglas technology, given the probability distribution of the future oil price. Of course, it is impossible to estimate any objective probability distribution. Consequently we have arbitrarily assumed three different distributions in order to illustrate the discussion.

Table 4.3 Probability distribution over future oil prices[a] and estimated gains of technological flexibility
10^6 SEK in the 1975 price level[b]

Q	π (gains)	Case A	Case B	Case C
0.2	1338	.16	.05	.05
0.6	35	.32	.32	.20
1.0	0	.22	.37	.50
1.4	663	.13	.15	.20
1.8	1681	.07	.07	.05
2.2	2828	.05	.03	0
2.6	4278	.03	.01	0
3.0	5623	.02	.00	0
Sum		1	1	1
$\sigma^2(Q)$		.448	.221	.128
$E(\pi)$		810	420	220

[a] Mathematical expectations for the oil price level is 1.0.

[b] By multiplying the estimates by 1.45, comparable values in the 1979 price level are obtained.

The distributions we have assumed are given in Table 4.3 together with the gains from having the flexible technology **ex post** (i.e. the vertical differences between the two curves in Figure 4.5). The gains are measured in 10^6 SEK (price level 1975).

One's intuition is confirmed in Table 4.3. The expected gains from a flexible **ex post** technology increase roughly in proportion to the variance of the distribution of future oil prices. Unfortunately, we do not know the cost of obtaining such an increase in flexibility or whether this increase is feasible. However, the estimated gains are of such a magnitude that the topic merits further studies.

4.5 Economic Flexibility

We have so far assumed perfect markets on which factors of production are immediately reallocated in response to price changes (we have of course assumed that invested capital in buildings and machinery do not have any mobility). In view of the development of the Swedish economy in the 70s this is hardly a tenable assumption. In the general debate on Sweden's economic problems there seems to be a consensus that one major difficulty is the lack of mobility in the labor market. We will therefore try to study the quantitative importance of labor market mobility by introducing some quite extreme assumptions on the functioning of the labor market.

We will assume that the real wage rate is sticky downwards. An increase in the oil price will thus not reduce the real wage rate. Instead it will cause unemployment and a fall in aggregate real consumption. Moreover, we assume that it is not possible to increase employment instantaneously in any sector. The impact of these assumptions will first be studied in a model with a Cobb-Douglas production technology and then in a model with fixed input-output coefficients.

The results from the simulations are given in Table 4.4. It is clear from the results that one's intuition is well founded; the most advantageous case is when we have flexible wages and technological flexibility while the worst case is when we have a fixed wage and rigid technology. This last case is strictly dominated by the others and the

Table 4.4 Private consumption (PC)[ab] and unemployment at various oil price levels and different assumptions on the adjustment of the real wage (w)

Q	Rigid[a] technology			Cobb-Douglas technology		
	Fix w		Flex w	Fix w		Flex w
	PC	Unemployment rate %	PC	PC	Unemployment rate %	PC
0.2	161.4	0	161.4	162.8	0	162.8
0.6	157.1	0	157.1	157.1	0	157.1
1.0	152.9	0	152.9	152.9	0	152.9
1.4	144.1	3.1	149.0	145.7	2.4	149.6
1.8	135.9	5.9	145.3	140.0	4.3	146.8
2.2	128.5	8.5	141.7	135.4	5.8	144.6
2.6	121.7	10.9	138.1	131.5	7.0	142.3
3.0	115.2	13.2	134.8	127.9	8.2	140.4
Expected private consumption						
Case A[d]		153.2		152.0		154.0
Case B[d]		153.1		152.0		153.5
Case C[d]		153.0		152.2		153.3

[a] In 10^6 SEK in the 1975 price level.
[b] Due to the specification of the model, changes in real private consumption is a good approximation of EV.
[c] Sectoral energy input coefficients fixed.
[d] See Table 4.3

first case dominates all other cases, though not strictly for oil price deviations downwards.

It is interesting to note, however, that for upward price deviations, the case with flexible technology and rigid wage rate is dominated by the case with rigid technology and flexible wage rate, although we have not included any costs for achieving increased technological flexibility. Assuming the same probability distributions over the oil price as in the previous section, the expected values of private consumption are also shown in the table.

The quite drastic falls in private consumption because of higher oil prices is associated with very high unemployment rates. It should be noted, though, that the underlying assumptions are rather extreme. The real wage rate does not adjust at all to the changes in the terms of total demand. Anyhow, the conclusion is obvious. Sticky real wages and low mobility on the labor market are very important factors behind bad economic performance in conjunction with oil price shocks. In this sense, the energy problem is not a problem of oil or other carriers of energy, but rather the lack of flexibility in the economic system. With perfect adjustments, the drop in private consumption due to a tripling of the oil price level is 8 percent and with a completely sticky real wage the same loss is 16 percent.

Possibly the conclusion to be drawn from this is that, instead of investing in energy conservation, oil substitution, domestic fuels etc, it would be much better to undertake measures which would increase the price flexibility on factor markets, thereby increasing the mobility between regions and between sectors.

5 RISK SHARING AND OIL PRICE STABILIZATION

5.1 Introduction

We have so far not introduced the notion of risk aversion formally in our analysis. Yet one could argue that this is perhaps the most important notion in a discussion of uncertainty and energy policy. In particular, the degree of risk aversion has a direct bearing on the question about the desirability of oil price stabilization.

By risk aversion is meant the behavior of an individual who, when faced with a choice between a certain outcome to an uncertain with the same expected value, prefers the certain outcome. Most of our discussion in this chapter aims at demonstrating some good reasons why society can be expected to be less risk averse than the individuals. The main reason for this assertation is that, in general, it is possible to spread a given risk over a greater number of individuals, thereby not only reducing the cost of risk to each individual but also the total cost of risk.

5.2 The Theoretical Argument

Let us start by analyzing a simplified model of a national economy. Consider a plan to build a plant producing a good which can be sold at a fixed price, p. The production will take place according to the following linearly homogenous production function

$$x = f\ (L,\ E,\ K) \tag{5.1}$$

where x is output, L input of labor, E input of imported oil and K the capital stock. Once the plant is built it is assumed that production is carried out at fixed factor proportions, i.e. we assume a putty-clay structure. Define production coefficients

$$\alpha_L = \frac{L}{X} \qquad \alpha_E = \frac{E}{X} \qquad \alpha_K = \frac{K}{X} \tag{5.2}$$

As f is linearly homogenous it follows that

$$1 = f(\alpha_L,\ \alpha_E,\ \alpha_K) \tag{5.3}$$

Let the prices of output, labor and oil be p, w and p_E, respectively, and let the capital rental be r.

The profit π is then

$$\pi = (p - \alpha_L\ w - \alpha_E\ p_E)\ x - rK \tag{5.4}$$

Let us now assume that the price p_E of oil is a random variable with distribution $\varphi(p_E)$. The profit then is also a random variable and we assume that the entrepreneur maximizes expected utility profit, i.e.

$$\int_0^\infty U(\pi(p_E))\ \varphi(p_E)\ dp_E \tag{5.5}$$

where U is a strictly concave utility function.

It could be argued that the assumption, that only the price of oil is a random variable, is inconsistent with general equilibrium theory. This is because changes in the price of oil eventually will affect the product price, as well as other factor prices. Later on we will consider the very important case where the world market product price is highly correlated with the oil price.

Assume that the entrepreneur has determined the production coefficients and the size of the capital stock. If the oil price is such that the revenues cover the operating costs, i.e. wages and expenditures on oil, it is obviously profitable to produce at full capacity. In that case the production is given by

$$x = \frac{1}{\alpha_K} K$$

If, however, the price of oil is so high that the variable costs are greater than the revenue, it is profitable to let the plant be idle, i.e.

$$x = 0$$

The critical value of the oil price is thus

$$p_E' = \frac{p - \alpha_L w}{\alpha_E} \tag{5.6}$$

The expected utility maximization problem can then be written

$$\max \int_0^{p_E'} U \{(p - \alpha_L w - \alpha_E p_E)\frac{K}{\alpha_K} - rK\} \, d\varphi_{p_E} +$$

$$+ \int_{p_E'}^{\infty} U(- rK)\, d\varphi_{p_E}$$

s.t. $1 = f(\alpha_L, \alpha_E, \alpha_K)$

$$p_E' = \frac{p - \alpha_L w}{\alpha_E}$$

Maximization over K yields

$$\int_0^{p_E'} U'\left(\frac{p-\alpha_L w-\alpha_E p_E}{\alpha_K} - r\right) d\varphi_{p_E} +$$

$$+ \int_{p_E'}^{\infty} U'(- r)\, d\varphi_{p_E} = 0$$

Multiplication by K yields

$$\int_0^{p_E'} U'(\pi) \{(p-\alpha_L w-\alpha_E p_E)\ x - rK\}\ d\varphi_{p_E} +$$

$$+ \int_{p_E'}^{\infty} U'(\pi)(- rK)\, d\varphi_{p_E} = 0 \qquad \text{or}$$

$$\int_0^{\infty} U'(\pi) \cdot \pi(p_E)\, d\varphi_{p_E} = 0 \tag{5.7}$$

The profit π is a non-increasing function of p_E and U' is decreasing in π. Let $\bar{\pi}$ be the expected profit. As π is monoton there exists a $\hat{p}_E$ such that $\bar{\pi} = \pi(\hat{p}_E)$ and we can rewrite the equation above as

$$0 = \int_0^{\hat{p}_E} U'(\pi)(\pi-\bar{\pi})\, d\varphi_{p_E} + \int_{\hat{p}_E}^{\infty} U'(\pi)(\pi-\bar{\pi})\, d\varphi_{p_E} +$$

$$+ \bar{\pi} \int_0^\infty U'(\pi)\, d\varphi_{p_E} < U'(\bar{\pi}) \int_0^{\hat{p}_E} (\pi - \bar{\pi})\, d\varphi_{p_E} +$$

$$+ U'(\bar{\pi}) \int_{\hat{p}_E}^\infty (\pi - \bar{\pi})\, d\varphi_{p_E} + \bar{\pi} \int_0^\infty U'(\pi)\, d\varphi_{p_E} =$$

$$= \bar{\pi} \int_0^\infty U'(\pi) d\varphi_{p_E} \quad \text{and}$$

$$\bar{\pi} > 0 \tag{5.8}$$

Thus the expected profit is strictly positive. This is in contrast to the classical case with the linearly homogenous production technology and complete certainty where the profit is zero. A superficial glance at the derivation shows that it is not uncertainty per se but the existence of risk aversion that is behind a positive expected profit. With risk neutrality, expected profit would be zero.

Let us now maximize over the production coefficients. The first order necessary conditions are

$$- \int_0^{p_E'} U'(\pi) \cdot w \frac{K}{\alpha_K}\, d\varphi_{p_E} + U(\pi(p_E')) \cdot \frac{\partial p_E'}{\partial \alpha_L} -$$

$$- U(-rK) \cdot \frac{\partial p_E'}{\partial \alpha_L} + \lambda f_L = 0 \tag{5.9}$$

$$- \int_0^{p_E'} U'(\pi) \cdot p_E \frac{K}{\alpha_K}\, d\varphi_{p_E} + U(\pi(p_E')) \frac{\partial p_E'}{\partial \alpha_E} -$$

$$- U(-rK) \cdot \frac{\partial p_E'}{\partial \alpha_E} + \lambda f_E = 0 \tag{5.10}$$

$$- \int_0^{p_E'} U'(\pi) \cdot \frac{p-\alpha_L w-\alpha_E\ p_E}{\alpha_K^2} \cdot K\ d\varphi_{p_E} + U(\pi(p_E')) \frac{\partial p_E'}{\partial \alpha_K} -$$

$$- U(-\ rK) \frac{\partial p_E'}{\partial \alpha_K} + \lambda f_E = 0 \qquad (5.11)$$

where λ is a Lagrange multiplier associated with the constraint

$$1 = f(\alpha_L,\ \alpha_E,\ \alpha_K).$$

As $\pi(p_E') = -rK$ it follows that the conditions above can be written

$$\frac{\alpha_K}{K} \lambda\ f_L = w \int_0^{p_E'} U'\ d\varphi_{p_E}$$

$$\frac{\alpha_K}{K} \lambda\ f_E = \int_0^{p_E'} U'\ p_E\ d\varphi_{p_E}$$

$$\frac{\alpha_K}{K} \lambda\ f_K = \int_0^{p_E'} U' \frac{p-\alpha_L w-\alpha_E\ p_E}{\alpha_K} d\phi_{p_E}$$

The following notations will prove to be useful:

$$\tilde{U}' = \int_0^{p_E'} U'\ (\pi) \frac{d\varphi_{p_E}}{\beta} \qquad (5.12)$$

$$\beta = \int_0^{p_E'} d\varphi_{p_E} \qquad (5.13)$$

$$\tilde{\varphi}_{p_E} = \frac{1}{\beta} \varphi_{p_E} \qquad (5.14)$$

from which it follows that $0 < \beta < 1$ and that $\tilde{\varphi}_{p_E}$ is the conditional probability density function for p_E given that

$p_E \leq p_E'$.

We will also use

$$\mu = \frac{\alpha_K}{K} \cdot \frac{\lambda}{\beta} .$$

Define the conditional expectation

$$\tilde{p}_E = \int_0^{p_E} p_E \, d\tilde{\varphi}_{p_E}$$

and the unconditional

$$\bar{p}_E = \int_0^{\infty} p_E \, d\varphi_{p_E} .$$

Obviously $\bar{p}_E > \tilde{p}_E$.

With these notations, the first condition can be written

$$\mu f_L = w^{\sim} U' \tag{5.15}$$

The second condition can be written

$$\mu f_E = \frac{1}{\beta} \int_0^{p_E'} U'(\pi(p_E)) p_E \, d\varphi_{p_E} =$$

$$= \int_0^{p_E'} U'(\pi(p_E))(p_E - \tilde{p}_E) d\tilde{\varphi}_{p_E} +$$

$$+ \tilde{p}_E \int_0^{p_E'} U'(\pi(p_E))d\tilde{\varphi}_{p_E} =$$

$$= \tilde{p}_E \tilde{U}' + \int_0^{p_E'} U'(\pi(p_E))(p_E-\tilde{p}_E)d\tilde{\varphi}_{p_E} \qquad (5.16)$$

Expanding $U'(\pi(p_E))$ around $\tilde{p}_E$ yields

$$\mu f_E = \tilde{p}_E \tilde{U} + \int_0^{p_E'} \{U'(\pi(\tilde{p}_E)) -$$

$$- U''(\pi(\tilde{p}_E))\alpha_E x(p_E-\tilde{p}_E)\}(p_E-\tilde{p}_E)d\tilde{\varphi}_{p_E} =$$

$$= \tilde{p}_E \tilde{U}' - U''(\pi(\tilde{p}_E))\alpha_E x\tilde{\sigma}^2_{p_E} =$$

$$= \tilde{p}_E U' - U'(\pi(\tilde{p}_E)) \cdot \frac{U''(\pi(\tilde{p}_E))}{U'(\pi(\tilde{p}_E))} x\alpha_E\tilde{\sigma}^2_{p_E} =$$

$$= \tilde{p}_E\tilde{U}' + 2U'(\pi(\tilde{p}_E)) \cdot R_u \cdot x\alpha_E\tilde{\sigma}^2_{p_E} \qquad (5.17)$$

where R_u is the Arrow-Pratt measure of absolute risk aversion (see f.e. Varian, 1978), i.e.

$$R_u = -\frac{1}{2} \frac{U''}{U'}.$$

Without making assumptions on the third order derivative of the utility function, it is impossible to compare $\tilde{U}'$ and $U'(\pi(\tilde{p}_E))$.

If the third derivative is zero, they are equal, if it is negative (for all relevant prices) $\tilde{U}'$ is greater than $U'(\pi(\tilde{p}_E))$ and vice versa. We will assume for simplicity that they are approximately equal.

Let us finally analyze the last condition

$$\mu f_K = \int_0^{p_E'} U' \cdot \frac{p - \alpha_L w - \alpha_E p_E}{\alpha_K} \, d\tilde{\varphi}_{p_E}.$$

Then

$$\mu f_K = \frac{1}{K} \int_0^{p_E'} U' \cdot (p - \alpha_L w - \alpha_E p_E) x d\tilde{\varphi}_{p_E} =$$

$$= \frac{1}{K} \int_0^{p_E'} U' \pi d\tilde{\varphi}_{p_E} + r\tilde{U}' \qquad (5.18)$$

According to (5.7) we then have

$$\mu f_K = - \frac{1}{K\beta} \int_{p_E'}^{\infty} U' \, \pi d\varphi_{p_E} + r\tilde{U}' =$$

$$= \frac{r}{\beta} \int_{p_E'}^{\infty} U' d\varphi_{p_E} + rU' > rU'.$$

Moreover,

$$\mu f_K = r\tilde{U}' + \frac{1}{K} \int_0^{p_E'} U'(\pi)\pi \, d\tilde{\varphi}_{p_E} = \text{(due to (5.7))}$$

$$= r\tilde{U}' + \frac{1}{\beta} \frac{1}{K} \int_{p_E'}^{\infty} U'(-rK)(-rK) d\varphi_{p_E} =$$

$$= r\tilde{U}' + r \frac{1-\beta}{\beta} \cdot \frac{U'(-rK)}{\tilde{U}'} \qquad (5.19)$$

We then have two second order approximations

$$\mu f_L = \tilde{U}'w$$

$$\mu f_E = \tilde{U}'\tilde{p}_E + 2U'(\pi(\tilde{p}_E)) \cdot R_u \cdot x\alpha_E \tilde{\sigma}^2_{p_E}$$

$$\mu f_K = \tilde{U}'r + r\,\frac{1-\beta}{\beta} \cdot U'(-rK) \tag{5.20}$$

or

$$\frac{\mu}{\tilde{U}'}\, f_L = w$$

$$\frac{\mu}{\tilde{U}'}\, f_E = \tilde{p}_E + \frac{U'(\tilde{\pi})}{\tilde{U}'}\, x\alpha_E R_u \tilde{\sigma}^2_{p_E} =$$

$$= \tilde{p}_E + 2\,\frac{U'(\tilde{\pi})}{\tilde{U}'}\,\frac{1}{E}\,R_u\,\tilde{\sigma}^2_\pi$$

$$\frac{\mu}{\tilde{U}'}\, f_K = r\left(1 + \frac{1-\beta}{\beta}\,\frac{U'(-rK)}{\tilde{U}'}\right) \tag{5.21}$$

The interpretation of these conditions for a maximum of expected utility are straightforward.

The first condition simply equates the marginal productivity of labor and the real wage rate.

The second is more interesting. It says that the energy coefficient should be chosen so that the marginal productivity of oil equates the conditional expectation of the oil price, given that this price is low enough to keep the plant in operation, plus a risk premium.

The risk premium is equal to

$$2\,\frac{U'(\tilde{\pi})}{\tilde{U}} \cdot \frac{1}{E}\,R_u\tilde{\sigma}^2_\pi$$

If we assume that $U'(\tilde{\pi})$ is approximately equal to $\tilde{U}'$ the risk premium can be interpreted as follows. $\tilde{\sigma}^2_\pi$ is the variance of the profit, given that the operating costs are covered. $R_u \tilde{\sigma}^2_\pi$ is the amount the decision maker is willing to pay for exchanging the uncertainty in the oil price with its conditional expectation. This amount divided with amount of oil demanded, then is the risk premium per unit of oil, which is added to the conditional expectation of the oil price.

If the decision maker is risk neutral so that $R_u = 0$, the marginal productivity of oil equals the conditional expected oil price. Note that this price is lower than the unconditional expected oil price.

If there would have been **ex post** substitution possibilities so that the operating costs could be covered, irrespective of the oil price, the conditional expectation and unconditional expectations would coincide. Moreover, with positive risk aversion, the firm would adjust to an oil price greater than the expected. This gives one way of interpreting the simulations we presented in chapter 2.

The last condition determines the choice of capital coefficient. That coefficient should be choosen so as to equate marginal productivity of capital and an adjusted interest rate. The adjustment consists of the multiplicative faktor

$$1 + \frac{1-\beta}{\beta} \frac{U'(-rK)}{\tilde{U}'}$$

This factor depends solely on the fact that there is a positive probability $(1-\beta)$ that the plant will not be used. The term $(1-\beta)/\beta$ reflects the ratio between the probabilities of not using the plant and using it. As $\tilde{U}'$ is the mean value of the marginal utility of income for the conditional distribution, it follows that $(U'(-rK))/\tilde{U}'$ is both a measure of risk aversion and the conditional average profit related to the loss incurred if the plant it not operated. Even wih risk neutrality (which means that $(U'(-rK))/\tilde{U}' = 1$) the marginal productivity of capital should exceed the interest rate because of the risk that the plant will be idle.

Thus our three conditions reduce to the classical ones if

i) decision makers are risk neutral, and
ii) the probability of closing the plant is zero.

5.3 Profit Sharing

Let us now assume that there are m firms producing the same commodity with the same inputs. Are there in this situation any reasons for establishing a system of sharing the risks? The risk is solely due to the stochastic nature of the oil price and a high oil price will affect all firms in the same direction. The risk is thus a collective risk not an individual risk. It is therefore not possible to rely on some law on large numbers to motivate the introduction of an insurance system. If all firms have the same technologies and all entrepreneurs have the same utility function differences in risk aversion do not either seem to support an insurance system. In spite of these remarks let us consider a complete pooling of the different enterprises to see what differences there will be compared with the case where there is no risk sharing.

If π_j denotes the profit of the firm j, the total profit in the society from this group of firms, denoted by π is given by

$$\pi = \sum_{j=1}^{m} \pi_j \tag{5.22}$$

Assume now that this total profit is distributed to the n taxpayers so that no i receives S_i. A Pareto optimal allocation can then be characterized by the solution to the following maximization problem for a suitable choice of weights β.

$$\max \int_0^\infty \sum_{i=1}^{n} \beta_i \; U_i(S_i) \; d\varphi_{p_E} \tag{5.23}$$

$$\text{st} \quad \sum_{i=1}^{n} S_i = \sum_{i=1}^{m} \pi_j$$

$$\pi_j = (p - \alpha_L^j \, w - \alpha_E^j \, p_E) \, x^j - rK^j \qquad j = 1,2,\ldots,n$$

$$1 = f(\alpha_L^j, \alpha_E^j, \alpha_K^j) \qquad j = 1,2,\ldots,n$$

$$x^j = \alpha_K^j \, K^j$$

As discussed above, let us assume that all entrepreneurs have the same technology available. Because of the symmetry it follows that the production coefficients will be the same for all plants and we will have, as an equivalent maximization problem, the following

$$\max \int_0^\infty \sum_{i=1}^n \beta_i \, U_i(S_i) \, d\varphi_{p_E} \tag{5.24}$$

$$\text{s t} \sum_{i=1}^n S_i = (p - \alpha_L w - \alpha_E p_E) \sum_j x_j - r \sum_j K_j = \pi$$

$$1 = f(\alpha_L, \alpha_E, \alpha_K)$$

$$\sum_j x_j \leq \frac{1}{\alpha_K} \sum_j K_j$$

It is apparent that, except from the objective function, this is an identical problem to the problem of maximizing the expected profit in a single firm. The objective function can, however, be transformed so the new problem is completely identical to the previous one. Assume that production coefficients, capital stocks and production volumes in the different plants have been decided upon. The resulting total profit π shall then be distributed among the taxpayers in such a way that

$$\max \int_0^\infty \sum_1^n \beta_i \, U_i(S_i) d\varphi_{p_E} \tag{5.25}$$

$$\sum_{i=1}^n S_i = \pi$$

The necessary conditions for this maximization problem is

$$\beta_i \, U_i' - \lambda = 0$$

where λ is Lagrange multiplier. (Remember that π is a random variable so these necessary conditions must hold for every feasible value on π.) This means in particular that the solution must solve the following problem

$$\max \sum_{i=1}^{n} \beta_i \; U_i(S_i) = V(\pi)$$

$$\text{s t} \quad \sum_{i=1}^{n} S_i = \pi$$

for every π. Here $V(\pi)$ is the social utility function.

The objective function to the problem above can now be written

$$\max \int_0^{\infty} V(\pi) \; d\varphi_{p_E} \tag{5.26}$$

and the constraints are

$$\pi = \sum_j \left((p - \alpha_L \omega - \alpha_E p_E) \; X_j - rK_j\right)$$

$$1 = f(\alpha_L, \alpha_E, \alpha_K)$$

$$X_j \leq \alpha_K \; K_j$$

This is obviously almost identical to the problem we discussed in conjunction with the single firm.

We have seen that the optimal solution to a large degree depends on the Arrow-Pratt measure of absolute risk aversion. What is the implicit attitude toward risk, implied by the social utility function compared to the individual risk aversion? We note that

$$V'(\pi) = \lambda$$

$$V''(\pi) = \frac{d\lambda}{d\pi}$$

Differentiation of the necessary conditions yields

$$V'' = \frac{U_i''}{\sum_{i=1}^{n} \frac{1}{\beta_i}} \tag{5.27}$$

The Arrow-Pratt absolute measure of risk-aversion R_u^i of the individual utility function is defined as

$$R_u^i = -\frac{1}{2}\frac{U_i''}{U_i'} \tag{5.28}$$

and the corresponding measure for the aggregated utility function V is given by

$$R_V = -\frac{1}{2}\frac{V''}{V'} = -\frac{1}{2}\frac{U_i''}{\beta_i \sum_{i=1}^{n} \frac{1}{\beta_i} \cdot U_i'}$$

Let $\frac{1}{\beta_k} U_k' = \min\limits_{i} \frac{1}{\beta_i} U_i'$

Then $R_V < -\frac{1}{2}\frac{U_i''}{n\beta_i \frac{1}{\beta_k} U'_k} = -\frac{1}{2}\frac{\beta_k}{n\beta}\frac{U_i''}{U'_k}$

Choose i = k

$$R_V < -\frac{1}{2}\frac{U_k''}{nU_k'} = \frac{R_u^k}{n}$$

We have thus reached the important conclusion that the aggregated utility function will exhibit smaller absolute risk aversion than the individual utility function. Moreover, if the number of taxpayers goes to infinity, the absolute risk aversion will tend to zero.

We have here assumed that the profit is shared among the individuals in such a way that welfare is maximized. Exactly the same conclusions can however be reached if we assume that the individuals own shares in the total profit. In both cases will the aggregate utility function exhibit a smaller degree of risk aversion. This result is, of course, an equivalent formulation of the celebrated Arrow-Lind theorem (Arrow-Lind, 1970) by which the total cost of bearing risk goes to zero if it is shared by a great number of individuals.

As $\pi = \sum_{j=1}^{m} \pi_j$ it follows that

$$\sigma_\pi^2 = \sum_{j=1}^{m} \sigma_{\pi_j}^2 + 2 \sum\sum_{i \neq j} \text{cov}(\pi_i, \pi_j)$$

If the individual profits have the same distribution and are perfectly correlated

$$\sigma_\pi^2 = m^2 \sigma_{\pi_j}^2$$

In this case, the cost of risk, in the sense of equivalent variation, when individual entrepreneurs carry their own risk, is given by

$$C_1 = \sum_{j=1}^{m} R_u^j \sigma_{\pi_j}^2$$

If all entrepreneurs have the same risk aversion R_U it follows that

$$C_1 = m R_U \sigma_{\pi_j}^2$$

If instead we let all n taxpayers share the risk the cost is

$$C_2 = R_V \sigma_\pi^2 = \frac{m^2}{n} R_U \sigma_\pi^2 = \frac{m}{n} \cdot C_1$$

Thus, if $n > m$, risk sharing has reduced the cost of the risk connected with oil prices. However, if $n = m$, a not unreasonable case, $C_1 = C_2$ and no reduction in the cost of risk is obtained.

The case we have considered is, of course, an extreme case. Due to technological differences between different plants the individual profits will not be perfectly correlated and we would have

$$\sigma_\pi^2 = \sum_{j=1}^{m} \sigma_{\pi_j}^2 + 2 \sum_{i \neq j}\sum \mathrm{cov}(\pi_i, \pi_j) <$$

$$< \sum_{j=1}^{m} \sigma_{\pi_j}^2 + 2 \sum_{i \neq j}\sum \sigma_{\pi_i} \sigma_{\pi_j} = \sum_{i=1}^{m} \sum_{j=1}^{m} \sigma_{\pi_i} \sigma_{\pi_j}$$

Thus with risk sharing the cost would be

$$C_2 < \frac{1}{n} R_U \sum_i \sum_j \sigma_{\pi_i} \sigma_{\pi_j} < \frac{1}{2} \frac{m^2}{n} R_U \sum_{i=1}^{m} \sigma_{\pi_i}^2 = \frac{m}{n} C_2$$

and risk sharing would again reduce the cost of risk.

In the extreme case when $n \gg m$, R_V is close to zero and a glance at equation (5.21) shows that the second condition becomes

$$\frac{\mu}{\tilde{U}'} f_E \approx \tilde{p}_E$$

if the social attitude to risk is applied.

But this can be accomplished by stabilizing the oil price to $\tilde{p}_E$. That will make σ_π^2 in eq (5.21) equal to zero and the entrepreneurs will behave as if they are risk neutral. Note, however, that $\tilde{p}_E$ is smaller than the expected oil price and we should thus try to stabilize the oil price at a lower level than the expected oil price.

Moreover, even with risk neutrality, the last condition in (5.21) shows that the capital coefficient should be chosen so that marginal productivity of capital exceeds the rate of interest. With stable oil prices β would be equal to one for the individual entrepreneur while for society it still would be desirable to have the capital coefficient determined by a modified interest rate. This can be accomplished by tax on capital use.

Thus, risk sharing seems to reduce the cost of risk from oil prices. This can be accomplished by stabilizing the oil price at a level lower than its expected value and by taxing the use of capital.

Now, these conclusion is based on the implicit assumptions that there is an objective probability distribution over future oil prices which is accepted by everyone and that all decision makers have the same attitude toward risk. If these assumptions are not valid, not only the risk premiums will differ between firms but also the expected future oil price. We will therefore have a distribution of oil price certainty equivalents, over firms and consequently also a distribution of technologies over firms. In this sense, as long as there is no reason to believe that somebody has better information about future oil prices then anyone else, there will automatically be a spreading of risk. With oil prices stabilized, every plant will be optimized at the same oil price and there will be no spreading of risk. Stated in another way, with domestic oil price stabilization we are putting all eggs in one basket instead of spreading it out into several.

We have not, so far, incorporated this possibility of having flexibility in the aggregate production function into our analysis. It is, however, clear that this risk spreading argument is an argument against oil price stabilization schemes.

6 POLICY IMPLICATIONS

6.1 Introduction

In Chapter 4, we came to the conclusion that in order to induce individual decision makers to choose flexible designs of their plants and thus not optimizing them for a given oil price, they should be faced with the full uncertainty about future oil prices. In Chapter 5, we found that there are good reasons for society to be more risk neutral than individual entrepreneurs and that this calls for stabilization of the oil price.

These two opposite views will be further discussed and an attempt to evaluate the importance of the view will be made in this chapter.

In order to reconcile the two views, two additional factors are included in the analysis. The first is the existence of moral hazard problems when oil prices are stabilized. The second concerns the possibility that the covariances between output prices and oil prices are different from zero.

6.2 Moral Hazard

The model used in the previous chapter was extremely simple in some respects. One particular feature was the absence of technological flexibility options, i.e., the feature we stressed in Chapter 4. We know from the previous chapter that the total cost of risk bearing can be reduced by letting more individuals share the risk. As soon as we introduce possibilities of avoiding some of the consequences from fluctuating oil prices, the situation will be different.

Assume that each entrepreneur has the possibility of designing his plant with different degrees of technological flexibility at the cost of reducing static efficiency. If the entrepreneur is guaranteed a fixed oil price, all incentives to design the plant so as to be flexible are effectively destroyed. We have here a clear case of what has been called moral hazard in the insurance literature.

Home insurance gives one example of a moral hazard problem. Consider a case where the homeowner can influence the probability of a fire. With complete insurance coverage he has no incentives to be careful with fire, and no insurance company would offer complete coverage. In home insurance, the problem of moral hazard is in general handled by co-insurance, i.e. the insured party has to pay a fraction of any loss, or by deductions where insurance is only paid on the excess of loss over some fixed sum. This may work quite well when the insured party has only a few alternatives to select among (be careful or not, having fire fighting equipment or not), but if the number of alternatives is large, the problem is harder to solve. Anyhow, it seems that whenever a moral hazard problem exists, complete insurance is not warranted.

Designing plants to be more flexible is a way of changing the probability distribution over profit realizations, and any attempt to completely stabilize oil prices will meet with moral hazard problems.

It is hard to think of a system of stabilizing domestic oil prices combined with deductions. That would require that each firm would have to bear the increased cost due to oil price increases, or to benefit from oil price drops, within certain bounds, but all profit variations in excess of that would be covered by insurance. In order to implement such a system we would need a simple and effective method of calculating objectively the losses or gains that are due to oil price variations. Even if we could disregard the administrative costs, this possibility of reducing moral hazard the problem can be dismissed straight away.

It is easier to conceive of a system of coinsurance by which the firm and the society share in the losses and gains that occur from fluctuating oil prices. The simplest system would consist of a partial stabilization of the domestic oil price. One could think of a taxation scheme which would reduce the variance of the domestic oil price subtsantially but not to zero. This will give the entrepreneurs incentives to build in some flexibility, but not to the same degree as would have been the case if no stabilizing attempts would have been made.

With no stabilization at all, private entrepreneurs are directly exposed to the uncertainty in oil prices. They will therefore have incentives to design their plants flexibly. The discussion in

Chapter 4 was based on the assumptions of risk neutral behavior. With risk aversion, it is clear that more flexibility will be built into the plants. According to our findings in Chapter 5, society should be more risk neutral than the individuals. Thus, we may have the situation in which we will have too much flexibility if the oil price is not stabilized.

We have also seen that complete stabilizations of the oil price is not warranted. Instead we have to make a trade-off between the cost of having partial stabilization and the cost connected with the moral hazard problems.

6.3 World Market Relative Prices

So far we have assumed that only one price has been uncertain, namely the world market price of oil. In reality, variations in this price will lead to variations in other world market prices. Thus, the covariances of Swedish output prices and the oil price are not equal to zero. If Sweden would stabilize the domestic oil price we would still be exposed to the secondary effects of variations in the world market price of oil through the induced variations in those other prices. Thus we would have created a wedge between the domestic cost of production (as determined by the domestic oil price) and the prices on our export commodities (which are determined by he world market price for oil). It is well known that the tax on the domestic oil consumption will have distortive effects and reduce national income compared to what it otherwise would have been during the period when the tax is positive. An advocate of domestic oil price stabilization could, however, argue that when the world market price of oil increases, Sweden will be better prepared, and that the gains made at that time outweigh the cost of distortion.

Obviously, this conclusion must depend on how long we have to wait for the increase in the world oil price. If that happens far away in the future, it is clear that the discounted benefits cannot outweigh the cost of having this wedge. On the other hand, if it is expected that the next oil price increase is just around the corner, the probability of benefits outweighing the costs increases.

This discussion has, however, not taken into account the fact that the wedge between domestic production costs and world market prices caused by the oil taxes will have effects on the industrial structure. A higher domestic oil price than the world market price for oil, but with unchanged prices on other goods and services traded on the world market, means that those Swedish plants which are heavy users of oil will have difficulties in covering their costs and may have to stop producing. Other activities, which are not oil intensive, will thereby get room for expansion. Thus, the domestic oil tax may change the domestic industrial structure in a way that would not have occurred if the world market prices, which would rise in case of a world market oil price increase, had increased correspondingly. That is, with world market prices on all traded goods and services adjusted to the new oil price level, the Swedish industrial structure would not have to change very much.

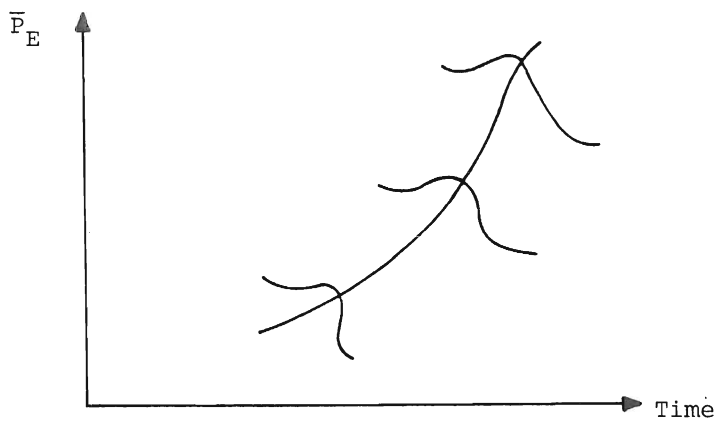
Moreover, with a domestic oil tax, the Swedish industrial structure may not be well adapted to the situation on the world markets if the world market price on oil increases and induces a further change in relative prices on traded goods. Stabilization of the domestic oil price may therefore imply greater instability in individual profits. That is, it is not the oil prices but the whole range of relative prices that should be stabilized. But this is neither possible nor desired, bearing in mind all the rigidities such a policy would imply.

Thus, it is by no means certain that a high domestic stable oil price level will improve our future adjustment to world market oil price increases. One can argue that it may reduce our possibilities of meeting such a price increase with as small disturbances as possible. In order to evaluate the empirical importance of these arguments, some numerical simulations have been carried out. These will be presented in Section 6.5. Before that the principles involved are briefly discussed.

6.4 The Costs and Benefits of Oil Price Stabilization

We maintain the hypothesis that there is an objective probability distribution of future oil prices, in the sense that all individuals and firms as well as the government agree on that distribution. Assuming that the expected oil price will increase according to Hotelling's rule, i.e., at a rate equal to the interest rate, the situation is illustrated in Figure 6.1.

Figure 6.1



However as we have seen, it is not expected oil prices that matters for the choice of technology, but rather the expected oil price, adjusted with the variance of the distribution and the attitude towards risk, i.e. eq (5.21)

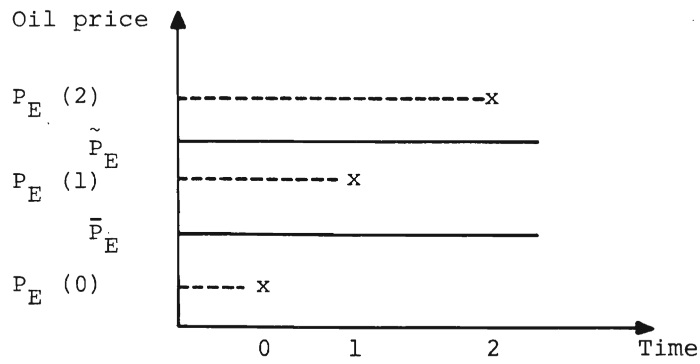
$$\tilde{p}_E + \frac{U'(\tilde{\pi})}{\tilde{U}'} \cdot \alpha_E x R_U \tilde{\sigma}^2_{p_E}$$

Assuming the variance to be constant over time, the adjusted expected price will also increase at the same rate (approximately) over time. The adjustment is, of course, for the individual risk aversion.

In order to simplify the discussion and focus on the stochastic nature of oil prices, let us abstract from the trend in prices and consider Figure 6.2.

An oil price stabilization scheme aims at guaran-

Figure 6.2



$\tilde{P}_E$ = Adjusted expected oil price
$\bar{P}_E$ = Expected oil price

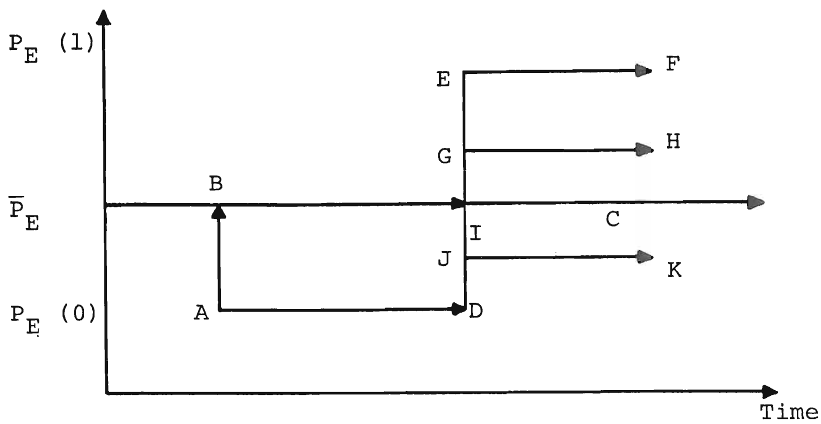
teeing a price equal to $\bar{p}_E$(assuming the number of individuals being so large that society is risk neutral). If the initial oil price is $p_E(0)$, the scheme would demand an oil tax increasing the price to $\bar{p}_E$ and then keeping that price forever.

In time period 1 the price increases to $p_E(1)$, greater than $\bar{p}_E$ but smaller than the individually adjusted oil price, i.e. $\tilde{p}_E$. The scheme would then require a subsidy in order to reduce the price to $\bar{p}_E$. In period 2, the price happens to be $p_E(2)$, greater than the individually adjusted expected oil price.

The gains to society from the price stabilization scheme is in this case the difference between the individually adjusted expected oil price, $\tilde{p}_E$, and the expected price, $\bar{p}_E$. This difference reflects the better allocation or risk bearing that can be obtained through the government. Thus the product of this difference and the quantity of oil demanded can be thought of as a measure of the total gain to society.

However, in deriving eq (5.21), we assumed that the output price was given and uncorrelated with the oil price. If this is not the case, stabilization of the oil price is, as we saw in the previous sections, connected with costs. These costs arise because of a biased development of the industrial structure. The stabilization scheme is in this case a wedge between domestic production costs and world market prices. The situation is illustrated in Figure 6.3 below.

Figure 6.3



If the initial price is $P_E(0)$, a stabilization scheme implies that the economy is following the path A, B, C. In the absence of such scheme, the path would be A, D, E, F. If, however, the output price is correlated with the oil price, the price of oil relative to the output price will follow a different path. In the absence of a stabilization scheme, the path would be A, D, G, H. The price rise on the world market in period 1 is thus moderated by the simultaneous increase in the output price. With a stabilization scheme, the path would be A, B, I, J, K. Thus there would be relative price decrease in period 1.

The cost to society is then represented by the adjustment to too high oil prices in the first period. Whether this is a net cost depends, however, on the length of the time period and the size of the oil price increase. As we will see in the next section, the net cost is substantial if the "waiting time" is twelve years and the oil price increase 60 percent.

It follows from this discussion that if we want a stabilization scheme, all relative prices should be stabilized. But that would require more information than is available and would also be impossible from a practical point of view.

In addition, there is the cost of moral hazard. A complete stabilization of oil prices would effectively kill all incentives to build in flexibility into the plants. It seems that these costs also may be substantial. Finally, we should add that instead of price stabilization schemes, it has been suggested that the oil price should be kept on permanent high level, in order to guarantee continued conservation efforts. It is hard to find any arguments at all for such a suggestion.

6.5 A Simulation Experiment

Obviously an oil price increase does not only affect the Swedish economy. Depending on a number of factors such as the oil exporters' propensity to spend, the level of net oil imports and the oil intensity of various productions processes, the real income levels, spending patterns and relative prices in essentially all countries are affected by major oil price increases. Thus an oil price increase affects the Swedish economy directly as well as indirectly, i.e. through its impacts on other economies. The analytical problems in connection with these indirect effects were discussed at some length in Chapter 3. One conclusion was that it is very difficult to get a reliable empirical estimate of the indirect effects associated with a given (unexpected) oil price increase.

Nevertheless it seems quite reasonable to expect that such an event tends to raise the relative price of oil-intensive goods. Moreover, if these effects on relative prices on internationally traded goods are neglected, the "home" country's real income loss due to an unexpected oil price increase tends to be overestimated. In order to somewhat elucidate this issue, a "Revised reference case" has been constructed. Except for the assumptions about world market prices, this case is based on the same assumptions as the "Reference case" presented in Chapter 2. These prices are assumed to adjust to changing oil prices and other exogenous factors as if the structure of the economy of the rest of the world was the same as the structure of the Swedish economy. Moreover, factors such as technological change, capital formation, change of the labor supply in the rest of the world are assumed to be the same as in the Swedish economy.

Clearly these assumptions are quite heroic. Yet the "revised reference case" is realistic in the sense that an oil price increase tends to increase the world market relative prices of oil intensive goods, whereas that was not the case in the original reference case. The results are also rather interesting. In the original reference case a 60 percent oil price deviation lead to a 23,470 millions SEK real income deviation (computed as an equivalent variation). (See Table 2.2). The corresponding figure in the revised reference case is 23,100 millions SEK. Thus, when the effect on international relative prices is taken into account, the computed domestic real income deviation is smaller than in the case where such indirect effects were disregarded. However, the difference is not very significant.

The purpose of the simulations presented here is to analyze the costs and benefits of a domestic oil price stabilization scheme. In practice such a scheme would, at least during some periods, imply a tax on domestic oil consumption. If the producers in the tradables producing sectors essentially are price-takers on international goods markets, the oil tax will induce a premature change in the economy's specialization pattern. The cost of the oil tax is thus due to the less than complete exploitation of the economy's current comparative advantages. The benefit of such a policy is paid out the day an unexpected oil price increase actually occurs, since then the economy will be relatively well adjusted to the pattern of comparative advantages established after the oil price increase. Again the question is whether the benefit exceeds the cost.

In order to illustrate this issue, another simulation experiment was carried out. Like in Chapter 2 only two oil price realizations, "Mathematical expectation" and "Mathematical expectation + 60 percent", were considered. The "Passive" energy policy strategy under "Revised reference case" conditions was taken as the basis for comparison. The policy strategy we want to analyze is one where the domestic oil tax is adjusted continuously in order to keep the domestic market price of oil at a constant level. That level happens to be the level actually attained in 1991 under oil price realization "Mathematical expectation + 60 percent". In terms of oil tax rates, this strategy means that the tax rate is around 100 percent in 1980, while it is 60 percent in 1991 under Oil price realization 1 and 0 percent under Oil price realization 2. The results of the simulations are presented in Table 6.1.

Table 6.1 Computed values of equivalent variations 1991
Millions SEK in the 1979 price level

Oil price realization, j / Energy, policy strategy, i	1 Mathematical expectation	2 Mathematical expectation + 60 percent	Conditional per unit cost of an oil price deviation* $(EV_{i2}-EV_{i1})/60$
0: Passive	0	-23 100	385
Active[a]	-15 400	-34 000	310

[a] Continuous adjustment of domestic oil taxation in order to stabilize domestic oil prices at a level corresponding to 210 percent of the actual 1979 level.

In spite of the fact that the government manages to predict the 1991 oil price level, the studied energy policy strategy is not very successful. The cost of the premature changes in the economy's specialization patterns is quite significant, while the benefit in terms of reduced real income loss when the "crisis" occurs is relatively small. In other words, the "Passive" strategy appears to dominate the other "Active" strategy.

6.6 Conclusions

The starting point of this essay has been the assumption, well founded in empirical evidence, that the main energy policy problem faced by Sweden today is not the level of oil prices or the high dependence of foreign energy sources, but the variability of oil prices. Although we have carried out our discussion in terms of oil prices, it is evident that the same kind of analysis is also relevant for variations in prices of other energy carriers. Thus, we would like to focus the energy policy discussions on the stochastic nature of energy prices.

Obviously, there are other reasons for energy policy than uncertainty of future energy prices. There are environmental and similar concerns which should be reflected in energy policy. There are indivisibilities in supply of certain forms of energy (f.e. district heating) which require collective action in order to achieve cost minimization. There are uncertainty about future deliveries of oil or other energy commodities (in contrast to uncertainty about future prices) which calls for energy emergency planning. However, in this essay we have chosen to disregard all these and other valid reasons for energy policy in order to enable a more thorough discussion of oil price uncertainty. We do not think that this abstraction in any way reduces the generality of the conclusions we can draw from our discussion.

As these conclusions are spread out over the previous chapters, and not always are as transparent as would be desirable, we have collected the, in our view, most important conclusions in this chapter.

i) Although we have not discussed it separately, it is quite clear that if the problem is stochastic oil prices, energy policy should not be formulated in terms of quantitative targets for different energy forms. Such targets tend to reduce the flexibility of the system because the optimal combination of different energy forms depends of course on the relative prices. By fixing quantitative targets one is therefore excluding the possibilities of adjusting to relative price changes. Instead the concept of energy policy strategy, meaning some kind of contingency planning, becomes important.

ii) Such an energy policy strategy should aim at increasing the flexibility of the Swedish economy in order to reduce the impact from sudden changes in world market conditions. There are two kinds of flexibility. First there is what we have called technological flexibility. By that we mean such a design of a plant or any other technical structure so that the operating costs do not increase rapidly with deviations in prices from those expected. In particular this means that the price elasticity of demand for oil (or any other energy commodity) is high. In order to obtain such increased technological flexibility one has in general to give up static efficiency, i.e. to accept higher average costs than otherwise would have been possible to obtain. Some of our simulations indicate that the gains from increased technological flexibility are not negligible.

However economic flexibility seems to be more important, i.e. the ability of the economic system to reallocate factors of production between different uses in response to changing environments. Our simulations indicate that inertia in labor mobility between different sectors may be the most important obstacle to a desired adjustment to changes in oil prices. Thus, energy policy should in part be viewed as a part of general economic policy, aiming at increasing wage flexibility and labor mobility. In general, however, this is not an energy policy problem but a problem of making the Swedish economy more flexible in order to make adjustments to changes in the world market conditions more rapid and more thorough. This need for increased economic flexibility does not reduce, however, the need for technological flexibility.

iii) Most individual entrepreneurs are risk averse; they will in the face of uncertain oil prices add a risk premium to the expected oil price when deciding on technology and the size of the plant. However, it is shown in Chapter 5 of this essay that under some very reasonable assumptions, it is possible to improve the allocation of risk by letting more individuals share the risk. Thus there is a market failure in the allocation of risk and some kind of policy intervention is warranted. This market failure has the interesting implication that without any intervention, the individual entrepreneurs tend to conserve more energy and build in more flexibility than seems optimal from a risk neutral society's point of view.

One example of an intervention aimed at correcting for the market failure would be an oil price stabilization scheme. It presupposes, however, that there is an objective probability distribution over future oil prices in the sense that all concerned agree on the distribution. If that is the case, a stable domestic oil price equal to the expected oil price, achieved by government taxation and subsidization, would imply a better sharing of risk and thereby a higher welfare.

Three quite strong objections against such a scheme can be raised, however. The first has to do with the existence of moral hazard. Entrepreneurs in general can avoid some of the costs of fluctuating oil prices by designing flexible plants. With a guaranteed price level they will not have any incentives to include such flexibility when designing their plants. Thus, a scheme aiming at complete stabilization of oil prices will in general not be a first best solution.

The second argument has to do with the fact that in reality there does not exist an objective probability distribution, nor is the attitude toward risk the same for all individuals. With no intervention we will therefore have a natural risk spreading over firms which are optimized for different probability distributions and risk attitudes. With the domestic oil price guaranteed at a certain level, this riskspreading will not take place and we would in fact "put all our eggs in one basket only".

The third objection is perhaps the strongest. It has to do with the fact that changes in world market prices of oil will lead to consequent changes in other prices. If Sweden then chooses an oil price level which differs from the one faced by our main trade partners, we will adjust our industrial structure to a different oil price level but to the same prices on other tradables. If and when a change in the oil price occurs, the Swedish structure will be badly adapted to the new set of relative prices then being established. Our simulations showed, that the cost of such a stabilization scheme, may be quite substantial and even for such a large price increase as 60 percent, a more passive approach would dominate the stabilization scheme. A complete stabilization scheme does thus not seem warranted.

iv) We have assumed above that there exists an objective probability distribution over future oil prices. This is obviously a very doubtful hypothesis and it could forcefully be argued that the government so far has been very bad in forecasting future oil prices (at least compared with some individual observers). In view of this any stabilization scheme or similar approaches seem more doubtful.

v) We have in this essay primarily analyzed the direct effects from oil price variations. The only indirect effects we have studied are the consequent changes in the prices of traded commodities. It may be that the most important indirect effect is through the consequent change in world real income and effective demand. As we have not analyzed that effect at all we can not draw any conclusions. We would like, though, to point out the possibility that oil conservation measures in Sweden may counteract economic policy measures necessitated by the fall in effective demand.

vi) Finally, we have focused on the problem of uncertain future oil prices. That uncertainty is exogenous to Sweden. We have not many possibilities to reduce that uncertainty (except by partaking in international cooperation and perhaps trade on future markets).

The energy field is, however, full of other kinds of uncertainties which very often are created by energy policy measures. The whole discussion on nuclear power is one example. Other examples are easy to find. But this kind of uncertainty can be reduced by establishing stable rules. The conclusion can then be phrased as follows: Exogenous uncertainty should be permitted to influence all decision makers - consumers, managers, civil servants - while endogenous uncertainty should be reduced by establishing stable rules in terms of domestic energy policy parameters.

APPENDIX

A.1 Introduction

The calculations presented in the preceding chapters were carried out by means of various so called computable general equilibrium (CGE) models, all being parts of a system of CGE-models. In this appendix the main features of this system of models are presented. The exposition is to a large extent based on Bergman (1982), and Bergman-Ysander (1983).

A.2 Some Common Features of the Models

The models presented here were especially designed for analysis of problems related to national energy policies in a small open economy, i.e., an economy with a relatively large trade-exposed sector, but with limited influence in its terms of trade. The model-set consists of a static model for projections of "long-run" equilibria, and a dynamic model for projection of certain aspects of the economy's evolution from a "short-run" equilibrium in the direction of a "long-run" equilibrium. In addition, there are a number of variants of the dynamic model which, in turn, can be regarded as a variant of the static model.

All of the models are "real", i.e., there are no financial assets and the exchange rate, being the numeraire of the price system, is given exogenously. This also applies to world market conditions, domestic technology and preferences and real public consumption. Moreover, the gross savings ratio is determined outside the models. In all models, labor supply is given exogenously and in the static model this also applies to the supply of capital.

In the solution to each of the models, a system of equilibrium relative prices of goods and the real wage rate are determined, as well as a specific pattern of production, consumption, foreign trade, and employment. The static model determines the sectoral use of capital, while all variants of the dynamic model determine the sectoral allocation of gross investments.

All product and factor markets are treated as if they were competitive, and relative product and factor prices are generally assumed to be flexible enough to clear all markets. In some variants of the dynamic model, however, the real wage is determined exogenously in all or some periods and consequently the labor market is not necessarily cleared.

In the models a distinction is made between the ex ante production function an the **ex post** production function. The **ex ante** production function is, in principle, a planning concept; it represents the technological constraints which apply in the planning stage when new production units are designed. The **ex post** production function, on the other hand, represents the technological constraints on the operation of existing production units.

The **ex ante** technology is assumed to exhibit constant returns to scale, and in each sector capital, labor, fuels and electricity are assumed to be substitutable factors of production. The use of manufactured non-energy inputs, however, is taken to be proportional to the output of the sector in which the inputs are used.

The **ex post** functions may be derived from the **ex ante** production functions if two assumptions are made. The first is that once capital has been invested in a given sector it cannot be reallocated to some other sector. The second assumption is that once the design (in terms of the use of fuels and electricity per unit of output) of a new production unit has been determined, the energy input coefficients are fixed. Thus, **ex post** the use of energy and of nonenergy produced inputs are determined in the same way. It should be noted that production units designed in period t can be put into operation in period t+1.

From the derivation of the **ex post** production functions it is clear that they exhibit decreasing returns to scale. However, because the **ex ante** production function is assumed to shift over time due to technical progress, production units of different "vintages" must be distinguished in each sector. Consequently, there will be a number of **ex post** production functions in each sector.

As it is assumed throughout that the producer's aim is to maximize profits, a dual representation of technology is more convenient than the traditional representation in terms of production functions. Thus, **ex ante** technology with constant returns to scale can be represented by an **ex ante** unit cost function for each sector, and the **ex post** technology can be represented by an **ex post** profit function for production units of each vintage in each sector. In accordance with Shephard's lemma, the **ex ante** factor proportions that minimize the cost are given by the partial derivatives of the **ex ante** unit cost functions, while Hotelling's lemma (see Varian, 1978) suggests that product supply and labor demand that maximize the profit in existing production units are given by the partial derivatives of the profit functions.

In a model dealing with large aggregates of goods rather than individual products, similar "goods" with different countries of origin can be regarded as less than perfect substitutes. This observation provides a rationale for incorporating the so-called Armington assumption in a CGE-model of a small open economy. According to Armington (1969) similar goods with different countries of origin are less than perfect substitutes, and domestic users of commodities with a given statistical classification actually use a mixture (composite) of imported and domestically produced goods with that classification.

The Armington assumption, which is incorporated in most CGE-models of open economies, implies that the price indices of domestically consumed composite goods are given by the unit cost functions corresponding to the "production" functions defining the composite goods. By Shephard's lemma, the "input" of domestically produced and imported goods, respectively, per unit of composite goods is given by the partial derivatives of the unit cost function for composite goods, with respect to the price of goods from the two sources of supply. Thus, the import functions are given by the product of the domestic demand for composite goods and the "input" of imports per unit of composite goods.

The goods exported from the small country are, of course, the goods imported by the rest of the world. Therefore, by applying the Armington assumption to the rest of the world, it is possible to obtain relative-price dependent export functions for the small country. From the assumption that the economy modelled has a very limited influence on export prices, it follows that the absolute values of the export price elasticities implied by the Armington export functions should be high. The models presented here all contain import and export function based on the Armington assumption.

Each model describes an economy with n+3 production sectors producing n+3 goods of which n are tradables. There is no joint production, and each good is produced in one sector only. Thus there is no real distinction between domestically produced goods and domestic production sectors. In the following exposition, goods and sectors will be denoted interchangeably by i and j. The production sectors are numbered from 0 to n+3, 0 being the sector producting fuels and 1 the electricity-generating sector, while n+1 is a private sector producting nontradeable goods, and n+2 is the public sector. There is also a "bookkeeping" sector, n+3 in which different goods are aggregated into one single capital good. On the demand side all households are represented by an aggregated household sector.

A.3 The Long-Run Static Model[1]

This model is intended to be a tool for analysis of long-run resource allocation problems. Here, "long-run" simply means that the time horizon is extended far enough to make it reasonable to let the **ex ante** unit cost function represent the technological constraints. The equilibrium condition for producers is then that the prices of domestically produced goods should be equal to the unit production costs of these goods.

As a consequence of the assumptions about the technology, the **ex ante** unit cost function can be divided into two parts. The first represents the minimum cost of fuels, electricity, capital, and labor per unit of output, while the second represents the corresponding cost of nonsubstitutable inputs. In the following, the first part is called "the net unit cost function". The producer's equilibrium condition can now be written.

$$P_j = \kappa_j^*(P_0^D, P_1^D, W_j, R_j; t) + \sum_{i=2}^{n} P_i^D a_{ij} + Q_j b_j; \quad (A.1)$$

$$j=0,1,\ldots,n+2$$

where $\kappa_j^*(\cdot)$ is the **ex ante** net cost function; P_j is the price of output j; P_i^D the price of composite good i; Q_j the price of complementary imports used as inputs in sector j; W_j the wage rate in sector j; R_j the user cost of capital in sector j; and t an exogenous shift parameter. The constants a_{ij} represent the input of composite good i per unit of output in sector j, and b_j is the corresponding parameter for input of complementary imports in sector j.[2]

The heterogeneity of labor is roughly accounted for by an exogenous wage structure, i.e.,

$$W_j = \omega_j W; \qquad j=0,1,\ldots,n+2, \tag{A.2}$$

where W is a general wage index and the ω_j's are constants. The user cost of capital is defined by

$$R_j = P_{n+3}(\delta_j + R); \qquad j=0,1,\ldots,n+2 \tag{A.3}$$

where P_{n+3} is the price of the aggregated capital good; δ_j the rate of depreciation in sector j and R the real rate of interest. The price index of capital goods is defined by

$$P_{n+3} = \sum_{i=1}^{n} P_{i,}^{D} a_{i,n+3}; \tag{A.4}$$

where the coefficients $a_{i,n+3}$ sum to unity. The equilibrium prices of composite goods are given by the unit cost functions of the composites, i.e., by

$$P_i^D = \phi_i(P_i, P_i^M); \qquad i=0,1,\ldots,n \tag{A.5}$$

where $\phi_j(\cdot)$ is the unit cost function corresponding to the "production" function defining composite good i, and P_i^M is the exogenously given world market price, in domestic currency, of goods with classification i.

Having now defined all prices and unit cost functions, the derivation of the static model is quite straightforward. As the **ex ante** technology exhibits constant returns to scale, the sectoral production levels are determined from the demand side, where three types of demand should be distinguished. There are two types of demand for composite goods; intermediate demand and final demand by the household sector. The third type of demand is export demand for the production sector outputs.

By Shephard's lemma and the assumptions about technology, the intermediate demand is given by

$$X_{ij} = \begin{cases} \dfrac{\partial \kappa_j^*(\cdot)}{\partial P_i^D} X_j, & \text{when } i=0,1 \\ & \qquad\qquad j=0,1,\ldots,n+2 \\ a_{ij}X_j, & \text{when } i=2,3,\ldots,n \end{cases} \tag{A.6}$$

where X_{ij} is the use of composite good i in sector j, and X_j is the gross output in sector j. Household demand is given by a function of the following type:

$$C_i = C_i(P_0^D \ldots P_i^D \ldots P_n^D, P_{n+1}, E); \qquad i = 0,1,\ldots,n+1 \tag{A.7}$$

where C_i is household demand for good i, E is total household consumption expenditure, and the functions $C_i(\cdot)$ are derived from the assumption that the household sector will maximize utility subject to a budget constraint.

By Shephard's lemma, the demand for competitive imports is given by

$$M_i = \frac{\partial \phi_i(\cdot)}{\partial P_i^M} \left\{ \sum_{j=0}^{n+3} X_{ij} + C_i \right\}; \qquad i=0,1,\ldots,n \qquad (A.8)$$

i.e., import demand is a function of the prices P_i and P_i^M, and the domestic demand for composite goods. Applying the same assumptions for "the rest of the world" thus means that export demand is given by functions of the type

$$Z_i = Z_i(P_i P_i^W; t); \qquad i=1,2,\ldots,n \qquad (A.9)$$

where Z_i is export demand for domestically produced goods with the classification i and P_i^W is the world market price for such goods produced elsewhere. The distinction between P_i^W is due to the fact that P_i^W is normally a f.o.b. price while P_i^M is normally a c.i.f. price. As the home economy is assumed to be small, the use of composite goods in the rest of the world is approximately equal to the production in the rest of the world. Thus the size of the world market can be represented by the exogenous shift parameter t.

Given the different demand equations, the equilibrium condition for the markets for domestically produced goods are given by

$$X_i = \frac{\partial \phi_i(\cdot)}{\partial P_i} \left\{ \sum_{j=0}^{n+3} X_{ij} + C_i \right\} + Z_i; \quad i=0,1,\ldots,n \quad (A.10)$$

$$X_i = \dot{C}_i; \qquad i=n+1,n+2 \qquad (A.11)$$

$$X_{n+3} = I + \sum_{j=0}^{n+2} \delta_j \frac{\partial \kappa_j^*(\cdot)}{\partial R_j} X_j; \qquad (A.12)$$

where C_{n+2} is the exogenously given public consumption and I is total net investments.

At equilibrium, household consumption expenditure, E, must be equal to the factor incomes of the household sector less net taxes and household savings. Instead of specifying such an inequality explicitly, it is determined implicitly by a current account constraint. Thus, at equilibrium, the following expression holds:

$$\sum_{i=1}^{n} P_i Z_i = \sum_{i=0}^{n} P_i^M M_i + \sum_{j=0}^{1} Q_j \bar{M}_j + D; \qquad (A.13)$$

where $\bar{M}_j$ is the demand for complementary imports and D is an exogenous variable representing net foreign transfers and net interest payments on foreign debt, expressed in domestic currency.

Finally, as capital and labor are supplies inelastically, the equilibrium conditions for the factor markets become

$$K = \sum_{j=0}^{n+2} \frac{\partial \kappa_j^*(\cdot)}{\partial R_j} X_j; \qquad (A.14)$$

$$L = \sum_{j=0}^{n+2} \frac{\partial \kappa_j^*(\cdot)}{\partial W_j} X_j; \qquad (A.15)$$

where K is total capital supply and L is total labor supply. Altogether these expressions, after appropriate substitutions, yield 6n+15 equations in the 6n+15 unknowns: $X_0 \ldots X_{n+3}$, $C_0 \ldots C_{n+1}$, $Z_1 \ldots Z_n; Z_1 \ldots Z_n$; $M_0 \ldots M_n$; $P_0 \ldots P_{n+3}$; $P_0^D \ldots P_0^D \ldots P_n^D$; E; W; and R.

In an alternative version of model, sectoral capital stocks are fixed, i.e., the model is converted into a short run static model. This means that the equilibrium condition A.14 is delated, and the variable R is delated. Moreover, the "user cost of capital" variable R_j are replaced by a set of sectoral quasi-rents, π_j, defined as the difference between gross receipts and variable costs.

A.4 The Dynamic Model

In the dynamic model there is, at some point in time, a "history" of technology and investment decisions in the form of production units of different "vintages" in each sector. In each production unit the technological constraints are given by the **ex post** production function derived from the **ex ante** production function that existed at the time of investment. The profit function of production units of a particular vintage, in each sector, represents the relevant technological constraints as well as the behavior of producers. Thus, gross profits in production units of vintage υ in sector J can be written

$$\Pi_{\upsilon j}(t) = \Pi_{\upsilon j}(P^*_{\upsilon j}(t),\ W_j(t);t) \quad \begin{array}{l}\upsilon=0,1,\ldots,t;\\ j=0,1,\ldots,n+2\end{array} \qquad \text{(A.16)}$$

where $\Pi_{\upsilon j}(\cdot)$ is the profit function of production units of vintage υ in sector j, and where[3]

$$P^*_{\upsilon j}(t) = P_j(t) - \sum_{i=0}^{1} P_i^D(t)a_{\upsilon ij} - \sum_{i=2}^{n} P_i^D(t)a_{ij} -$$

$$- Q_j(t)b_j; \quad \upsilon=0,1,\ldots,t;\ j=0,1,\ldots,n+2 \qquad \text{(A.17)}$$

Except for the dating, the symbols have the same meaning as in the preceding section. Observe that the profit functions shift over time as a result of exogenously determined depreciation of the initially invested capital. However, not all depreciation is determined exogenously; employment reductions in excess of those corresponding to the exogenously determined depreciation of old vintages can be interpreted as endogenously determined scrapping of inefficient production units.

By Hotelling's lemma the profit-maximizing supply of domestically produced goods in period t and sector j is given by

$$X_j(t) = \sum_{\upsilon=0}^{t} \frac{\partial \Pi_{\upsilon i}(\cdot)}{\partial P^*_{\upsilon j}}; \qquad j=0,1,\ldots,n+2 \qquad \text{(A.18)}$$

and by the same lemma the profit-maximizing demand for labor in period t and sector j can be written

$$L_j(t) = \sum_{\upsilon=0}^{t} - \frac{\partial \Pi_{\upsilon i}(\cdot)}{\partial W_j}. \qquad \text{(A.19)}$$

Looking at the allocation of resources at a given point in time, these are the only essential differences between the static and the dynamic model. Observe that the specification of the dynamic model implies that the number of vintages increases over time. In the initial period there is only one vintage in each sector, but then a new vintage is introduced in each period. In the case where t is set equal to zero, the dynamic model simply becomes another "snapshot" model, differing from the static model by the fixed sectoral capital stocks and energy input coefficients. In the following, this version of the dynamic model will be called the "Short-Run Static Model". Table A.1 gives a summary description of the three basic variants of the resource allocation model for a single period, say t. Where the models differ, the specification which applies to the Long-Run Static Model is indicated by LRS, while SRS and DYN indicate the specification adopted in the Short-Run Static Model and the Dynamic Model, respectively.

Table A.1 Three alternative models of resource allocation in period t[a]

Output supply

SRS[b] $$X_j = \frac{\partial \Pi_j(\cdot)}{\partial P^*_j}; \qquad j=0,1,\ldots,n+2$$

DYN $$X_j = \sum_{\upsilon=0}^{t} \frac{\partial \Pi_{\upsilon j}(\cdot)}{\partial P^*_{\upsilon j}} \equiv \sum_{\upsilon=0}^{t} X_{\upsilon j}; \qquad j=0,1,\ldots,n+2$$

LRS[c] $$P_j = \kappa^*_j(P^D_0, P^D_1, W_j, R_j; t) + \sum_{i=2}^{n} P^D_i a_{ij} + Q_j b_j; \qquad j=0,1,\ldots,n+2$$

Input demand

(a) Intermediate inputs

SRS $$X_{ij} = a_{ij} X_j; \quad i=0,1,\ldots,n; \quad j=0,1,\ldots,n+3$$

DYN $$X_{ij} = \begin{cases} \sum_{\upsilon=0}^{t} a_{\upsilon ij} X_{\upsilon j}; & i=0,1 \\ a_{ij} X_j; & i=2,3,\ldots,n \end{cases} \qquad j=0,1,\ldots,n+3$$

$$\text{LRS} \qquad X_{ij} = \begin{cases} \dfrac{\partial \kappa_j^*(\cdot)}{\partial P_i^D} X_j; & i=0,1 \\ a_{ij}X_j & i=2,3\ldots n \end{cases} \qquad j=0,1,\ldots,n+3$$

(b) Labor

$$\text{SRS} \qquad L_j = \frac{\partial \Pi_j(\cdot)}{\partial W_j}; \qquad j=0,1,\ldots,n+2$$

$$\text{DYN} \qquad L_j = \sum_{\upsilon=0}^{t} - \frac{\partial \Pi_{\upsilon j}(\cdot)}{W_j} \equiv \sum_{\upsilon=0}^{t} L_{\upsilon j}; \quad j=0,1,\ldots,n+2$$

$$\text{LRS} \qquad L_j = \frac{\partial \kappa_j^*(\cdot)}{\partial W_j} X_j; \qquad j=0,1,\ldots,n+2$$

Household demand for composite goods

$$C_i = C_i(P_0^D, P_1^D \ldots P_n^D, P_{n+1}, E); \qquad i=0,1,\ldots,n+1$$

Export demand[d]

$$Z_i = Z_i(P_i, P_i^W; t); \qquad i=1,2,\ldots,n+1$$

Gross investments

SRS $\quad I^G$ exogenous

$$\text{DYN} \qquad sY = P_{n+3}I^G + D$$

$$\text{LRS} \qquad I^G = I + \sum_{j=0}^{n+2} \frac{\partial \kappa_j(\cdot)}{\partial R_j} X_j$$

Definitions

$$P_{\upsilon j}^* = P_j - \sum_{i=0}^{t} P_i^D a_{\upsilon ij} - \sum_{i=2}^{n} P_i^D a_{ij} - Q_j b_j; \quad j=0,1,\ldots,n+2$$

$$P_i^D = \phi_i(P_i, P_i^M); \qquad i=0,1,\ldots,n$$

Table A.1, cont.

$$P_{n+3} = \sum_{i=2}^{n} P_i^D a_{i,n+3}$$

$$R_j = P_{n+3}(\delta_j + R); \qquad j=0,1,\ldots,n+2$$

$$W_j = \omega_j W; \qquad j=0,1\ldots n+2$$

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[a] As all variables apply for period t, the time indices have been left out. The models are SRS=The Short-Run Static Model, DYN=The Dynamic Model, and LRS=The Long-Run Static Model.

[b] As SRS is defined for the initial period only, production units can have only one vintage and consequently the vintage index is left out.

[c] Note that $b_j \neq 0$ for j=0,1 only

[d] Note that $Z_0 = 0$.

Definition of symbols used in Table A.1

A. Endogenous variables:

X_j	gross output in sector j = 0,1,...,n+3;
X_{ij}	use of composite good i=0,1,...,n in sector j=0,1,...,n+3;
L_j	use of labor in sector j=0,1,...,n+2;
I^G	total gross investments;
C_i	household consumption of composite good i= 0,1,...,n or the domestically produced good i= n+1;
E	total household consumption expenditures;
Z_i	export of domestically produced good i=1,2,...,n;
M_i	competing imports of good i=0,1,...,n;
$\bar{M}_j$	complementary imports to sector j=0,1;

P_i	price of domestically produced good $i = 0,1,\dots,n+3$;
$P^*_{\upsilon j}$	value added per unit of output in vintage $\upsilon=0,1,\dots,t$ in sector $j=0,1,\dots,n+2$;
P^D_i	price of composite good $i=0,1,\dots,n$;
W_j	wage rate in sector $j=0,1,\dots,n+2$;
W	index of the level of wages in the economy as a whole;
R_j	user cost of capital in sector $j = 0,1,\dots,n+2$;
R	real rate of return on capital;
Y	gross national income.

B. Exogenous variables

L	supply of labor;
K	supply of capital;
I	net investments in the economy as a whole;
C_{n+2}	public consumption;
P^M_i, P^W_i	world market price in the domestic currency unit, c.i.f. and f.o.b., respectively, of good $i=0,1\dots n$;
Q_j	world market price, in the domestic currency unit, of complementary imports to sector $j=0,1$;
D	sum of net foreign transfers and net interest payments on foreign debt.

C. Parameters

$a_{ij}(a_{\upsilon ij}$	input of composite good $i = 0,1\dots n$ per unit of output (production units of vintage $\upsilon=0,1\dots t$) in sector $j=0,1\dots n+3$;

b_j input of complementary imports per unit of output in sector $j=0,1...n+3$;

ω_j wage rate in sector $j=0,1...n+2$ deflated by the index of the general wage level;

δ annual rate of depreciation of capital in sector $j=0,1...n+2$;

s the gross savings ratio in the economy as a whole.

By letting the real wage rate $\left(W(t)\right)$ be exogenously determined, and thus the labor market equilibrium condition corresponding to A.15 become an accounting relation additional variants of SRS and DYN are obtained. In LRS, net investments (I)in the economy as a whole are determined exogenously, whereas this applies to gross investments (I^G) in SRS. In DYN, however, the level of gross investments is determined by an exogenously given gross savings ratio, s(t), in accordance with the equation

$$s(t)Y(t) = P_{n+3}(t)I^G(t) + D(t), \tag{A.20}$$

where Y(t) is the gross national income at current (relative) prices.

The creation of new vintages, however, is an important part of the dynamic model. The approach adopted in this part represents a quite significant simplication of what one might consider a "realistic" approach. It is assumed that producers have expectations about future prices and that all producers have the same expectations. Thus, denoting expected prices by a tilde (~), the following expressions hold:

$$\tilde{P}_j(t) = \tilde{P}_j(P_j(t),\ \hat{P}_j(t));\quad j=0,1,\ldots,n+2 \qquad (A.21)$$

$$\tilde{P}_i^D(t) = \tilde{P}_i^D(P_i^D(t),\hat{P}_i^D(t));\quad i=0,1,\ldots,n \qquad (A.22)$$

$$\tilde{Q}_j(t) = \tilde{Q}_j(Q_j(t),\ \hat{Q}_j(t));\quad j=0,1 \qquad (A.23)$$

$$\tilde{W}_j(t) = \tilde{W}_j(W_j(t),\ \hat{W}_j(t));\quad j=0,1,\ldots,n+2 \qquad (A.24)$$

where the cares (^) denotes exogenous variables. These are the price expectations held during period t, and will influence the design of production units put into operations in period t+1. If the exogenous variables do not affect the expected prices, expectations are said to be static; an assumption about rational expectations can be modeled by a suitable choice of exogenous variables. Producers are likely to invest only if the expected unit cost does not exceed the expected unit price of the output. This rule is incorporated in the model in two stages. In the first step, a set of sectoral interest rates, $r_1(t)$, which satisfy the investment rule in each sector is determined by means of the **ex ante** unit cost function and the expected prices. Thus, the $r_j(t)$'s are determined by the following equations:

$$\tilde{P}_j(t) = \kappa_j^*(\tilde{P}_0^D(t),\ \tilde{P}_1^D(t),\ \tilde{W}_j(t),\ \tilde{R}_j(t);t) +$$

$$0 \qquad + \sum_{i=2}^{n} \tilde{P}_i^D(t)a_{ij} + \tilde{Q}_j b_j;\quad j=0,1,\ldots,n+2 \qquad (A.25)$$

where

$$\tilde{R}_j(t) = P_{n+3}(t)(\delta_j + r_j(t));\quad j=0,1\ldots n+2 \qquad (A.26)$$

By Shephard's lemma, the **ex ante** coefficients for labor, capital, fuels, and electricity are given by the partial derivatives of the **ex ante** cost functions evaluated at the expected prices. Thus, the energy input coefficients in production units designed in period t and put into operation in period t+1 are determined by

$$\frac{\partial \kappa_j^*(\cdot)}{\partial P_i^D} = a_{t+1,ij}; \qquad i=0,1; \qquad j=0,1\ldots n+2 \qquad (A.27)$$

The desired capital-output ratios are determined in a similar way, i.e., by the partial derivative of κ_j^* with respect to R_j, evaluated at the expected prices.

The second stage is to allocate total investment over those sectors for which $r_j(t)$ is not lower than the market rate of interest, $r(t)$. This is done by means of the equation

$$I_j(t) = \begin{cases} \dfrac{\partial \kappa_j^*(\cdot)}{\partial \tilde{R}_j} \delta_j X_j(t) \left(\dfrac{r_j(t)}{r(t)}\right)^{\psi_j} & \text{if } r_j(t) \geq r(t) \\ 0 & \text{if } r_j(t) < r(t) \end{cases}$$
$$j=0,1,\ldots,n \qquad (A.28)$$

where $I_j(t)$ is the total investment in sector j in period t. Public investments, $I_{n+2}(t)$, however, are determined exogenously. Observe that when $r_j(t) = r(t)$, the existing capacity is maintained by replacement of depreciated capacity by new production units, and if $r_j(t) > r(t)$, the capacity in sector j is increased. The market rate of inte-

rest is determined in such a way that the market for investable funds are cleared. Thus, the following expression holds:

$$I(t) = \sum_{j=0}^{n+2} I_j(t). \qquad (A.29)$$

Where this, the description of the models is complete.

A.5 Implementation and Parameter Estimation

In order to implement these models, it is necessary to specify the functions $\kappa_j^*(\cdot)$, $\phi_i(\cdot)$, $C_i(\cdot)$ and $Z_i(\cdot)$. Moreover a large number of parameters has to be estimated.

A.5.1 Sectors, Goods and Data Sources

The sector classification adopted can be seen in Table A.2. It reflects an attempt to keep the number of sectors at a minimum, given the desire to elucidate the main effects on the industrial structure of changes in oil prices in the extremely trade-dependent Swedish economy.

There are several reasons for keeping the number of sectors at the smallest possible level which is compatible with a meaningful analysis of the issues under study. One is that the costs for solving and storing the model are quite sensitive to its size. Another is that input-output relations, which represent a significant share of the model's data bases, tend to be more stable over time if

Table A.2 Production sector definitions

Sector	SNI
0 Fossil fuels production	353, 354
1 Electricity production	4
2 Mainly important competing industries	11, 13, 31, 32, 33, 3412, 3419, 342, 355, 361, 362
3 Mainly exporting energy intensive industries	12, 2, 3411, 351, 37101 37102
4 Other mainly exporting industries	352, 356, 3699, 37103, 372, 38, 39
5 Sheltered industries and service production	3691, 3692, 5, 6, 7, 8, 9 (priv)
6 The public sector	
7 The capital goods sector (book-keeping sector)	

the model's production sectors are large aggregates of sectors rather than individual industries. A third reason is that the possibilities of getting good estimates of exogenous variables (such as world market prices, technical changes etc) for a large number of sectors from published data sources are quite limited.

For the type of models presented here, the main data source is input-output data. In fact, the models can be regarded as elaborated input-output models. As input-output data generally is not available in the form of time-series, most of the parameters in the models are estimated on the basis of one single input-output table.

The latest complete input-output table for Sweden is estimated on data from 1975. There is also a 1979 input-output table, but except for the energy input coefficients, that table is constructed on the assumption that the 1975 input-output coefficients were valid in 1979 as well. There is, however, another important difference between the 1975 and 1979 input-output tables. In the latter some important revisions of the national accounts have been taken into account, while that has not been done in the 1975 table. Thus, the 1979 table gives a better representation of the actual state of the economy. For this reason it was chosen as the point of departure for the projections of the future development of the Swedish economy discussed in Chapters 2 and 5. Tables A.3-A.5 give a brief account of some relations derived from the 1979 input-output table.

For the comparative statics presented in Chapters 3 and 4, however, another data-base was constructed. The basic aim in that work was to construct a data-base which reasonably well represented an equilibrium allocation of resources in the Swedish economy. The starting point was the 1975 input-output table. However, as only one year had elapsed since the 1973/74 oil price increases, it is quite likely that the energy input coefficients in this table do not represent equilibrium values. Moreover, the table also revealed significant intersectoral profit differentials.

To get around these problems, a new input-output table was generated by means of the long run static model (LRS) and the following assumptions:

1) The pre-1973/74 oil input coefficients represented equilibrium values.

Table A.3 Base year sectoral employment, energy use and value added shares

Sector	$\frac{L_j}{L}$	$\frac{X_{0j}}{X_0+M_0}$	$\frac{X_{1j}}{X_1+M_1}$	$\frac{Y_j}{Y}$
0	0.0009	0.0251	0.0025	0.0223
1	0.0095	0.0814	0.0249	0.0255
2	0.1226	0.0595	0.0620	0.1721
3	0.0472	0.1006	0.1557	0.0612
4	0.1303	0.0470	0.0862	0.1562
5	0.4258	0.4213	0.5346	0.3514
6	0.2637	0.0309	0.1138	0.2113
7	-	-	-	-
Σ	1.0000	0.7658[a]	0.9795[a]	1.0000

[a] The difference between this value and unity is made up of the shares of household consumption and exports.

Table A.4 Base year input coefficients for capital, labor, fuels and electricity

Sector	K_j/X_j	L_j/X_j	X_{0j}/X_j	X_{1j}/X_j
0	0.2174	0.0003	0.0512	0.0023
1	6.3451	0.0031	0.1850	0.0255
2	0.7361	0.0047	0.0159	0.0075
3	1.5517	0.0044	0.0649	0.0452
4	0.6229	0.0052	0.0132	0.0109
5	2.6974	0.0093	0.0639	0.0366
6	1.5461	0.0118	0.0096	0.0159
7	-	-	-	-

2) No change in oil input coefficients had occurred between 1973/74 and 1975. Thus the sectoral oil expenditures per unit of output was equal to the "old" oil input coefficient and the "new" oil price level.

3) The increased oil costs had lead to lower operating surpluses in the production sectors.

With revision, corresponding to these assumptions, of the input-output table a set of revised intersectoral profit differentials were generated. Thus eq. (A.3) became

$$R_j = P_{n+3}(\delta_j + \beta_j R); \qquad j=0,1,\ldots,n+2$$

where the parameters β_j reflected the revised intersectoral profit differentials. Using the revised input-output table for estimation of the model's parameters, and solving LRS under the assumption $\beta_i=1$ for all i, generated a quasi-equilibrium allocation of resources in the Swedish economy 1975. Since the observed intersectoral wage differentials (see eq (A.2)) were not revised, it was not a "full" equilibrium. On the basis of the thus generated input-output table for 1975, a data-base to the models was constructed.

A.5.2 Functional Forms and Parameter Values

Clearly the knowledge about **ex ante** production functions is very limited. This would suggest that a flexible functional form such as the translog production function or a generalized Leontief cost function should be used for the representation of the **ex ante** technology. However, in view of the difficulties to obtain relevant price-data for the estimation of these functions, they were not too attractive. Instead it seemed reasonable to choose a functional form with a small number of parameters, and in which each one of the parameters has a simple economic interpretation. In other words, if one is forced to use a lot of "guessitimates", the number of guesses should be kept at a minimum and concern economically meaningful magnitudes.

On the basis of these considerations, the following nested CES-Cobb-Douglas structure was chosen for the representation of the **ex ante** technology.

$$X_j = A_j \left[a_j F_j^{\rho_j} + b_j H_j^{\rho_j} \right]^{1/\rho_j} e^{\lambda_j} \qquad \forall_j$$

$$F_j = K_j^{\alpha_j} L_j^{1-\alpha_j} \qquad \forall_j$$

$$H_h = \left[c_j X_{1j}^{\gamma_j} + d_j X_{2j}^{\gamma_j} \right]^{1/\gamma_j} \qquad \forall_j$$

$$X_{ij} = a_{ij} X_j; \qquad i=2,3,\dots,n \qquad \forall_j$$

where thus K_j is capital input, L_j labor input, X_{ij} input of produced intermediate goods and X_j is output. The **ex post** production functions were then derived by assuming fixed capital stocks and fixed energy input (i.e. i=0,1) coefficients.

The distribution parameters (α_j) in the Cobb-Douglas part of the function were estimated by means of income distribution data for the base-year, i.e., for 1979, and the input-output coefficients (a_{ij}) are estimated by means of the ratios of intersectoral flows (X_{ij}) and gross output (X_j) that year. The **ex ante** elasticity of substitution between the capital-labor composite and the fuels electricity composite was set equal to 0.75 in all sectors presented in Pindyck (1980)[4], but of course subject to significant uncertainty. Lacking better information, finally, the same values were assumed for the elasticity of substitution between fuels and electricity. A selection of the adopted parameter values are displayed in Table A.6.

For the representation of household demand, a linear expenditure system was chosen. This choice was motivated by the fact that such systems have been estimated on Swedish data. The linear expendi-

Table A.5 Base year shares of export and import, and export and import shares in individual production sectors

Sector	Z_i/Z	M_i/M	Z_i/X_i	$M_i/X_i+M_i)$
0	0	0.1946	0	0.6060
1	0.0030	0.0059	0.0210	0.0494
2	0.1530	0.2454	0.1277	0.2024
3	0.2283	0.1056	0.4597	0.2086
4	0.4963	0.3745	0.4342	0.2888
5	0.1194	0.0740	0.0566	0.0417
6	-	-	-	-
Σ	1.000	1.000		

Note: All import measures inclusive of complementary imports.

ture system used here is estimated by Dargay & Lundin (1981). It differs from other systems in that it treats fuels as a separate household consumption good (see Table A.5), which is an advantage in the types of studies the present model will be used. However, as all linear expenditure systems it does not take substitution effects into account, which clearly is a disadvantage.

The "production functions" defining the composite goods consumed in the home country and the composite goods consumed in the rest of the world were all specified as CES-functions. The CES-specification is convenient since it leads to import and export functions which are relatively easy to estimate. However, the assumption that the same "production function" applies to all domestic users of good i is generally not plausible. If goods produced in different countries actually are qualitatively different, the substitutability between imported and domestically produced goods of the same "type" should, in general, differ between domestic users. In particular, for industrial users the substitutability should reflect the properties of technology, while it should reflect the properties of preferences for users in the household sector.[5]

However, whereas the model would remain fundamentally the same if different composite goods were defined for different domestic users, the estimation problems would increase significantly. In view of these problems the simplest possible specification was chosen. Thus, all domestic users of a given composite good, say i, are assumed to use the same type of composite good, i.e. use the same "production function" to define the composite good.

The numerical values of the parameters of the import and export functions have been chosen partly on the basis of econometric evidence, partly on the basis of theoretical considerations. Thus, one source of information is Hamilton (1980). However, this source, or other possible sources, uses a sector classification which can be aggregated into the one used in this study. Moreover, many of the estimated export price elasticities have absolute values which are so low that they are hard to accept on theoretical or even common sense grounds. Consequently a considerable amount of judgement and "fingerspitzgefühl" has gone into the estimates of ε_i and μ_i displayed in Table A.6.

Table A.6 Estimated values of some key parameters

Sector	α_j	$(1-\rho)_j^{-1}$	$(1-\gamma)_j^{-1}$	ε_j	μ_j
0	0.8362	0.25	0.25	0.0	0.5
1	0.7555	0.25	0.25	-1.0	0.5
2	0.3770	0.75	0.75	-2.0	4.0
3	0.3076	0.75	0.75	-5.0	0.5
4	0.2053	0.75	0.75	-4.0	2.0
5	0.3600	0.75	0.75	-2.0	0.5
6	0.0436	0.75	0.75	-	-

It should be noted that the export functions and the current account constraint are specified in such a way that the "home country" has some autonomy in the pricing of its exports. Whether or not a significant deviation between domestic production cost, i.e. the variable $P_i(t)$, and the corresponding world market price, i.e. the variable

$P_i^{WE}(t)$, would exist in equilibrium depends on the absolute values of ε_i as well as on the properties of the supply functions. It turned out that when the weighted average of the ε_i-parameters (in absolute value) was below 2, forms of trade gains of the "optimum tariff type" resulted from domestic energy taxation. For the ε_i-values actually used, that problem was negligible.

NOTES

[1] As the static model describes the situation in one single period, the variables are written without a time-index. However, when the exact specifications of a function depend on which particular period is to be analyzed, a time-dependent shift parameter is included.

[2] Complementary imports are only used in the energy sector, i.e., when j=0,1.

[3] If eq (A.17) leads to $P^*_{\upsilon j}<0$ for some vintage, that equation is replaced by $P^*_{\upsilon J}=0$ for the vintage in question.

[4] On the basis of pooled time-series data from ten countries, Pindyck estimated, among other things, the elasticity of substitution between capital and labor (σ_{KL}), between capital and energy (σ_{KE}) and between labor and energy (σ_{LE}) for the industrial sector. His results should be regarded as estimates of the long run elasticities of substitution-, and can thus be used to characterize the properties of the **ex ante** technology. With our assumptions included in parenthesis, Pindyck's results were the following:

σ_{KL}: 0.77-0.82 (1.00), σ_{KW}: 0.61-0.86 (0.75), σ_{LE}: 0.93-0.97 (0.75).

[5] Available economic evidence does not support the hypothesis that the same "production function" can be used to define the composite good i for all sectors. See Frenger (1980).

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Oil Prices and Economic Stability — Simulation Experiments with a Macroeconomic Model

by Tomas Nordström and Bengt-Christer Ysander

1 THE PROBLEM OF ENERGY POLICY

The need for a national energy policy, for government interfering with the supply and demand of energy, is - at least in the case of Sweden - mainly due to the instability of the oil prices. A primary task of economic analysis is therefore to trace the impact of changing oil prices on the national economy. The major challenge of national energy policy is to devise ways of reducing or accomodating this instability and uncertainty of oil prices.

These are bold, and undoubtedly oversimplified statements. Let us try to develop and clarify the reasoning behind them, introducing at the same time the aim and methodological approach of the present study.[1]

The Instability of Oil Prices

The real price of oil declined steadily from the end of the war up to 1970. At the same time the advances in nuclear technology opened up prospects of an inexhaustable source of cheap electricity. Aside from partnering and monitoring the ventures in nuclear technology - and controlling the exploitation of natural energy resources - the national governments had little cause for intervening in the energy markets.

All this changed in the early 70s. The oil price hike in 1973 - compounded by rising costs and safety concerns for nuclear power - brought home the lesson that cheap energy and stable energy prices could no longer be taken for granted. Since then real oil prices have been fluctuating widely with a new all time record in 79-80 and a slump in 1983. Fig. 1.1 shows the dramatic change that took place both in regard to level and stability in the prices confronting Swedish oil importers. The detailed story of what happened in '73, how the initial price rise on the Rotterdam spot market, due mainly to the Suez embargo, was translated into a huge permanent rise of contract prices, still remains controversial. We do not know for sure the relative importance of the raw material boom, of the OPEC-cartel and the seven sisters, of strategies aiming at transferring money and of policies for strategic control.

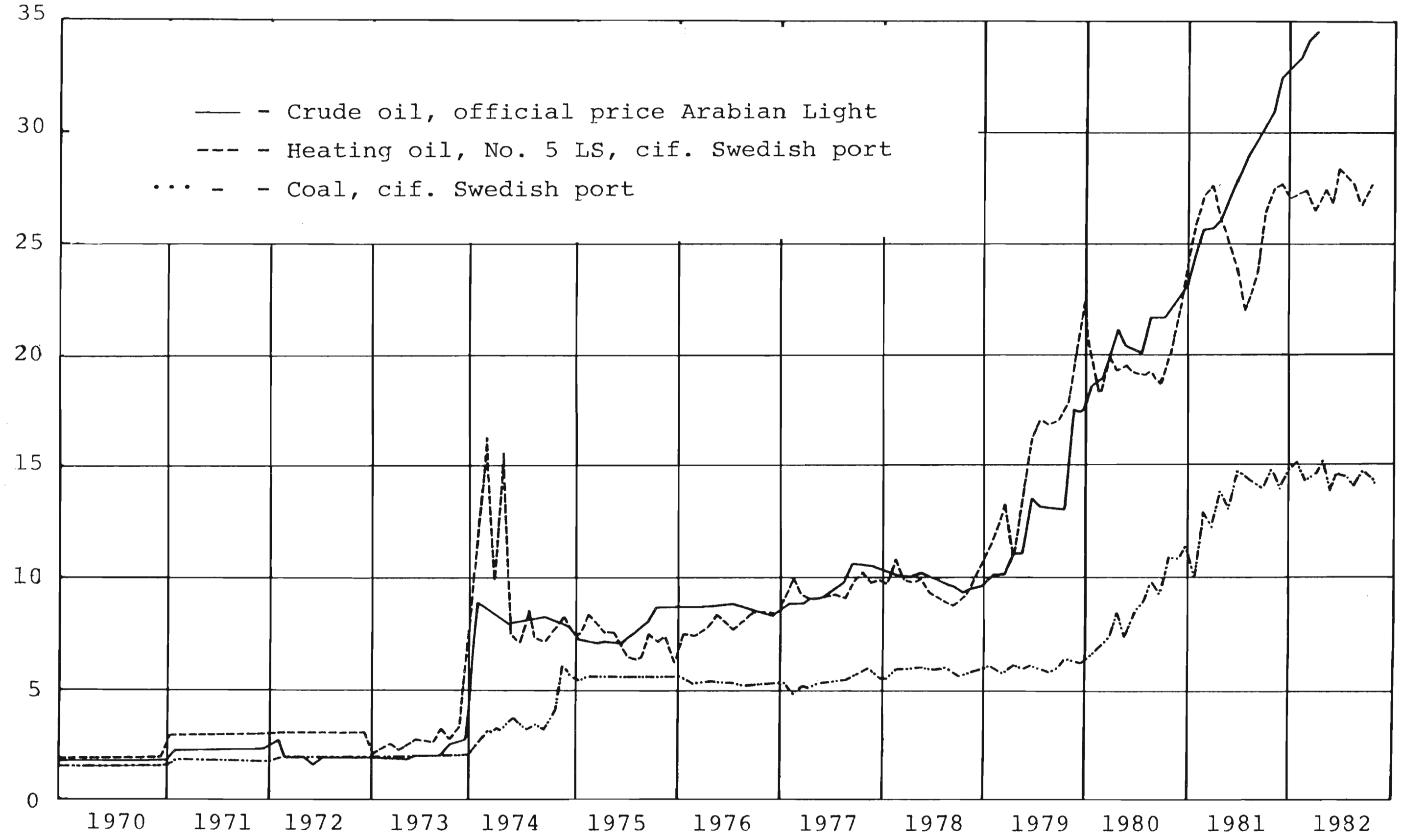
What we do know is that conditions in the international oil market have changed radically with respect to price stability. To a large extent it seems to be a case of uncertainty breeding on uncertainty. A tendency towards a shortening of contract times, a convergence of contract prices, an increased sensitivity for changes in spot prices and a growing propensity to inventory speculation, all contribute to this impression. This inherent market instability is accentuated by the political instabilities of some oil-producing countries creating risks of major supply disturbances. It is further boosted by the tendency of cartel prices to "overshoot", setting off cyclical changes in world economic activity and energy demand.

The volume of existing forward oil markets in London and New York is still far too small to contribute in any substantial way to a stabilization of oil prices. The buying and selling of future contracts could not be expected anyhow to cope with the price instabilities arising from major supply disruptions. Nor has the oil-saving efforts of the industrialized countries necessarily made these countries less vulnerable to supply disruptions, less insensitive to price in precarious situations.

There are thus many reasons to assume that the international oil market will remain instable also during the coming decade. In the long run, extending the horizon to the turn of the century,

Figure 1.1 The price of oil and coal 1970-1982

SEK/GJ (Source: The National Central Bureau of Statistics, Monthly Bulletin: Energy Prices



real oil prices will be determined by the marginal costs of producing oil from secondary deposits, and will therefore undoubtedly tend to rise. In the meantime we may however reasonably expect wide and sometimes abrupt fluctuations. As a representative, although somewhat extreme example of these possible price changes, we have in the following simulation study chosen to focus attention on an abrupt 60 percent oil price hike, occurring in 1991 after several years of relatively stable price developments. We can thus be said to project into the future a renewal of the '73 experience.

We have not found it necessary to look as closely at the possibility of a major sharp price decline. There are very obvious asymmetries between the case of a price hike and that of a correspondingly large price decline. The impact on the international markets of a price decline will primarily be connected with the liquidity and solvency problems of some less developed oil producing countries and by certain general "withdrawal symptoms" in the international monetary system. We have little of empirical evidence from which to make concrete projections for this case, but the little we have seems to indicate that - assuming a responsible monetary management - the expansion of the "winners" would tend to outweigh the contraction of the loosers in regard to world trade.

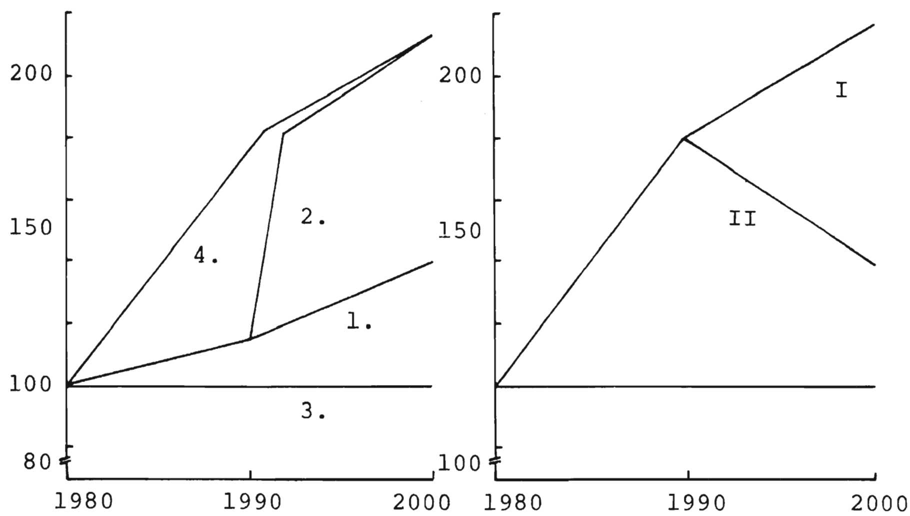
The asymmetry becomes even more pronounced when we turn to the direct impact on the Swedish economy. In as far as a dominant part of the policy issues raised by an oil price hike is concerned with containing and controlling the inflation and the deficit problems, there are simply no corresponding problems in the case with a price decline. The major task of the government in such a case would be to try to stop individual investors from misinterpreting the temporary low prices and from going on an energy spending spree.

Tracing the Impact of an Oil Price Hike

In analyzing the impact of an oil price hike we have worked with several alternative assumptions as to the world economic environment. As for oil price development, apart from the possible price hike, we have used both rising real price trends and a stagnating one.

Figure 1.2 Simulated real* oil price developments 1980-2000.

1.2 a Without oil tax   1.2 b With oil tax



* The prices for imported oil have been deflated with the world market price for finished goods (SEK) as used in the reference case.

Fig. 1.2 illustrates the alternative oil price assumptions used in the simulations. In the reference case we have assumed a slowly rising real oil price - alternative 1 in the Figure. The reference case is used as the main standard for measuring the impact of an oil price hike - alternative 2. We also made simulations with a stagnating and a fast rising oil price - alternatives 3 and 4 - for the purpose of evaluating the importance of long-term price trends and of the time profile of price change respectively. When studying the effects of imposing a cumulative oil tax during the 80s, two alternative policies were used in the 90s for the case where no oil price hike occured. Either the accumulated tax level is kept unchanged - alternative I - or successively reduced down to zero level at the turn of the century - alternative II.

In modeling the repercussions of the price hike on the international markets, we have drawn both on the experience of the 70s and on experiments performed with the LINK model (Sarma, 1983). A shortlived boom in raw material is supposed to be followed by several years of slowed-up growth in world trade. By measuring the impact on the Swedish economy with and without international repercussions we can at least exemplify the possible relative importance of the world market disturbances - the indirect effects.

When it comes to analyzing the direct effects of oil price changes, there is one major question which confronts you right from the start. Is it the new high level of oil price which is the main perceived threat or is it the abrupt and unexpected way it jumps up? The general experience of the two price hikes in the 70s seems to point to the latter.[2] In particular much of Sweden's present difficulties, manifested by a mounting deficit both in public budgets and in external exchange and by a shrinking and underutilized export industry, can be viewed as arising out of a failure to cope with the stabilization problems caused by the oil price hikes (Eliasson, Sharefkin, Ysander, 1983). As we shall see later this intuition is confirmed by comparing, in the simulations the impact of a sudden oil price hike with that of a gradual and anticipated increase of oil prices over the entire 80s.

If macroeconomic stabilization is the main worry, then the stabilization policies pursued - or not pursued - will obviously be of decisive importance for the final outcome.[3] In the simulation we have worked with three different policy instruments: Wage, tax and public consumption policies. We have not included an active exchange policy among our policy instruments since it appears in the model to be a substitute rather than a complement to wage policy.

What we then first do is to model and measure two "extreme" alternative outcomes. In the one case no policy changes are made after the "oil crises", which means that inflation will slowly be forced down by unemployment, while the foreign debt continues to cumulate. The welfare implications of this "worst case" is then compared with a "best case", where an optimal employment of available policy instruments contains the crises and restores balance in external payments and in the labor market within three years.[4]

The impact problem is thus narrowed down to a question about how probable it is that we will in fact be able to cope adequately with the stabilization problems.

In the following simulations we have tried to use as "substitute measures" for this probability - or rather for its inverse - the development of real wage, employment and public consumption required by the stabilization program and interpretable as symptoms of the concomitant political strains.

The chances of coping will be diminished if further restrictions - due e.g. to binding promises to various voter groups - are placed on the available policy instruments. If the central government has its hands tied by political commitments to groups of consumers and wage earners, this will in general increase the amplitude of the policy changes needed and with that the "political strains", or the improbability of coping effectively with the crises. In the simulations we have in this fashion successively climbed down a ladder of political feasibility, placing restrictions on wage policy, on public consumption and finally on tax policy. The relative outcome of these experiments demonstrates how limited flexibility in fiscal and budgeting policy may affect and inflate the impact problem.

In thus modeling the impact of an oil price hike we are however exemplifying only some special cases. We only treat one major price upheaval, not the prospect of general price instability. Moreover the model does not take into explicit account the ways in which anticipated future instability modifies current behavior. The investors in the model e.g. are assumed to have simple adaptive price expectations, which means that the risk and uncertainty surrounding future oil prices are not to any substantial extent foreshadowed in their current investment plans. Our experiments really deal only with the rather special case where a period of stable prices have effectively lulled all anxieties so that the oil price hike takes everybody with complete surprise.

Policies to Counter Instability

If instability of oil prices is the major problem, it then follows that the main thrust of energy policy must be directed towards countering the effects of that instability - always assuming that a small country like Sweden cannot hope alone to modify the behavior of the international oil market. Such an energy policy can aim at reducing the total risk involved as well as pooling the risk for individual risk-bearers.

These aims are of course already reflected in today's energy policy in Sweden. By taxing energy and by subsidizing oil-saving investments and development costs we both encourage total oil saving and redistribute some risks - mainly the risk of cheap future oil - among the taxpayers. Both the consistency and the efficiency of these policies may however be questioned. The level of energy taxes often seems more determined by fiscal considerations than by long-term aims of energy price stabilization. Investment subsidies may be an unprofitable way of hedging against possible oil price slumps and moreover often requires decisions on choice of technique and fuel, that should rather be left to decentralized decision-makers in the market.

The question might reasonably be raised, why central government should interfere at all with the market and its agents by way of energy policy. Leaving aside those arguments for state support of technological development and infra-structure investments which are not specific for energy investments, a first line of approach stresses asymmetries in information. Putting it crudely - the central government may know better, may have more foresight, have longer horizon and may be more expertly staffed than the individual agents in the economy. The "track record" of central government forecasting and action in the energy field may not be particularly convincing compared with that of big companies, but it could still be the case that e.g. households and local governments tend to be even more biased or myopic. The Swedish experience over the last decade seems indeed to indicate that local governments sometimes need central guidelines to venture into new areas of energy opportunities.

Even if we leave out informational asymmetries there are some rather solid reasons for central government to aid in stabilizing energy prices. Let us just mention two. The first is a simple risk-pooling argument. The oil price risks are now very unevenly distributed in the economy. Some investors e.g. in oil substitutes stand to loose considerably in the event of an oil price slump - which may contribute to dwindling investments - while the opposite is true of heavy oil users and their customers etc. Given a certain common degree of relative risk-aversion the economy as a whole stands to gain by having some kind of risk-pooling installed.[5] The second kind of argument is one that will be underlined by our results in the following. If oil saving not only pays for the individual, but also helps the total economy by easing the stabilization strains, then these "external effects" of the saving efforts should somehow be signalled by the government.

In the present Swedish context this latter line of reasoning could be further pursued. A "tariff" on imported oil implies - at least in the short run - a certain terms-of-trade gain, which will be larger the more price sensitive Swedish oil consumers are and the less price sensitive our foreign customers are. In as far as we must adhere to a very hard-fisted domestic demand policy over the next few years in order to support an export-offensive, a "forced" oil saving may help in easing this adjustment.

One way for central government to counter the adverse effects of oil price instability and uncertainty would be to guarantee a certain domestic oil price development - within suitable margins - over the next decade, and adjust oil taxes - or subsidies as the case may be - accordingly. The guaranteed price path could e.g. be such, that the expected value of the guarantee was equal to nil and the guaranteed price at the turn of the century - or the projected extension of the guarantee to that year - equalled the expected international market price. There are several possible time profiles of guaranteed price that could meet with these requirements. If we expect the 80s to become the lean years for domestic consumption, but hope to be able to raise living standards during the 90s, we could utilize the terms-of-trade gains from a rising oil tax during the present decade, while allowing tax levels to go down - if no oil crises occurs - in the 90s. Since such a "price umbrella" would automatically shelter the development and use of oil substitutes and of oil-saving devices there should be room for considerable cuts in current energy subsidy schemes.

One way of looking at the price guarantee is as an offer to domestic customers of favorable forward contracts - hedging price hike risks. At the same time there would be a hedge against the risk of price slumps, since the forward contracting is, as it were, obligatory and spot operations are made unprofitable. The government may to a certain extent reinsure itself by operations on the international forward markets and by long-term contracting.[6]

The exact terms of the guarantee could be phrased in several ways. They could e.g. be limited to maximizing the annual percentage change in real prices, be confined by the amount of tax in the domestic price and/or be such as to leave domestic oil prices free to fluctuate within a - 10 percent of a preset price path.

The experiments we have performed with the model are necessarily simplified and stylized compared with such flexible schemes. Just as we confine our study to one singular price hike in '91 we also focus our interest on a rather special form of tax scheme. We add a cumulative oil tax during the eighties, so that by '91 - if the oil crises occurs - we can just off-set the price hike by lifting off all tax. If there is no price hike we can alternatively keep the tax level unchanged or reduce it successively so as to stabilize or lower oil prices in the 90s.[7] This kind of experiment certainly cannot tell us the whole story. What it does is to provide an insight into the costs and benefits of a price guarantee in a specific but still representative case.

Our model experiments labor under another, and perhaps more serious handicap, when it comes to illustrate the possibilities of stabilizing domestic oil prices. Since, as we underlined above, price expectations in the model are formed in a simple adaptive way we do not catch the probably very important expansive effects of limiting price uncertainty for the economic agents. On the other hand we probably tend for the same reason to overestimate the amount of misdirected choices of technique and investments that unstable price trends and market signals would call forth. We may therefore end up by slightly overestimating both costs and benefits of the price stabilization schemes.Although we have no firm evidence to quote in support, we tend to think that in the final balance this model handicap will mean that our results understates the case for oil price stabilization.

NOTES

[1] For a short resumé of study results cf. Ysander, 1983.

[2] Comparisons made between the effects of gradual vs abrupt oil price increases in e.g. Jacobson and Thurman, 1981, also lend support to this interpretation.

[3] The theoretical analysis by i.a. Svenson, 1981, and the simulation experiments by J.D. Sachs reported in Bhandari and Putnam, 1982, exemplify studies that instead focus on intertemporal welfare and balance-of-payment effects.

[4] The optimal choice of instruments in this case turns out to be wage policy and tax policy, which are rather complementary in respect to the two targets. With two targets and with two instruments changed in a linear fashion, the policy solution moreover turns out to be unique or nearly so. We thus avoid the choice between alternative stabilization policies (cf. Gramlich, 1979 for a discussion of the dimensions and issues of that choice).

[5] For a thorough development of this argument within the context of Neumann - Morgenstern utility theory cf. Hey 1981 and Borch 1968. The general conclusion could also be derived from alternative approaches to decision under uncertainty (cf. e.g. Kahneman - Tversky 1979, Simon 1978, Schackle 1979.)

[6] The hedging argument could also be couched in terms of transaction costs. To insure against all kinds of price risks involved for substitutes and complement commodities would require a quite extensive network of future markets. Even if such a "free market alternative" was available it could be profitable to save transaction costs by a common oil price guarantee.

[7] The crises scenario we have chosen to treat could be regarded as a "maximal perceived threat". Particularly we assume that no retrenchment of real oil prices from the high level attained in 1991 has yet occurred by the year 2000. Any downward adjustment towards a slowly rising long term equilibrium price is thus postponed till after the turn of the century. This does in fact tally reasonably well with our overall experience for the 9 years 1973-82, but also means that the impact measured includes effects of a raised price level during the 90s, as well as consequences of unexpected fluctuations.

2 THE MACROECONOMIC FRAMEWORK

To evaluate the economic effects of different oil price developments and oil tax policies we have used a fairly disaggregated growth model for the Swedish economy.[1] The ISAC-model, which will be briefly described in the next section, was originally built for medium and long term analysis. For the simulations discussed in this report, however, some short run dynamics - primarily related to wage and price formation - was added to account for the immediate impact of sudden external price hikes.

Also a submodel for energy supply and demand, was added to ISAC. However, in order to keep down total model size, only those parts of the energy system essential to our main interest - primarily industrial demand of energy - were treated extensively. Thus energy demand for house heating as well as for transport was dealt with in an aggregate and simplified way. On the supply side, production of primary as well as secondary (refined) energy is again rather crudely modeled.

Finally, to account quantitatively for the impact of world events and the effects of different policy measures, one needs also a "zero point" or reference simulation as a measuring rod. Levels of future economic variables are undoubtedly more uncertain than differences between levels. This does not imply, however, that absolute levels are unimportant and that a reference case could be chosen at random. One important example of this in the simulations reported here, is the restriction on future nuclear power capacity in Sweden. In a slow growing economy this may be of little importance, while a fast growing energy demand will call for compensating energy sources. A reasonably designed reference point for the simulations may also convey important information by itself.

The Macro Model

The model used for the simulation experiments is fairly large. A comprehensive account of the model is given in Jansson, Nordström, Ysander, (1982). The purpose of this section is to describe its main structure and dynamic properties.

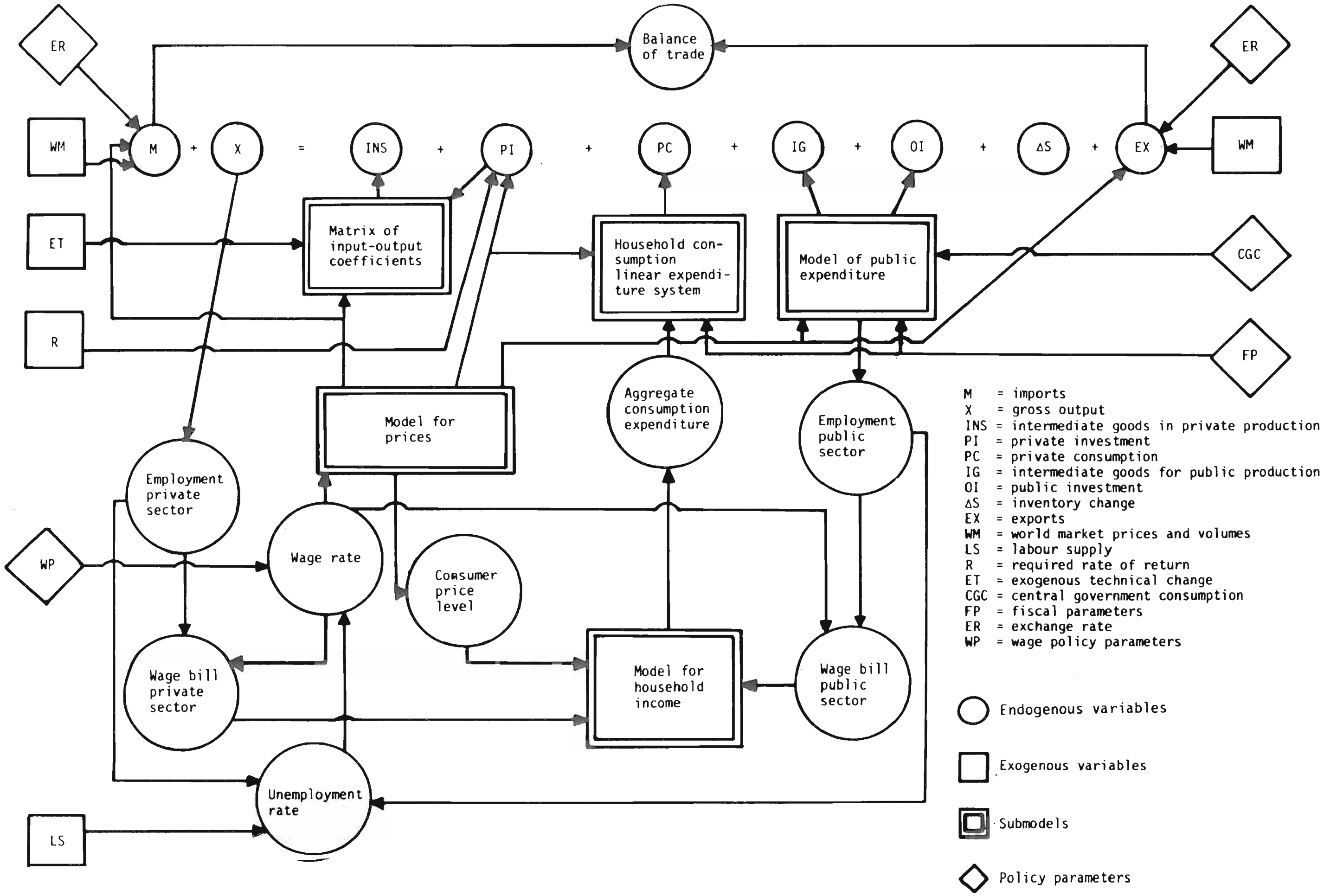
Figure 2.1 is an attempt to illustrate the overall structure of ISAC. The figure shows the main variables and submodels and their inter-relations. The block diagram is built around a multisectoral balance for the economy which assures that supply equals demand. The exogenous determinants of the developments of the model economy can be divided into two sets. The first set of variables are external to the economy in the sense that neither the development of the economy nor political decision-making exerts any influence on them. These variables, marked by single-squares in the figure, are world markets (prices and trade volumes), disembodied technical change, labor supply and, finally, a rate of interest that is assumed to be imposed on the economy from abroad.

The other set of exogenous variables is made up of policy instruments, indicated by rhombs. They are the exchange rate, central government consumption and various kinds of fiscal parameters affecting the household sector through taxes and transfers and also acting on the local government sector through i.a. the grant system.

Finally there is a policy instrument influencing the long run wage rate although not controlling short run fluctuations.

Given these two sets of exogenous variables every item of the sector balance will be determined. The demand for intermediary goods in industry (INS) is given by current production (X) and the matrix of input-output coefficients. The model allows for substitution between energy, capital and labor in production processes. The rest of the i/o-matrix is constant over time.

Figure 2.1 The structure of the ISAC model 1983

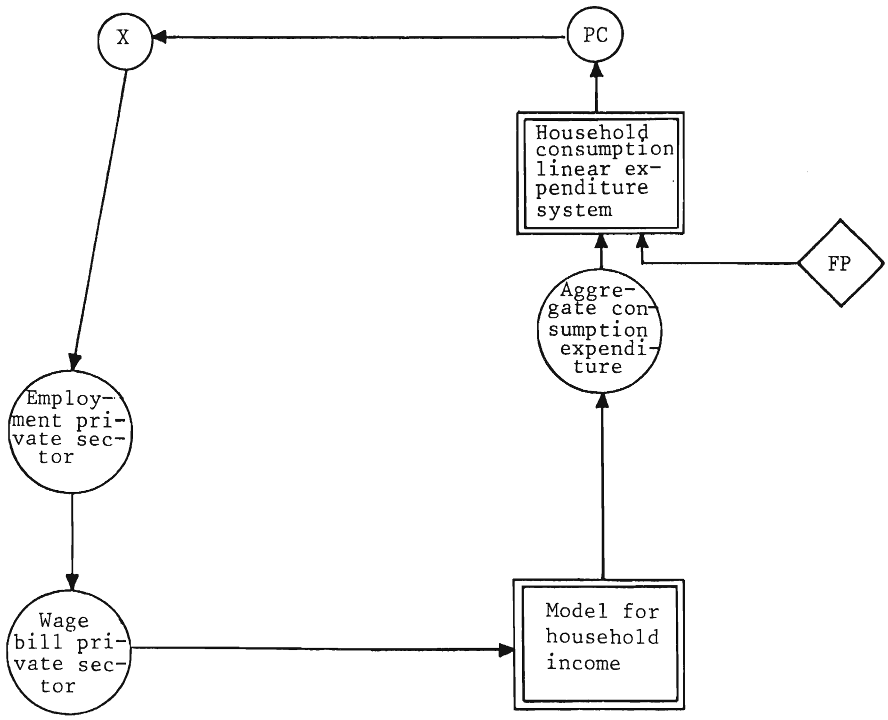


Investments in industry (PI) are determined by profit expectations as well as by current capacity utilization. Real capital is described by vintages with different technical properties. Through the vintage mechanism the volume of investment will affect average capital- and labor-productivity. Productivity growth also depends on the rate of scrapping of old vintages which is assumed proportional to the quasi-rents earned in each vintage. So far the vintage approach has only been implemented for branches in the manufacturing sector while capital in other branches is treated as homogenous in each branch. In the same way investment functions are specified and estimated only for manufacturing branches but elsewhere determined either as an exogenous trend or as related to production in some simple manner.

Private consumption (PC) is determined by a rather detailed specification of income and expenditure in the household sector. The main source of gross income is wages and salaries from industry, thus providing the multiplier link shown in Figure 2.2 between the activity level in the economy and private consumption expenditures. An exogenous change in fiscal parameters (FP), e.g. a reduced income tax rate, will increase household income. Since the savings ratio is exogenous, most of the tax reduction will be translated into consumption expenditure, thus increasing demand for commodities. Some of these will be imported, but domestic production and employment will increase, creating more wage income and so on.

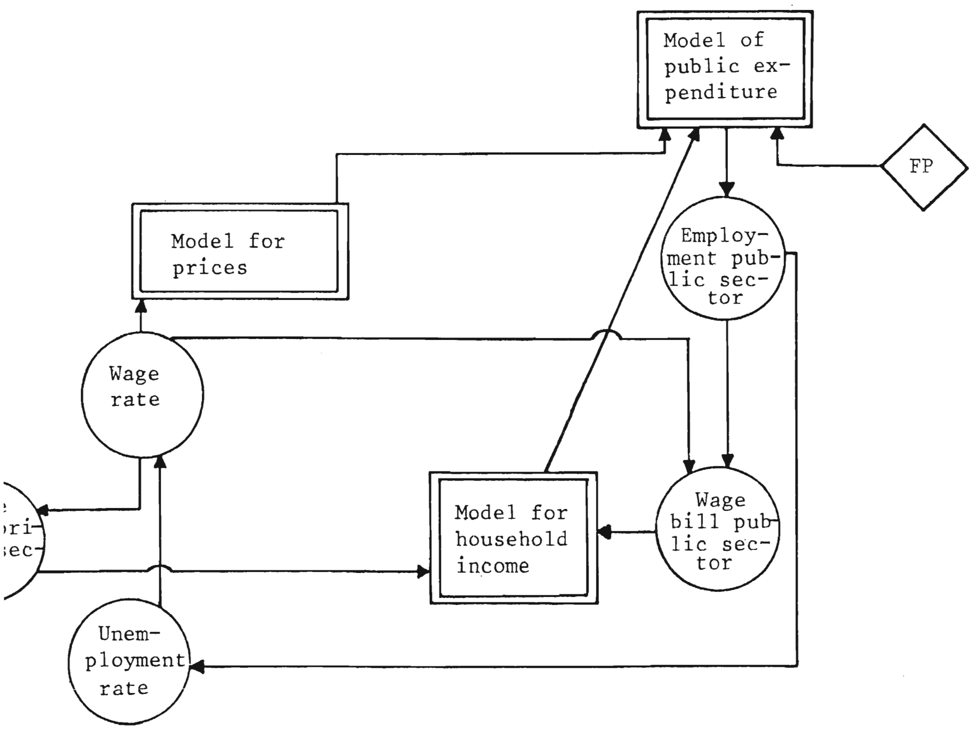
The size of the multiplier can also be affected by the wage inflation resulting from a higher activity level in the economy. This mechanism, which is not shown in Figure 2.2, will on the one hand, positively affect total wage income through higher wage rates. On the other hand, it will also limit the real multiplier effect by deflating nominal income through higher inflation, and still further through increased imports and reduced exports following the rise in the domestic price level. The net real effect of these secondary mechanisms after 2-3 years may be positive or negative depending i.a. on the price elasticities in

Figure 2.2 The production-consumption loop



foreign trade and on the sensitivity of wages to increased pressure in the labor market. Other important sources of household income are wages, salaries and transfers from the public sector. After deduction of various taxes households are left with disposable income. Real consumption expenditure is distributed between fourteen consumption categories by a linear expenditure system. The feed-back mechanism between the production system and consumption demand through the household sector explains much of the model's short term response to an exogenous disturbance, whether in the form of e.g. a change in world market growth or through a change in some fiscal measure towards the household sector.

Figure 2.3 The local consumption - labor market loop



Public sector demand for intermediary and investment goods (IG, OI) is partly a policy variable (central government), partly endogenous (local government). The local government model, as it is presently implemented, tends to produce fairly strong oscillations in the economy through its interactions with the labor market on the one hand and the household sector (via the endogenous local tax rate) on the other. These links are shown in Figure 2.3.

Suppose central government increases the categorical grants to local governments, in the figure indicated by a change in fiscal parameters (FP). The immediate impact will be to decrease local governments' net costs of production and hence induce them to step up real expenditures. The grants will also improve their financial situation making tax increases unnecessary. Since no other fiscal measures are assumed, i.e. the original grants increase is not financed by increased taxes from central government, the activity level in the economy will go up and so will employment. The resulting wage inflation will partly "finance" the local government expenditure increase by eroding household income and by worsening the external balance. But the wage increase will also lead to increased net costs of production for local governments and slow down their expansion. However, because of the two year lag in the disbursement of centrally collected local tax-income, the financial situation of local governments will tend to improve again later when wages are moderate as a consequence of weak demand. Thus, with a two year lag, the inflated household income will feed back to local governments, acting as a stimulus to increased expenditures.

Some explorative experiments have been carried out with this submodel (Nordström-Ysander, 1981). The simulations in this study still work, however, with the assumption of exogenous local governments.

Changes in stocks (S) are modeled in a very simple fashion with total stocks in the economy being set in proportion to production in some "stockholding" branches. Mostly, however, the model is run with exogenous stock investments.

Finally the sector balance for industry includes imports and exports (M, EX). These are, of course, of great importance considering the large export- and import-shares, especially for manufacturing branches, in the Swedish economy. We assume that price differentials between imported and domestically produced goods can persist over long periods, and also that Swedish exporters are not necessarily price-takers on the world market.[2] One implication of these assumptions is that imports and exports will depend on relative prices and that domestic producers can price themselves out of domestic as well as foreign markets - as indeed they did in the middle of the 70s.

Used together with the wage equation, the foreign trade functions introduce a mechanism, indicated in Figure 2.4, that tends to dampen the effects of world market disturbances. The immediate impact of a general world market price increase, for example, will be higher domestic inflation through imports and a pressure on the labor market due to improved relative prices and to an induced increase of net demand from abroad. This will, however, create both inflation expectations and wage drift in the labor market, then pushing up wages. The higher wages will not only remove pressures on the labor market, but will also reduce the initial surplus on foreign account.

Prices and Wages

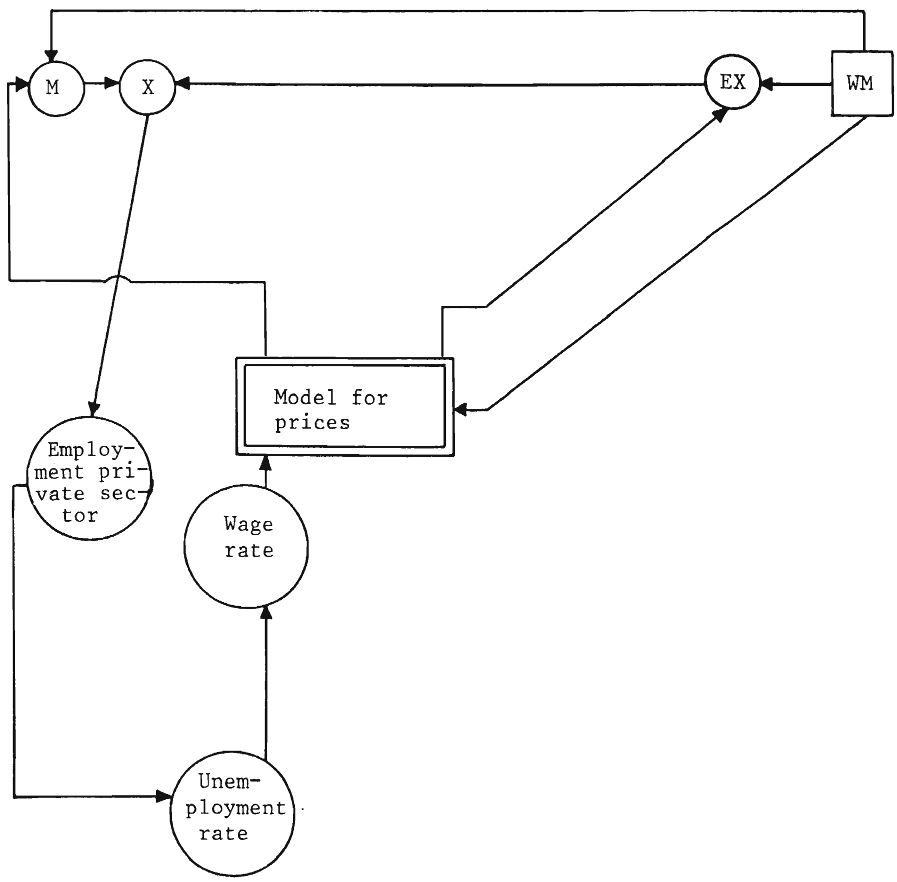
Obviously price and wage formation play an important role for the solution of the model. Prices are based on average rather than marginal costs. Unit cost is taken to include "normal" profits, i.e., the mark-up over average operating costs is equal to average capital cost share. Theoretically this kind of pricing can be underpinned by assuming market imperfections and adjustment costs. It also seems to be well in accordance with observed behavior.

For a small country, however, with large export shares one would not expect producers to just pass on their costs to the world market without regard to competitors' prices. The price equations in ISAC also allow for an influence from price competition being specified as a geometric average of unit cost and world market price (in Swedish currency):

$$P \sim C^{\alpha} \cdot PW^{(1-\alpha)} \text{ or } \dot{P} = \alpha \cdot \dot{C} + (1-\alpha) \cdot \dot{PW}$$

where dotted variables are growth rates. The size of the parameter α is of crucial importance. α equal to unity implies pure mark-up pricing with strong effects on foreign market shares from

Figure 2.4 The foreign trade-labor market loop



domestic cost inflation. With equal to zero, producers are, on the other hand, assumed to follow world market prices. In this case exports will always grow with world trade while domestic wage inflation will cut down profit shares.

In the discussion above, costs were treated as unaffected by the world price increase. But price increases abroad will of course influence domestic inflation. One way this will be done is through imported goods. Another is through price increases by domestic producers, taking the opportunity to raise their profit margins.

The model economy, however, also includes an internal source of inflation with a kind of expectations augmented Phillip's curve. The overall wage rate growth is explained by last year's consumer price growth, current rate of unemployment, profit levels and finally productivity growth.

Phillip's curves can be specified, and justified, in a great many ways. Two features of this particular specification should be noted, since they are important to the model behavior. The first one is the rather unsofisticated formation of expectations that is assumed. The one year lagged consumer price variable could also be thought of as a compensatory mechanism for past inflation, especially since the estimated parameter did not differ significantly from unity. The second noteworthy characteristic of the chosen wage equation is the absence of lags in the unemployment variable.[3] These two properties both contribute to make wages sensitive to inflationary pressures. They thus confer a certain stability to the economy, making e.g. the domestic repercussions of external inflationary shocks fade away in a rather short period.

NOTES

[1] The ISAC-model, Industrial Structure and Capital Growth, has been developed at the Industrial Institute for Economic and Social Research by the authors together with Leif Jansson. ISAC has been used in the Institute's medium term surveys and will partly be integrated into the system of models for medium and long term analysis used at the Ministry of Economics. The model is described in Jansson, L. - Nordström, T. - Ysander, B.-C. (1982).

[2] The rationale for these assumptions are discussed in Jansson, L. - Nordström, T. - Ysander, B.-C., (1982).

[3] Various lags were tried when estimating the equation, cf. Jansson, L: "The Wage Equation in the ISAC Model", Mimeo, IUI, 1981.

3 THE ENERGY SYSTEM 1980-2000

The ISAC model was originally not designed for energy analysis. In order to carry out the simulations described in this report, energy flows was built into its i/o-structure. Efforts was also made to estimate energy demand functions mainly in the manufacturing and household sectors. As already noted above the supply side and demand from other sectors were dealt with in a more aggregate and simplified way. No vintage structure has been implemented for energy sensitive consumption capital like houses or cars. In some instances we could only "estimate" the required energy demand function by calibration i.e. by comparison with other projections. We do believe, however, that the structure of the energy submodel gives a fair representation of the basic mechanisms and problems in Sweden's energy situation and that the estimated relations are robust enough to reflect accurately, if not exactly, our energy policy options.

Energy Supply and Energy Prices

Primary fuels from domestic (wood, peat) and foreign (oil, coal) sources are assumed to be supplied in any quantity at given prices. The assumed price development for primary fuels in the reference case are given in Table 3.1. Oil prices are assumed to increase by 8 percent per year throughout the simulation period. This implies, that the real price of oil is assumed to grow by 1.5 percent per year during the 80s and some half percentage point faster during the 90s relative to the world market price for finished goods. Throughout the study we assume that oil prices on the domestic market grow at the same rate as import prices given the current rates of oil taxation. This simplification overlooks the fact that taxes may be related to quantities rather than values and that domestic refining and transport services are part of the consumer price. Coal prices are assumed to be proportional or follow oil prices. The difference in rate of price increase during the 80s shown in the table simply reflects how the coal

Table 3.1. Prices of primary fuels in the reference simulation
(Growth rate in per cent)

	1980/90	1990/2000
Oil	8.0	8.0
Coal	8.9	8.0
Domestic fuels	6.0	5.0
CPI	6.2	6.5
GDP-deflator	6.7	7.2
World market price for finished goods	6.4	6.0

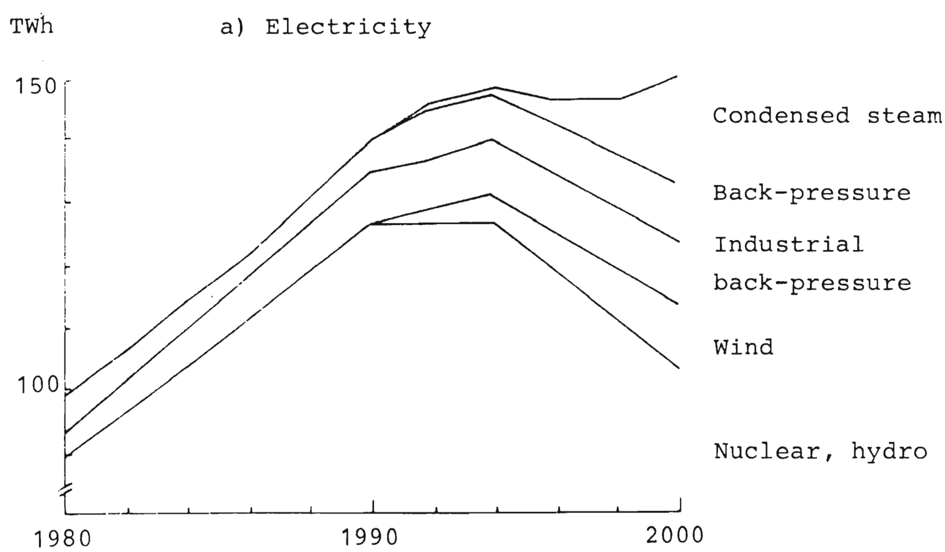
price with a certain time lag "catches up" with the oil price hike in 1978/80. This "catching up" is assumed to take place during the first years of the 80s. Prices for domestic primary fuels grow with costs in the forestry branch. Some allowance is made for improvements in the extraction technology, assuming a slight increase in productivity growth during the 90s. The price of domestic fuels relative to oil is therefore decreasing at an accelerating rate - from minus 2 percent per year during the first half of the period to minus 3 percent per year during the second half. It should be noted, however, that these prices only hold for primary fuels. Substitution between them is also affected by "conversion" costs, which may differ considerably. Turning coal or domestic fuels into useful energy requires more inputs (labor and capital) than if oil is used. Generally, this will make coal energy prices develop more favorably than shown in the table and energy produced from domestic fuels develop less favorably in relation to oil based energy.

Turning to the supply of electricity and distant heating the political restrictions imposed on the use of nuclear and hydro power is accounted for in the model. Total gross production of nuclear and hydro power (i.e., including internal use in the power stations) is assumed to increase by almost 4 TWh per year during the 80s and then to decline at approximately the same rate from 1995 due to the gradual closing of nuclear power stations. Adding further exogenous assumptions on industrial production of back-pressure power, wind power development, possible combined production of electricity and distant heating, etc. the production system shown in Figures 3.1-2 emerges. Although the assumptions made and the resulting supply structure may well be disputed, it seems necessary to account for the rather strong shifts imposed on the electricity - distant heating production system during the simulation period by political decisions. This will have strong implications i.a. on the use of fuels - domestic and imported.

As shown in Figure 3.1 production of electricity is assumed to increase fast during the 80s with the nuclear power still building up. Although direct use of electricity for heating purposes will also increase, there will still be capacity left to replace fuels in the distant heating system. However, when demand for electricity catches up with the stagnating prodution in the 90s, the use of electric power to boil water for distant heating will have to end.

The assumed decrease of fuel input in the distant heating system in the 80s may very well be reversed in the 90s. The same holds for the fuel input in electric power production. Part of the gradually reduced nuclear capacity may have to be replaced by condensed steam or combined power plants using domestic or imported fuels. The reference case development of fuel use in electric power/distant heating production is summed up in Figure 3.2. With the asssumptions made, the figures show a very fast increase in fuel input and even a slight increase in the use of oil towards the end of the 90s. This explains an important part of the rising demand for fuels during the 90s, which will be further discussed in the next section. Increased use of imported fuels with rising relative prices, will make the real price of electricity and distant heating rise in the 90s. This will slow down demand growth but - according to the model - not enough to prevent large increases in the use of fossil fuels in power plants.

Figure 3.1 Production of electricity and distant heating
(Reference case)



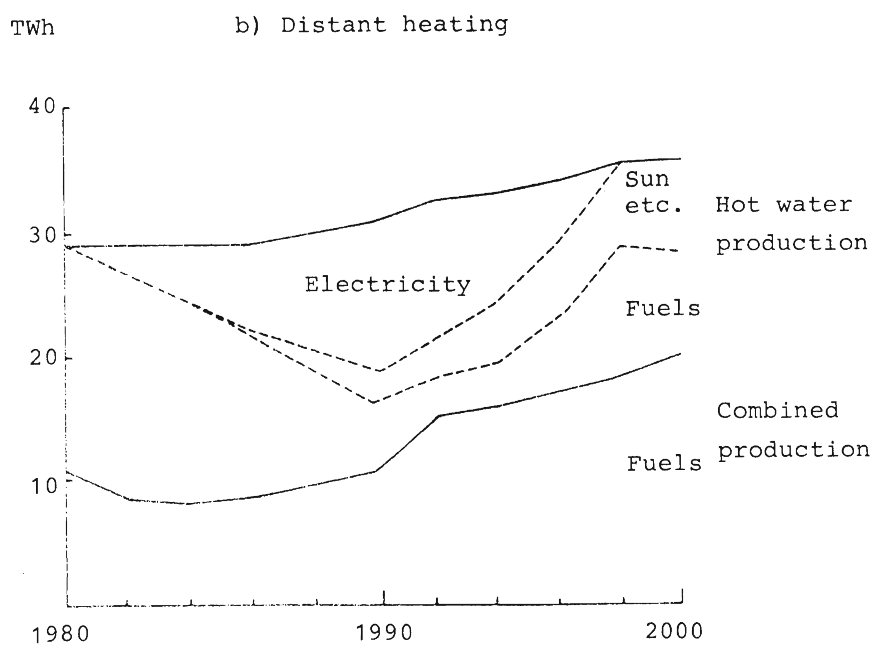
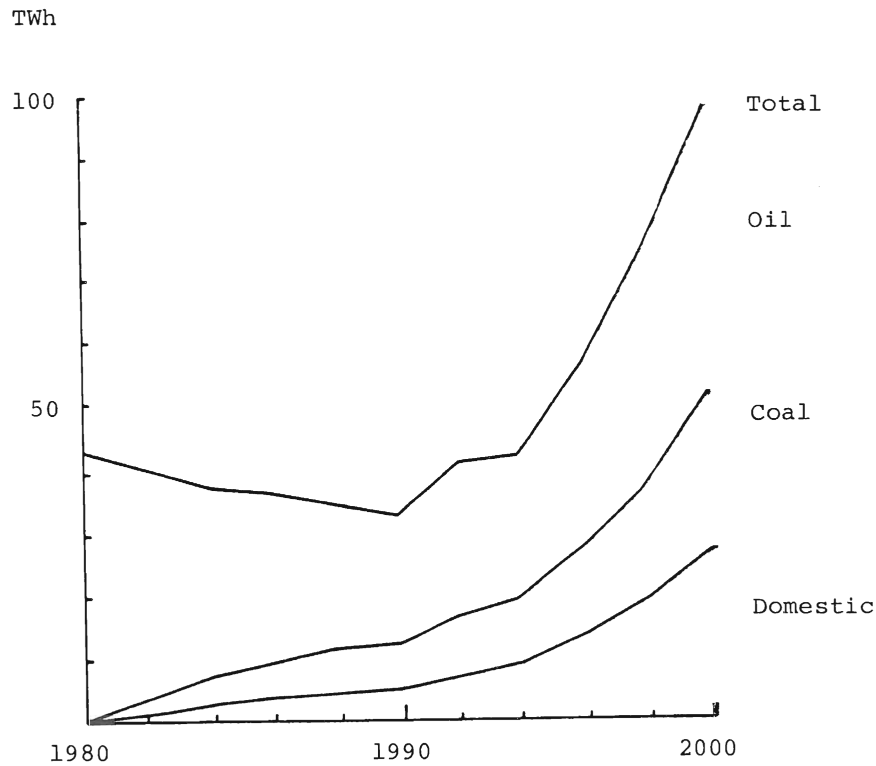


Figure 3.2 <u>Use of fuel in the electric power/ distant heating production system</u> (Reference case)



Energy Demand

Some thirty sectors are distinguished in the determination of final energy consumption. For each of these sectors total energy demand is usually separated into five categories i.e. electricity, distant heating, oil, coal and domestic fuels (wood and peat). For producing sectors energy demand is mostly projected as energy use per unit output (the energy coefficient) times production volume, while households' consumption of energy is formulated slightly differently.

The description of energy demand will follow the main sector groupings in the macromodel. Although this may not be the most suitable way to analyze energy use these groupings have been maintained for practical reasons. The main energy consumer sectors thus are the following:

- Manufacturing sector (14 branches)
- Rest of industry (9 branches)
- Household sector (3 purposes)
- Public sector (2 purposes)

This grouping i.a. implies that the heating of buildings is split up between all four sectors. Heating of homes will e.g. take place partly within the "rest of industry" (apartments for rent) and partly within "household sector" (owner-occupied houses).

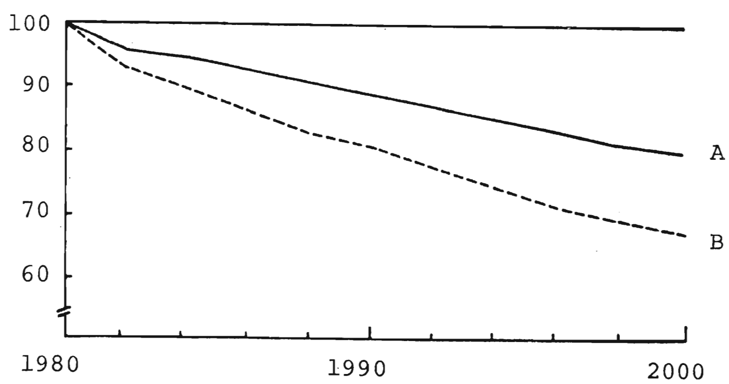
The most elaborate part of the energy demand sub-model relates to the manufacturing sector. The total energy coefficients for each branch is determined by three mechanisms - the vintage effect, ex ante substitution between (aggregated) inputs, and finally ex post substitution between fuels.

The ISAC model utilizes a vintage description of production capacity and technology for manufacturing branches. Although the empirical implementation in the present version of the model is incomplete in some respects it nevertheless takes account of important parts of the substitution effects. New choices of technology in investments due to a shift in relative input prices will be successively realized as new capacity is installed and old scrapped. Substitution between inputs thus continues many years after a change in the input price structure. A price shift occurring at the beginning of the simulation period - usually 20 years - will have effects throughout the period, since real capital turnover time is more than 20 years. This also means that part of the initial capacity - between one fourth and one half - will still be used after 20 years. One obvious reason for this rather sluggish rate of substitution is the treatment of machinery and buildings as an aggregated real capital stock. A good deal of technical change is, of course, due to investments in new machinery and equipment within existing factory buildings. With aggregated real capital it is, however, not possible to increase the speed of substitution by investing more in machinery and equipment in response to price shifts. The model therefore tends to underestimate the medium term (5-10 years) substitution possibilities in the economy.

Another deficiency in the implementation of the vintage mechanism is the lack of initial capacity distributions. A rectangular initial distribution is assumed, i.e., input coefficients are set equal between all vintages. This holds except for labor input where the marginal coefficient is assumed to be 0.6 times the average coefficient in all branches. For energy this is a very cautious "estimate" of marginal input coefficients since price developments during the recent decade may very well lead to reduced energy use in today's optimal production technique. The assumptions about initial average and marginal input coefficients will have a decisive influence on the development of aggregated energy coefficients and thus on the full employment energy demand levels in the economy. This is illustrated in Figure 3.3, which shows the effect on the total energy coefficient for the manufacturing sector of different assumptions regarding the marginal coefficient in the initial distribution. In case B the initial marginal coefficient is set at 60 percent of case A value. With new capacity being added through investments, this will result in a faster decrease of the energy coefficient although the development of relative prices is identical in the two cases. Thus, different assumptions on marginal versus average coefficients for the initial simulation year will affect future levels of energy consumption.

As stated before, however, most of the simulations reported in the following and the conclusions drawn, do not really depend on absolute levels of future energy use, but rather on differences between projected levels under alternative assumptions.

Figure 3.3 Aggregated energy coefficients with different initial marginal coefficients in the manufacturing sector



Note: The curves show total energy use in physical units per unit output in fixed (1975 year's) prices with 1980 value equal to index 100. A is the reference case discussed below. B shows the effects on the energy coefficient in the manufacturing sector if the marginal coefficient in the initial distribution is assumed to be only 60 percent of the reference case value.

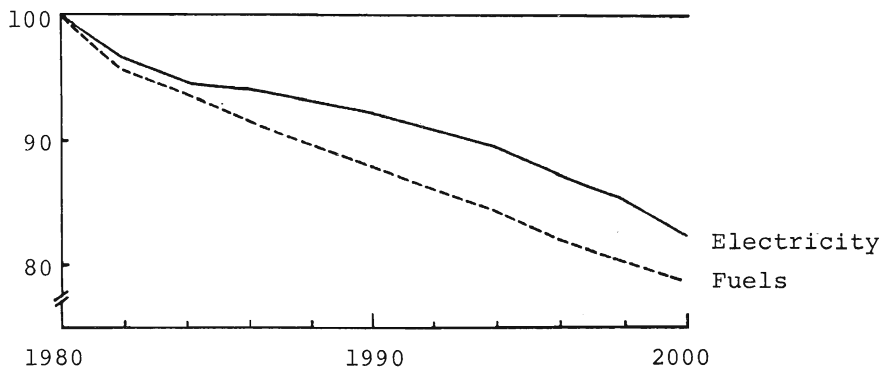
The second substitution mechanism is the choice of technique in new vintages. In each branch, input coefficients for electricity, fuels, capital and labor are computed from (last years) relative prices using constant elastic functions estimated from historical data (cf. Dargay, 1982, 1983). The results of this econometric approach to the ex ante substitution possibilities should be interpreted with caution for two reasons. The first reason is that, due to lack of data on technological choice in new plants, our estimates relate to average technology in a branch. Substitution possibilities, however, are undoubtedly far greater on the margin than what they seem to be when measured intermarginally on the whole capital stock. We have tried to correct for this by scaling up substitution elasticities.[1]

The second reason for caution is that estimates have been made for a period (1950-75) when real energy prices were steadily falling. This means we cannot know whether substitution possibilities are symmetric or not. We still use the results for a period when real prices of energy - or at least of fuels - are steadily increasing. The alternative would be to use engineering data on possible future production techniques which, however, suffers from uncertainties related to technical and commercial full scale implementation. Of course, the two methods should be used together and checked off against each other.[2] This has generally not been possible to do within the work presented in this report. Some attempts to compare the two approaches have, however, been made within the Energy and Economic Structure project (cf. Ysander, 1983).

The coefficients for electricity and fuels in the manufacturing sector in the reference case are shown in Figure 3.4. Although the coefficients are subject to aggregation effects due to changing industrial structure, the general pattern is clear. The use of energy per unit output will fall and the fuels coefficient will decrease faster than the electricity coefficient.

Having determined the aggregated input coefficient for fuels the next step must be to distinguish between different kinds of fuels. To separate the choice of other input coefficients from the choice of fuel type, means we assume that a decision to use, e.g., coal instead of oil will not affect labor and capital coefficients. This is not strictly true in most cases. The rationale behind the chosen procedure is that estimates of substitution elasticities for different energy types on a disaggregated branch level were not available when the model was imnplemented. Substitution between fuels within a branch is furthermore assumed to be possible across all existing plants, e.g., the type of fuel used in a boiler can be switched without much change in the technique used in the rest of the production process. This is a sufficiently accurate description of the use of fuels in the manufacturing sector except for those branches, such as iron and steel, where a particular fuel is also an integrated part of the production process itself.

Figure 3.4 Energy coefficients for electricity and fuels in the manufacturing sector. Reference case

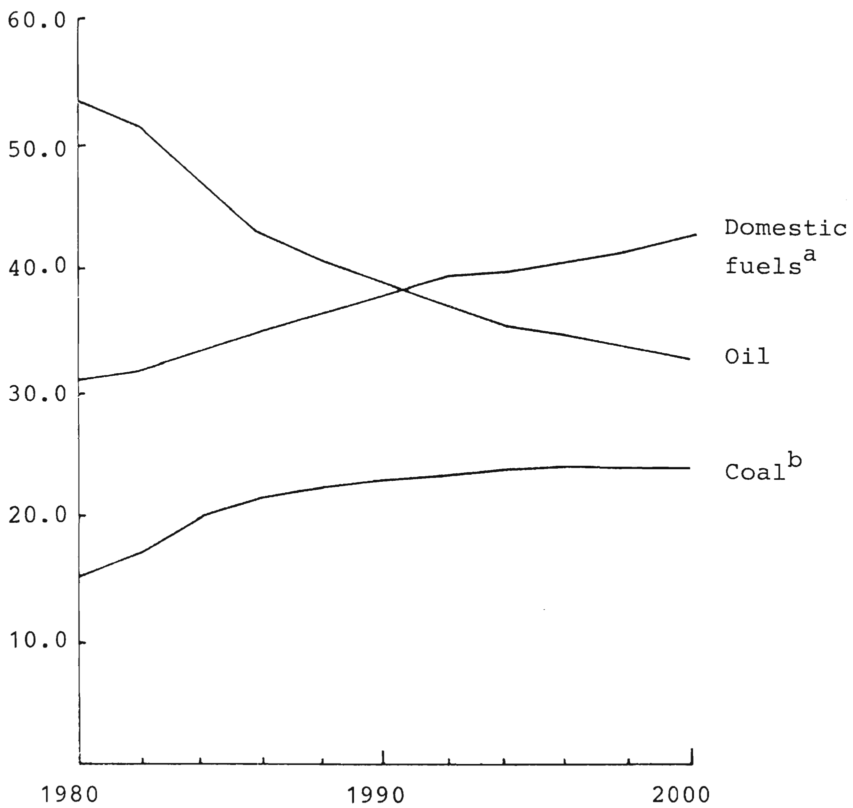


For convenience we measure substitution between fuels in terms of physical energy units which makes it easier to calibrate the reference projection against other projections.[3]

While the use of fuels per unit output in the manufacturing sector falls, the share of oil will also decrease due to the unfavorable relative price development as shown in Figure 3.5. Coal and domestic fuels will each increase their share with some ten percentage points during the simulation period.[4]

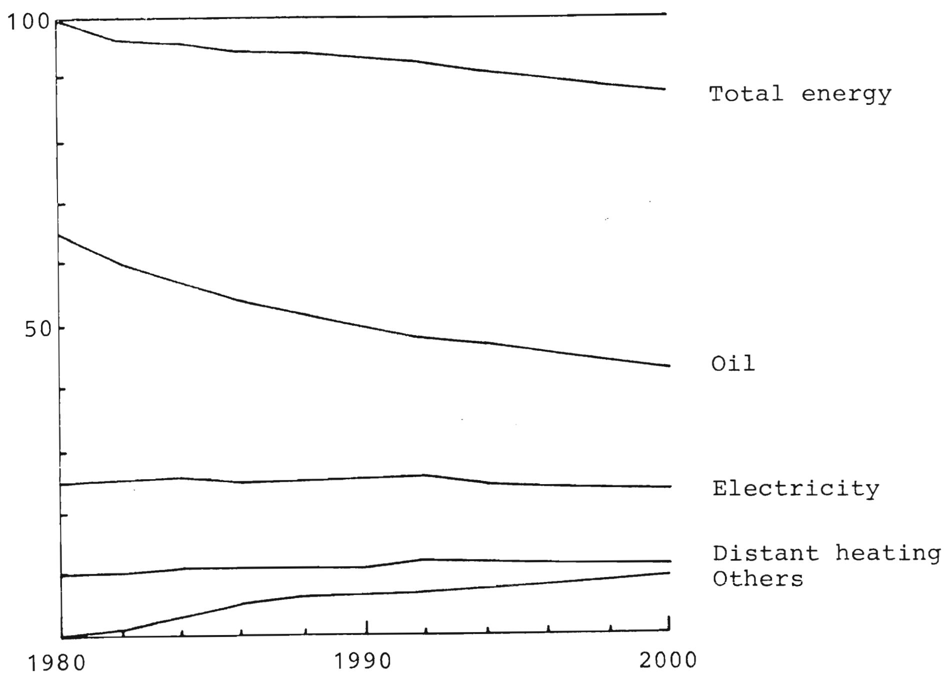
Energy substitution in the eight industrial branches outside the manufacturing sector is treated in a more conventional way. Ex post substitution possibilities between inputs (electricity, fuels, labor and capital) are given by constant elastic functions in relative prices. The procedure to determine the share of different types of fuels - given the input coefficients - is the same as before. Estimates of elasticities are, however, based on "calibration" and "informed judgement" to a greater extent than for the manufacturing sector.

Figure 3.5 Use of oil, coal and domestic fuels in the manufacturing sector
(Percent of total fuel use)



[a] Incl. internal fuels in paper and pulp industries.
[b] Incl. coke.

Figure 3.6 Energy use per unit output in the public sector and "other industry". Reference case. (Total energy use per unit output in 1980 = 100)



The same holds for energy use in the public sector. Energy use in the reference case for these two sectors is shown in Figure 3.6. The total energy coefficient is falling - although slowly - during the simulation period. The share of oil consumption per unit output will fall from two thirds to one half. The sluggish decrease of energy and oil demand is i.a. explained by the fact that transports are included in this sector making it more difficult to substitute oil for other energy. Also saving - and substitution - possibilities in the heating of buildings, which is responsible for a great part of the sector's total energy use, have been judged cautiuosly in the model.

The last energy consuming sector is the household sector. The basis for the energy projection in this sector is a linear expenditure system, comprising three energy "goods" directly consumed by households along with the other eleven consumer goods in the system. One difficulty, which makes the numerical results harder to interpret, is that electricity used for heating and other purposes (light, machines, etc.) cannot be distinguished in the statistics long enough to allow for proper estimation (cf. Dargay-Lundin, 1978).

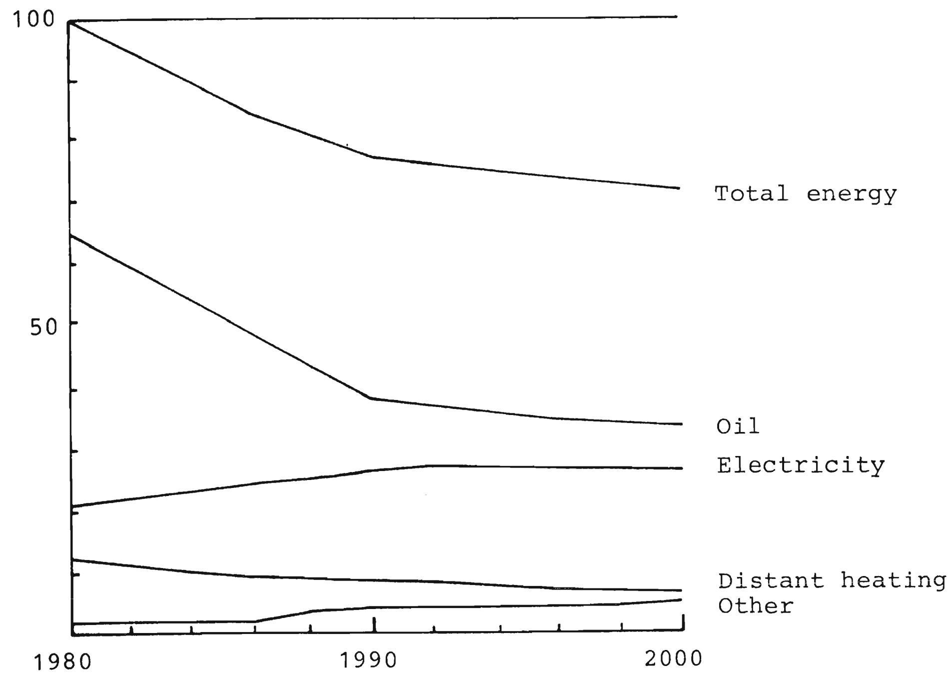
Since the price of electricity for heating develops favorably during the first half of the simulation period, one should expect increased electricity consumption. As shown in Figure 3.7 the model "predicts" a slight increase in the coefficient for electricity use in the household sector, despite a fairly strong decrease in total energy use (per consumption unit) during the 80s. This development is primarily explained by the combination of a fast reduction in house heating - the distant heating coefficient is even reduced and a fast substitution toward electric heating. Hence, households' direct consumption of electricity will increase by more than 40 percent over the decade.

Again it should be noted that energy use in this sector also includes motor fuels. The slow substitution of oil used for this purpose shows up in the figure as a slow increase of "other energy" which is made up of mainly motor fuels other than gasoline.

Total Energy Use and Aggregate Substitution

The total use of energy in the model economy is determined i.a. by those assumptions on prices, substitution elasticities, political restrictions, etc. discussed above. The general economic growth is, of course, also of paramount importance. The macro-economic assumptions used to construct the reference growth path will be described in the next chapter. In this section we will briefly discuss what all these assumptions imply for total energy use.

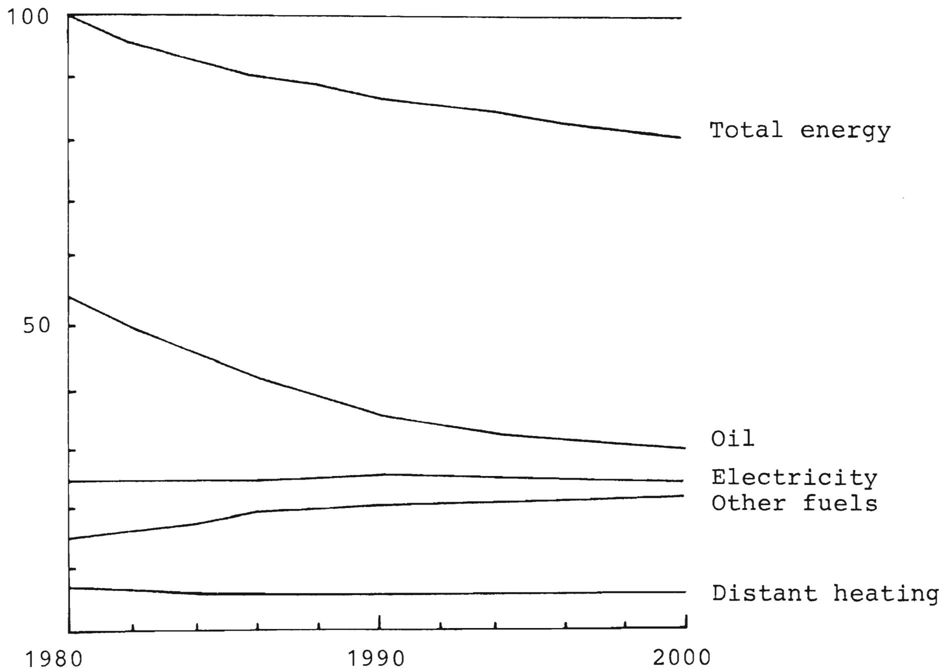
Figure 3.7 <u>Energy use per unit private real consumption in the household sector. Reference case</u>
(Total energy use per unit real consumption in 1980 = 100)



Final demand of energy per unit GDP falls in the reference case - altogether by 20 percent - throughout the entire simulation period as shown in Figure 3.8. Since, however, GDP grows by more than 50 percent, the level of final energy use will end up at a 20 percent higher level compared to the 1980 consumption. A large part of the reduction of oil consumption per unit output is evidently explained by energy saving. Only a minor part is replaced by other kinds of energy - notably coal and domestic fuels (wood and peat).

Turning to the input of primary energy, the picture is much the same. During the 80s abundance of nuclear power contributes to

Figure 3.8 Final energy use per unit output (GDP)
Reference case (1980 = 100)



a reduction of oil use for the production of distant heating and electricity as well as for direct house heating. Towards the end of the simulation period, nuclear power is partly replaced by fuel based energy, even forcing a slight increase in oil input per unit GDP. It must be emphasized, however, that levels of energy consumption in the reference case are not primarily meant to be used as independent projections or forecasts. They do however seem to fit the "conventional wisdom" about future energy consumption as documented by numerous official studies during recent years. Some of these projections are gathered in Table 3.2. They show some crude consensus, at least at an aggregate level, with the one notable exception reported in column F. This study

Table 3.2 Recent energy projections (TWh)

	1990					2000		
	A	B	C	D	E	A	B	F
Nuclear + hydro power	126	126	124	130	-	103	126	65
Oil	219	225	267	189	230	258	179	100
Coal	43	60	31	55	46	70	107	
Domestic fuels	67	70	58	79	77	112	98	95
Other	4	4	3	6	-	19	10	11
Total	459	485	483	459	-	562	520	271

A = This study, reference case

B = SOU 1979:83

C = SIND 1980:17

D = Prop 1980/81:90

E = SOU 1982:16

F = Steen et.al., 1981

projects a level of energy use 20-25 years ahead, that is less than half the reference case level (column A). This rapid energy saving is supposedly brought about by implementing those most profitable techniques, which are energy conserving. Given the rate of depreciation of real capital and of gross investment it is possible to calculate future energy use with "best technology" and to do this for different economic growth scenarios. With a low marginal energy coefficient the average coefficient will also decrease with time. The approach is much the same as adopted in the ISAC- model although more interest is focused on the marginal coefficients which tend to be lower than those used in our study. These coefficients are, however, not formally implemented into a macromodel of the ISAC-type.

The principal aim with the model experiments carried out in this study is to compare the outcome under different assumptions on oil prices. The general economic consequences will be extensively dealt with later. To illustrate some energy substitution mechanisms the energy consumption effects will, however, briefly be discussed here.

Let us compare the reference path with an "oil tax" case, where the price of oil on the domestic market is gradually increased through the 80s. The tax is assumed to inflate the oil price paid by consumers by 4.5 percent per year above the reference case. During the 90s oil prices will grow at the same rate as in the reference case, but the price level will be higher by more than 50 percent. The resulting difference in primary energy use relative to the reference case is shown in Table 3.3. We see that the oil coefficients for the whole economy will continue to decrease in the nineties in the tax case, even though oil prices then are assumed to grow at the same rate as in the reference case. This is due to the sluggish reaction to price changes and the slow adjustment of real capital structure.

With the vintage capital approach used for investments in the manufacturing sector, the low marginal oil coefficients chosen in the eighties will, ceteris paribus, decrease average oil use until the whole capital stock is renewed. In the oil tax case there is no tendency for the decrease in the oil coefficient to halt, since the oil price differential will grow to the maximal 54 percent in 1990. Rather there seems to be an accelerated decrease in average oil use in this sector, partly as a result of structural shifts towards less energy intensive branches.

The same continued decrease in oil use during the 90s arises in the rest of the production system (including production of public services). However, reduction in oil use is here much slower i.a. due to a large share of gasoline which is hard to substitute.

Table 3.3 The effects on oil coefficients from an oil tax increase during the 80s[a]
(Reference case coefficients = 1.00)

	1990	2000
Manufacturing sector	0.77	0.45
Other industry and public sector	0.84	0.76
Household sector	0.64	0.63
Production of distant heating and electricity	0.80	0.25
Total economy	0.75	0.56

Development of oil use in the household sector when taxes are raised does not, however, exhibit these lingering effects. Since much of the households' oil consumption is tied to capital goods, one would expect continued decrease of oil use during the 90s with the turnover of the stock of houses and cars. However, no such vintage mechanism is implemented for capital goods in the household sector. The model specifications for household energy consumption will therefore probably overestimate the price-effects during the 80s and underestimate the long-run effects.

In the oil tax case there is also a fast decrease of oil use in the production of distant heating and electricity during the 90s due to particular reasons. Because of the nuclear power build-up, the use of fuels in this sector will be halved during the 80s, leaving little room for investments in new plants for coal or domestic fuels. The full impact of the oil tax will therefore be felt during the 90s when fuel based production of electricity and distant heating expands by a factor three. In the oil tax case, the use of oil per unit output will be one fourth of the reference case level at the end of the simulation period.

Finally, from Table 3.3 it is possible to compute a kind of approximate aggregate price elasticity of oil, assuming that the elasticity of oil use with regard to GDP is close to unity. Given the size of the tax increase the aggregate price elasticity during the 80s could be calculated as -0.6. Since, however, the relative decline of the oil coefficient continues during the 90s without any further increase in oil price differentials, the price elasticity measured over the whole simulation period would be twice as large i.e. -1.2.

NOTES

[1] For a related discussion of the costs of adjustment in energy demand for manufacturing cf. Berndt-Fuss-Waverman, 1979.

[2] For a discussion of methodological options and some attempts at comparison cf. Berndt-Field, 1981.

[3] It should be noted, however, that the reference projection was constructed with an aggregate manufacturing sector and was not based on detailed studies of substitution possibilities between fuels for each manufacturing branch.

[4] In comparing this development with the prices given in Table 3.1, two things should be noted. The table refers to the price of the fuel. Since fuel cost is a relatively large share of the production cost of energy when oil is used, the price of the fuel will then have a stronger impact on energy price. Assuming that the costs of other inputs (labor and capital) per unit output follow the general inflation, this implies that there will be a slight decrease in coal produced energy price relative to oil energy price - at least from 1985 on - and that the price development for energy based on domestic fuels will be somewhat less favorable than it appears in Table 3.1. There is also a 4 year lag assumed in the fuels substitution which evens out the 1980-85 difference between coal and oil. The coal price rise during this period will in fact catch up with the oil price thus restoring the "normal" relation between coal and oil prices.

4 THE SIMULATION DESIGN

Economic Developments in the 80s and 90s

As a measuring rod for our simulations we have used a "reference case", i.e. a standard scenario for the development of the Swedish economy during the next two decades. The assumptions concerning the international markets and the domestic labor supply are listed in Table 4.1.

We assume that the rate of increase in the volume of international trade will be stable but somewhat lower than in previous postwar decades. For raw materials and semi-finished goods this will mean an annual rate of increase of 2.3 and 2.6 percent respectively during the 80s and 90s, while the trading in finished goods is supposed to increase annually 5.7 and 5.0 percent respectively and that of services 4.5 and 5.0 percent. There are good reasons to expect a stagnating supply of labor in the next two decades. The number of hours worked per employee will continue to decrease at a fairly rapid rate during the 80s yielding a falling labor supply in terms of hours. These developments are however assumed to come to an end in the 90s with a slight increase in number of persons in the labor force, offset by a small decrease in the number of hours worked per employee, thus making labor supply in number of hours almost constant during the decade.

The price of oil is assumed to increase annually with 1.5-2.0 percent relative to the price of finished goods in international trade. The coal price is throughout the simulations assumed to adjust proportionately, although with a certain lag, to changes in the oil price, thus maintaining the relative level vis-à-vis the oil price that it had reached before the oil price rise in 1979-80.

As described in Chapter 2 a model simulation also requires a number of policy variables to be given exogenously in order to

Table 4.1 Assumptions for the 80s and 90s

World trade development

Annual increase, %	1980/1990		1990/2000	
	Volume	Price[a]	Volume	Price[a]
Raw materials and semifinished goods[b]	2.3	5.5	2.6	4.1
Finished goods	5.7	6.4	5.0	6.0
Services	4.5	7.0	5.0	6.0

[a] In international currency.

[b] Includes the following branches: agriculture, forestry and fishing; mining and quarrying; manufacture of wood products, pulp and paper; basic metal industries.

Labor supply development

Annual increase	1980/1990	1990/2000
Number of persons[a]	32.7	14.2
Number of persons[b]	0.7	0.3
Hours worked per employee[b]	-1.0	-0.2
Labor supply, number of hours[b]	-0.3	0.1

[a] Yearly change in thousands of persons.

[b] Yearly percentage growth.

reach announced targets of economic policy. There is in principle a great many ways of controlling the economy, i.e. to reach specific macro economic targets.

We have employed three main policy instruments: wage policy, wage tax and public consumption.

"Wage policy" really means controlling the long term growth trend of wages. Technically this is attained in the simulations by varying the constant term in the estimated relation for the growth rate of nominal wages. In actual life this could correspond to the efforts, frequently exemplified in Sweden during the 70s, to keep down the nominal wage claims in the collective bargaining by various fiscal adjustments, particularly directed towards the rate of personal income tax.

The second type of policy instrument is the wage tax, which is assumed to be entirely shifted back onto the wage earners even in the short run. It can be looked upon as a representative of a wide variety of tax and transfer measures. It is, however, a natural candidate since there are strong reasons to suppose that future increases in central government taxation will predominantly take this form.

Finally we assume full control not only of central government consumption and transfers but also of local government expenditures. What this means is that we have simplified the interpretation of the experiments by treating local government expenditures - and taxes - as exogenous.[1]

Among our policy instruments we have not included an active exchange policy. The reason is that, in the model, changes of the exchange rate appear to be substitutes rather than complements to wage policy. The price compensation claims built into the equation explaining the rate of wage increase, tend to counteract and, after 2-3 years, almost completely neutralize any change of the exchange rate. That an active exchange rate policy thus requires the cooperation of the parties on the labor market to keep back compensatory claims would seem to agree rather well with our experiences from the 70s.

Three target variables are considered in the reference simulation: the rate of unemployment, the balance of payment and the growth rate of public consumption.

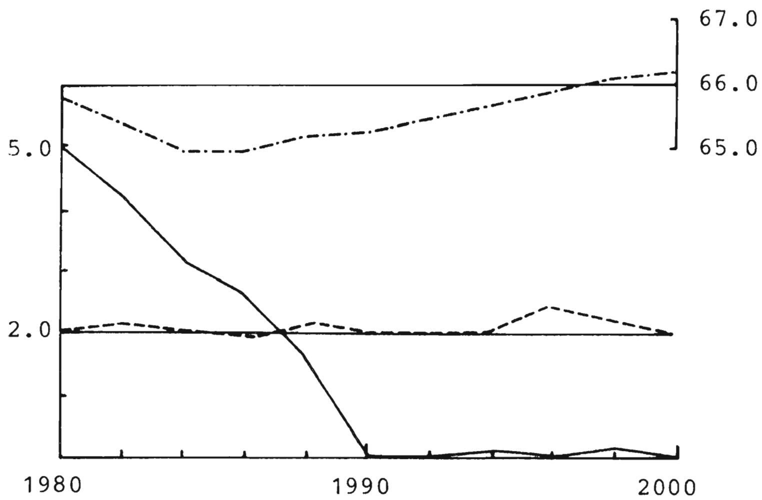
The policies adopted in the reference case - Figure 4.1 - have had the following main targets. The current balance of payment

Figure 4.1

Target variable values 1980-2000

Reference case

Deficit on current account, percent of GDP at factor values (———)
Unemployment, percent of total labor force (-----)
Real private consumption, percent of total consumption (right hand scale) (—·—·—)



deficit should be eliminated by 1990 and stay close to zero for the rest of the period. Unemployment should be kept around what is considered a "normal" rate of frictional unemployment - 2 percent of the labor force. The assumed strategy for public consumption has been to let it grow at a slightly faster rate than private consumption during the 80s but evening out the accounts in the 90s, thus attaining on the average a roughly proportionate increase over the two decades of public and per capita private consumption.[2]

Table 4.2 Real GDP by expenditure 1980-2000. Reference case

Annual increase, %	1980/1990	1990/2000
Consumption	1.3	2.4
Investments[a]	1.8	2.1
Exports	4.6	3.8
Imports	2.9	4.3
GDP	2.1	2.3

[a] Including changes in stocks.

Table 4.2 shows the simulated development of the economy in the reference case. The need to restore the external balance before 1990 is reflected in the gap between the growth of exports and imports during the 80s with repercussions primarily on private consumption growth. In the 90s a faster consumption growth compensates for the meager previous decade.[3]

Stagnating Oil Prices

How would this reference scenario change with other assumptions about oil price development?

In the standard reference case we have assumed for the oil price a 1.5-2.0 real growth rate for the rest of the century - if deflated by the price of finished goods. Oil price forecasting is, however, a highly uncertain business and no one can exclude the possibility of e.g. a stagnating real oil price. However, our main results do not depend critically on these assumptions.

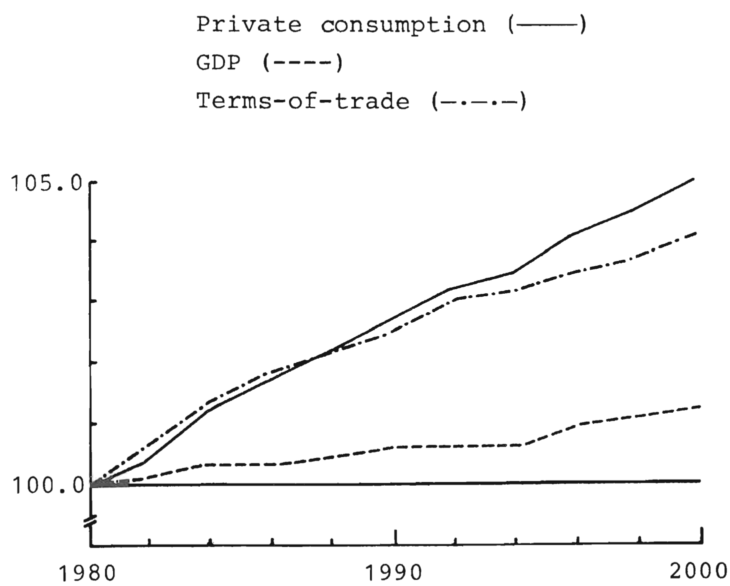
Our main aim is to analyse the impact of oil price shocks on the economy and different ways to alleviate the problem they cause. Most of our conclusions relate to differences between simulations rather than to absolute levels. The effects of an oil price hike is here measured by the difference in e.g. private consumption levels between a simulation with the sudden oil price increase and a simulation without if. Within certain bounds this difference does not vary very much with the oil price assumption used as reference. We shall, however, briefly discuss the effects of stagnating oil prices. The exact price assumptions are given in Table 4.3.

Table 4.3 World market prices

Annual increase %	Reference case 1980/1990	1990/2000	Stagnating oil prices 1980/1990	1990/2000
Finished Goods	6.4	6.0	6.4	6.0
Oil	8.0	8.0	6.0	6.0
Coal	8.9	8.0	6.9	6.0

The reduced energy import prices will certainly improve terms-of-trade for the Swedish economy. The consumption level corresponding to full employment and external balance will accordingly be

Figure 4.2 Effects of stagnating oil prices
(Reference case = 100)



higher as shown in Figure 4.2. The total gain at the end of the simulation period will amount to 5 percent of the reference case private consumption level. The improved terms-of-trade are not solely due to the oil prices. Since the total oil import bill will be smaller the need to generate a trade surplus for other goods is somewhat relaxed. Hence the need to gain market shares by lower relative prices and deteriorating terms-of-trade will be correspondingly less.

Simulation Experiments

The main experiments we have performed with the model are summarized in Table 4.4. Below the reference case and the case of a gradual oil price increase different variations of the oil crisis scenario are listed in order of increasing adjustment problems.

The oil crisis itself is modeled as a close to 60 percent rise in the relative oil price, occurring early in 1991 with the gradual price increase (GO), the same total relative price increase is reached in 1991 by a steady rise throughout the 80s. In the first type of oil crisis simulation (O, OI), the oil price hike occurs without interrupting world trade.

In the second type of oil crisis scenario (OW, OS, TOS), various cyclical repercussions on other world markets are taken into account. Based on the experience of the 70s and on some experiments carried out for this purpose on the LINK model (Sarma, 1983), the resulting world trade cycle is modeled as a 3-year pattern led by a short-lived speculative boom in raw material and investment goods, of dominant importance still for Swedish exports, followed by a general trade slump. Over the first 4 years of the 90s the annual increase in the volume and price of world trade (excepting services) will be, on the average, multiplied by a factor of 0.5 and 1.0 respectively, compared to the reference development. To facilitate comparisons, we let, in both cases, public consumption develop as in the reference case, registering the shrinking room for increased consumption in terms of private consumption.

In the simulations listed in the left-hand column - O, OW - no policy adjustments are made to compensate for the oil price hike. The impact measured will thus be the outcome of market reactions to the changed relative prices.

When instead full use is made of available policy instruments in order to restore balance in external payment and in the labor market in three years, the result will be as in the simulations OI and OS, listed in the middle column.

The 3 variations MW, MP, and MR listed below in the same co-

Table 4.4 Eleven simulations 1980-2000

	No oil tax		Oil tax
	No policy adjustment		Policy adjustment
No oil price hike		REF - The reference case (increasing/stagnating oil prices)	TREF - Oil tax without oil price hike UPA
		GO - Gradual oil price increase UPA	
Oil price hike with increasing economic and political adjustment costs	O - Oil price hike without world market repercussions	OI - Oil price hike without world market repercussions UPA	
	OW - Oil price hike with world market repercussions	OS - Oil price hike with world market repercussions UPA	TOS - Oil tax with oil price hike UPA
		MW - Minus wage policy	
		MP - Minus also public consumption policy	
		MR - Minus also the possibility of lowering real wages	

PA = Unrestricted Policy Adjustment

lumn simulate the effect of successively taking into account restrictions on the use of economic policy instruments which, judging from the experience of the 70s, may well be perceived as binding by Swedish decision-makers. In MW, we take away the wage policy instrument, making it impossible to influence the long-term trends in nominal wage increase. This must then be compensated for by an active use of the control of public consumption. In MP, this policy instrument is also blocked, public consumption again being prescribed to follow the reference pattern. Finally, in MR, the need for trade union support is supposed to force the government to guarantee no decline in real wages, thus increasing the unemployment needed to ensure external balance.

Two additional cases, in which an oil tax is used as a buffer against the possibility of an oil-price hike, are listed in the right-hand column of Table 4.4. The oil tax we study has a very simple construction. It is successively stepped up during the 80s, annually adding an extra oil price increase of around 5 percent, so that by the beginning of 1991 it has raised the domestic oil price as much as the assumed size of an eventual oil price hike.

If the oil crisis materializes - the TOS-case - the tax is used as a buffer, the lifting of the tax neutralizing the raised import price. We then measure the benefits by comparing the resulting development during the 90s with the uninsured case, OS, assuming the same access to policy instruments. If the oil crisis does not come (the TREF-case), the oil tax remains and causes some retardation in growth during the following decade. The cost of the tax insurance is evaluated by comparison with the outcome in the reference case which, apart from the tax, rests on identical assumptions. A comparison is also made with the case, SO, of a gradually rising import price in order to differentiate between the effect of changed terms-of-trade and that of changed domestic relative prices.

NOTES

[1] For an account of the interaction between local governments and the rest of the economy and its effects on stabilization problems and policies, cf. Nordström - Ysander (1981).

[2] For a more detailed discussion of alternative conditions and strategies for Swedish economic development 1980-2000, cf. Nordström - Ysander (1980).

[3] The difference in growth rate between exports and imports in 1990/2000 is due to the fact that volumes are expressed in 1975 years prices. The 1990 export volume is 25 percent larger than the import volume implying a slower growth rate required for export volume to keep export value increase equal to import value increase. Also the fairly favorable growth assumptions for world trade developments actually permit a slight increase in relative export prices, thus further reducing the necessary export volume growth rate.

5 THE IMPACT OF AN OIL PRICE SHOCK

In this chapter we will describe the impact of an oil price hike on the economy using the reference case as a standard of comparison. Both short term responses and long term substitution effects will be discussed. Changing oil prices also have important effects on the world market. These effects may be of great importance to a small open economy like the Swedish. Economic policy must also be taken explicitly into account since an oil price crisis makes policy changes necessary, at the same time increasing the pressures on policy-makers.

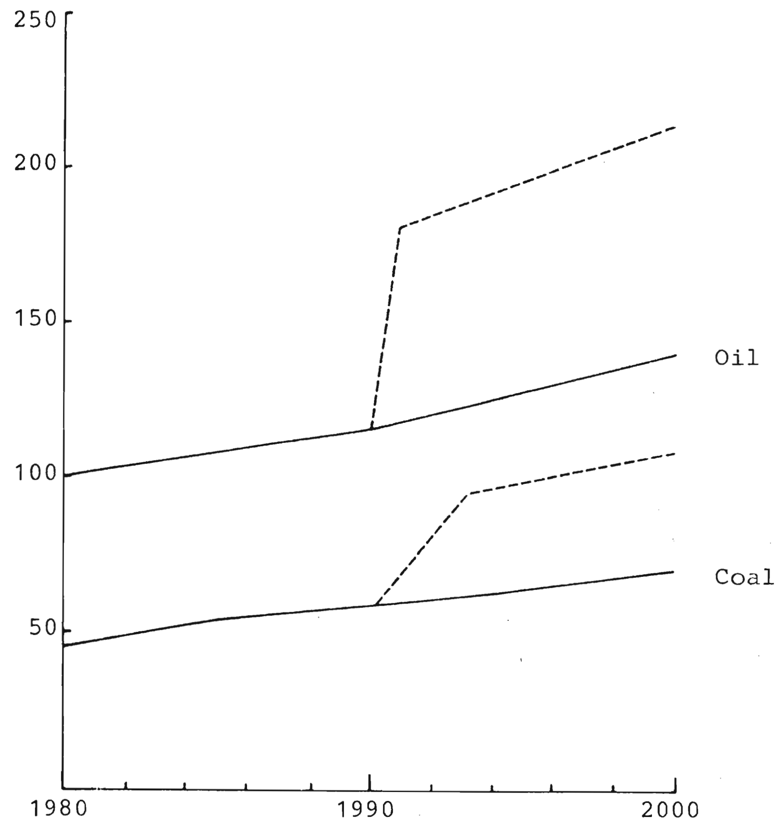
Impact Without World Market Repercussions

Let us first trace the direct impact of an oil price hike on the Swedish economy disregarding the repercussions on the world markets. In 1990/1991 the price of imported oil is assumed to increase by 2/3 instead of the reference 8 percent increase. Through the 80s and again from 1991 onward oil prices will increase by the reference case rate. Prices on coal are assumed to follow oil prices albeit with a certain lag as shown in Figure 5.1.

Although target variables will be displaced by the oil price increase it may clarify the analysis if we start by keeping policy variables unchanged. The question we thus try to answer is: what would happen with the economy in an oil crises if the Swedish government decided to ignore it and to go on doing "business as usual"?

The immediate impact of a large oil price rise on the model economy is to boost inflation, e.g. as measured by the consumer price index. This comes about in two ways - directly through the households' use of oil and indirectly through increased costs of production in the business sector. The inflation impact is shown in Figure 5.2. After the initial inflation peak in 1991, the inflation rate will gradually approach that of the reference case.

Figure 5.1 Real price of oil and coal



Note: The dotted lines show price developments in the oil price hike case. Real price of oil (SEK per MWh) in 1980 = 100.0. Nominal prices are deflated by the world market price for finished goods.

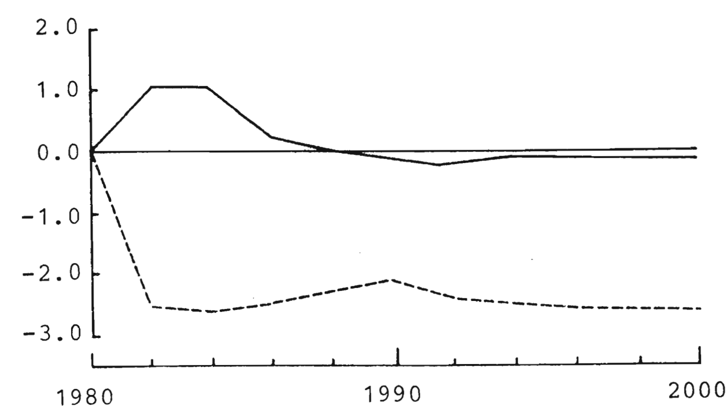
However the oil price hike and its inflation impact will set forces in motion which will affect the real development of the economy and feed back on prices with various lags. One important mechanism coming into play is the wage formation mechanism. As is evident from Figure 5.2a the initial impact on wages is negative. Wage rate growth in 1990/1991 will fall below the reference case by three percentage points. A fairly strong wage response to excess demand in the labor market comes into play immediately while wages respond to prices only after a year. Inflation will deflate private income and will make industry lose market shares abroad. This fall in real demand will promptly show up in open unemployment as shown in Figure 5.2b, thus causing wages to fall relative to the reference case. There is a fairly large cut in real wages in 1991 - minus 6.5 percent compared to the reference case and minus 3.5 percent relative to the wage level of the previous year. This assumed wage formation mechanism will bring the economy back to full employment within a few years. Thus, the model asserts or assumes that a total lack of accomodation on the part of the government will cure the economy both of unemployment and inflation within 3-4 years. The fall in domestic real income is however not large enough to offset the loss of terms-of-trade imposed on the economy by the oil price increase. The initial deficit on current account will thus persist as shown in Figure 5.2b. (The exchange rate is assumed fixed.)

The limited fall in consumption demand - 3 percent during 1991 compared to the reference case - is due to the progressive income tax as well as to the inflation compensated transfers which make up a considerable part of the households' disposable income. Another contributing factor is the assumption that public wage increases lag one year behind the business sector. So, some of the reasons why stabilization after an oil price hike cannot safely be left to the markets has to do with the fact that "inbuilt automatic stabilizers" in the tax and transfer system and various forms of inflation indexing cushions the inflationary impact so much as to impede the adjustment of the domestic consumption level, leaving us with an external deficit.

Figure 5.2 Effects on inflation, unemployment and current account from the oil price hike

a) Consumer price index (———)
Wage rate in business sector (—•—•—)
(Difference in growth rates from reference case)

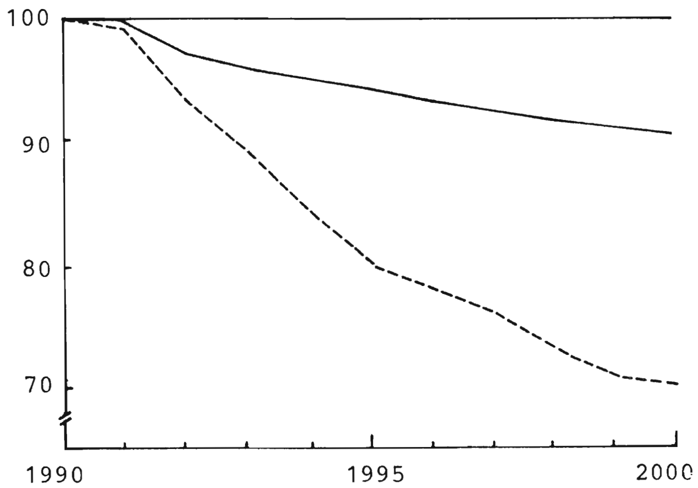
b) Unemployment rate (———)
Current account as percent of GDP (-----)
(Difference from reference case)



Note: The difference in oil price growth in 1990/1991 compared to the reference case i 54 %. For coal this difference is spread over three years. Apart from oil and coal prices all growth rates of international prices are identical between the two simulations.

Figure 5.3 <u>Effects on energy use from the oil price hike. Primary energy input to GDP</u>
(Reference case = 100)

Total energy (———)
Oil (-----)



Turning briefly to the energy consequences, the use of oil will decrease compared to the reference case. A minor part of the reduction is explained by slower economic growth. More important, however, is reduced energy use per GDP unit and reduced share of oil in total energy use. As Figure 5.3 indicates, oil use in TWh/GDP is reduced by 30 percent during the 90s as a result of the oil price rise in 1991. Total primary energy input will be 10 percent lower. The decline in energy coefficients is gradual due to the inertia in energy substitution built into the model, i.a. through vintage mechanisms the capital formation in the business sector.

Impact of World Market Repercussions

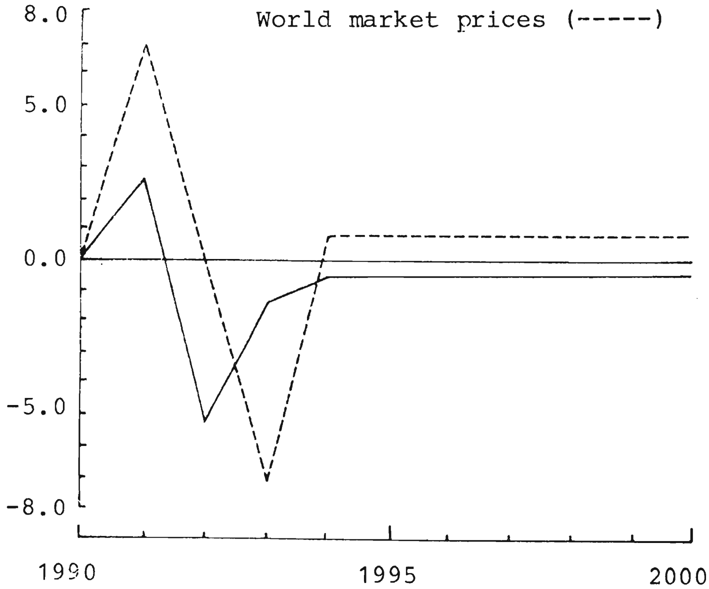
In our discussion so far world markets were assumed to be completely unaffected by the oil price shock. We did this for analytical reasons to isolate the "direct" oil price impact from "indirect" effects from unstable world markets. The assumption could be interpreted as reflecting perfect adjustment or stabilization policies being carried out throughout the world. At least at an aggregate level this would imply i.a. that inflation is contained and that the financial transfers inherent in an oil price hike are organized without depressing real income and demand. This could of course be true only at an aggregate level. To ascertain this stability, patterns of trade and production would have to change in response to shifts in wealth among countries and relative prices among goods.

Judging from historical experience, crises of the type discussed here are however not likely to be handled in a cooperative spirit or to be accomodated smoothly by the international community. It seems therefore reasonable to introduce some kind of world market effects into our simulation experiments. This will add considerably to the arbitrariness of the calculations since future international policy responses are not easy to predict. Our aim, however, is only to illustrate the increased strains that domestic policy makers will be facing when international stabilization policies are not pursued in an optimal way.

Based on the experience of the 70s and on some experiments carried out on the LINK model for this purpose (Sarma, 1983), a world trade cycle is modeled as a three year pattern led by short-lived speculative boom in raw materials and investment goods - of dominant importance still for Swedish exports - followed by a general trade slump. Over the first four years of the 90s the annual increase in the volume and price of world trade will on the average be multiplied by a factor 0.5 and 1.0 respectively.

Figure 5.4 Oil price hike and world market repercussions
(Differences in growth rates from reference case)

a) Raw materials excl. fuels
World trade (———)
World market prices (-----)



b) Finished goods
World trade (———)
World market prices (-----)

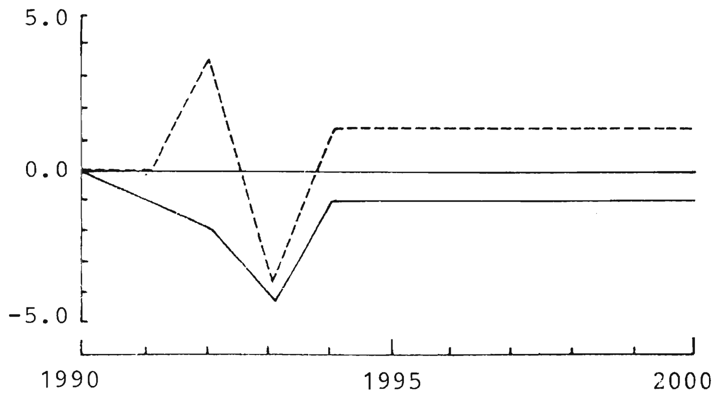


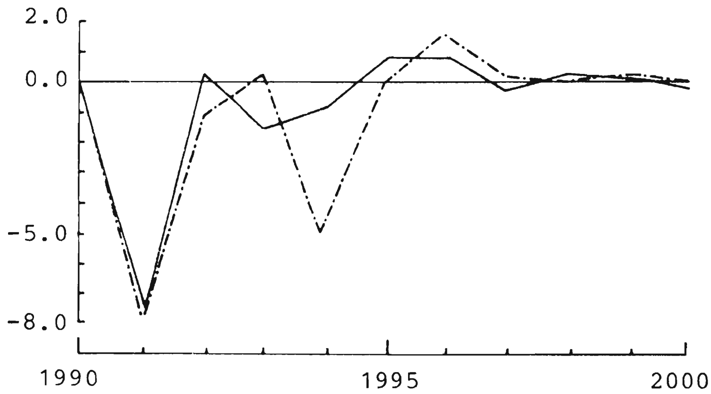
Figure 5.5 Effects of oil price crises and world market repercussions

(Difference from reference case)

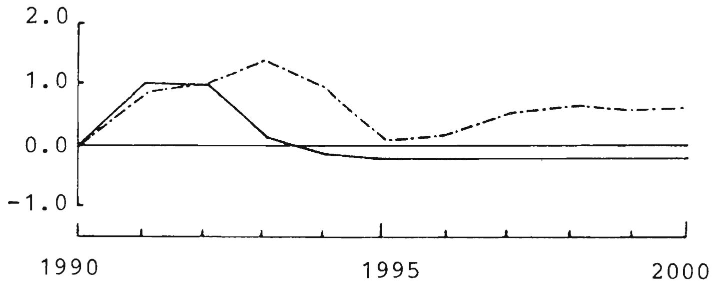
Oil price hike only (———)

Oil price hike plus world market repercussions (—·—·—)

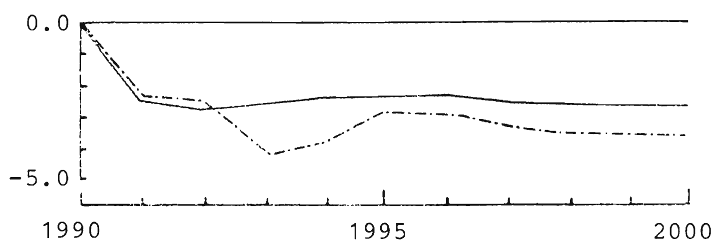
a) Real wage rate growth



b) Unemployment rate



c) Current account as percent of GDP



For the rest of the decade, markets are assumed to be stable but with lower trade growth rates and higher inflation rates than in the reference case, as shown in Figure 5.4. World markets for services are assumed to develop with the same patterns as markets for finished goods.

Initially the assumed world market cycle will in fact somewhat alleviate the negative effects of the oil price increase for the Swedish economy. This is evident from Figures 5.5a-c, which show differences between oil price hike simulations with and without world market repercussions.

The reason is the raw material boom in the first phase of the cycle which favors the relatively large Swedish exports of such goods. The balance on current account will therefore improve somewhat during 1991-1992. When markets turn down, however, the negative effects will be correspondingly stronger. Since the domestic activity level - given e.g. by the employment rate - will not improve even during the third year of the crisis, the increase in domestic unit labor costs will be modest. Compared to a simulation without disturbed world markets, real wages will on average decrease by one percentage point per year during the first five years of the decade. Figure 5.5b-c show that economic imbalances - unemployment and external deficit - will be reenforced by the world market crises. The rate of unemployment caused by the combined oil price rise and world market repercussions will amount to 3.4 percent and 2.5 percent respectively in 1993 and 2000. The deficit on current account for those two years will be respectively 4.2 percent and 3.7 percent of GDP.

Stabilization Policies

We have so far only studied the impact of an oil price hike in the case where the government takes no countermeasures, but allows the foriegn debt to accumulate. That is obviously an untenable position in the long run and we will now go on to see what solution can be offered by an active stabilization policy.

Economic policy in the simulation experiments is pursued towards two main goals: full employment and balance on current account for external transactions. The three instruments used to achieve desired target levels are taxes, real public expenditures and wage-policy.

Tax policy is modeled as a wage tax. In using public consumption as an instrument it is tacitly assumed that policy makers exercise full control not only of central government expenditures but of local government expenditures as well. The ISAC-model does in fact include an expenditure model for local governments where the central expenditure control can be substituted by more realistic policy variables like different kinds of grants. This submodel is however not used in the present simulations.

The wage policy instrument, finally, is implemented as an autonomous wage rate increase that is assumed to be directly or indirectly controlled by the government policy makers. Altogether this does not yield a very rich framework for stabilization policy analysis but works satisfactory for our purposes.

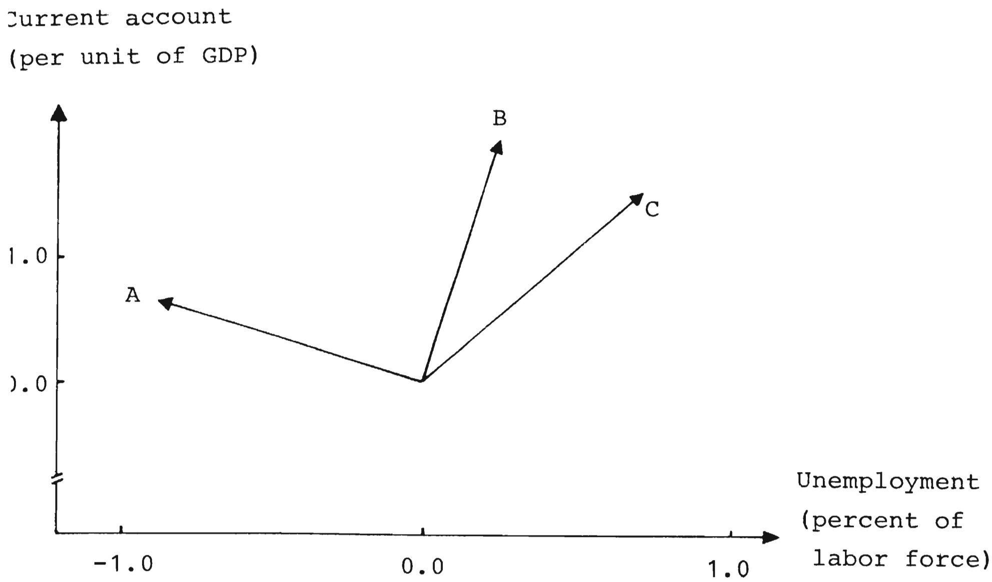
Throughout this section we will keep the public expenditure growth unchanged and analyze the use of tax and wage policy to reach the specified targets. Variations in public consumption growth will, however, be necessary when the use of other policy instruments is restricted, as we will see later on.

The effects of parameter changes in the ISAC-model has been described elsewhere and shall not be repeated in detail (cf. Jansson, Nordström, Ysander, 1982). As is seen from Figure 5.6 a reduction of the autonomous wage rate growth (A) will improve the current account and increase employment in a medium term perspective (3-5 years). This is mainly the result of improved competitiveness on the world market. Instruments B and C in the figure on the other hand will primarily affect domestic demand by increased taxes and reduced public expenditures respectively. A desired improvement of the external balance can be accomplished with smaller negative effects on employment if measures are directed towards private consumption, due to its higher marginal import propensity.[1] In both cases, however, the incresed unemployment will depress wages, thereby also boosting net exports through improved international competitiveness.

We saw already (cf. Figure 5.5) that the oil price crisis will bring about internal as well as external disturbances throughout the 90s if no counter measures are undertaken. When world market effects are taken into account, unemployment will reach a peak level at 3.5 percent in 1993 and will then remain around 2.5 percent. The principal problem will, however, be the current account which will deteriorate to a deficit amounting to 3-4 percent of GDP. The outflow of currency will then sooner or later make policy adjustments necessary. We have here chosen to use parameters in the tax and wage functions as policy instruments. We have also, for analytical reasons, chosen to bring the economy back on target as soon as 1993 and to keep it close to target for the rest of the decade. By this standardization it is possible to compare the austerity required by different policy packages.

The changes in tax and wage-policies necessary are rather selfevident. Although the crisis by itself will lower real wages, the decrease is not large enough to offset the rising energy costs in production and the deteriorating terms-of-trade. As shown in Figure 5.6 a downward adjustment of the "autonomous" wage rate increase will improve the external balance as well as the employment situation. To reach the targets in 1993 tax rates must also be raised. Thus economic policy must depress real wages and private consumption shares of GDP, even further than what would be the case in an "uncontrolled" development of the crises-ridden economy. This is illustrated by the shaded areas in Figure 5.7. Policy measures will have to be rather harsh during the first three years of the crisis. Real wages, which grow by more than 3 percent a year in the reference case, must decrease by more than 2

Figure 5.6 Effects of policy instruments on target variables
(Differences to the reference case)



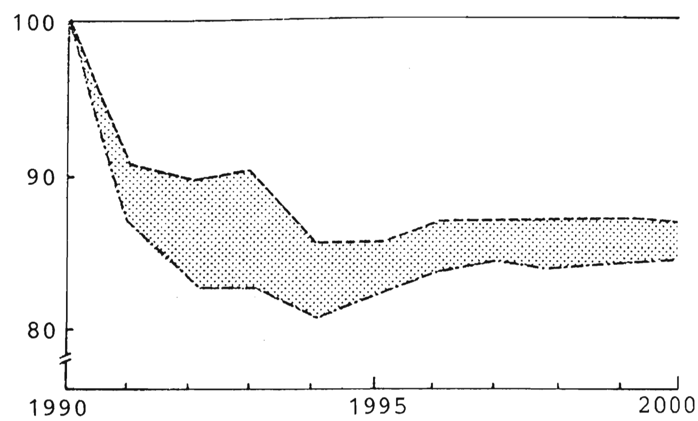
A: Wage policy
B: Tax policy
C: Public consumption policy

percent per year during 1990-1993. For the rest of the decade real wages may grow at approximately the reference case rate. Also tax policies must be hard-fisted enough to force down private consumption and make room for the net export expansion necessary to restore external balance. Although GDP growth is not much changed by the policies measures, private consumption will decrease by 1.6 percent per year between 1990 and 1993. It should be emphasized that labor supply is exogenous in the model and thus not affected by taxes or wages. When the crisis has been contained after three years, the economy resumes a "normal"

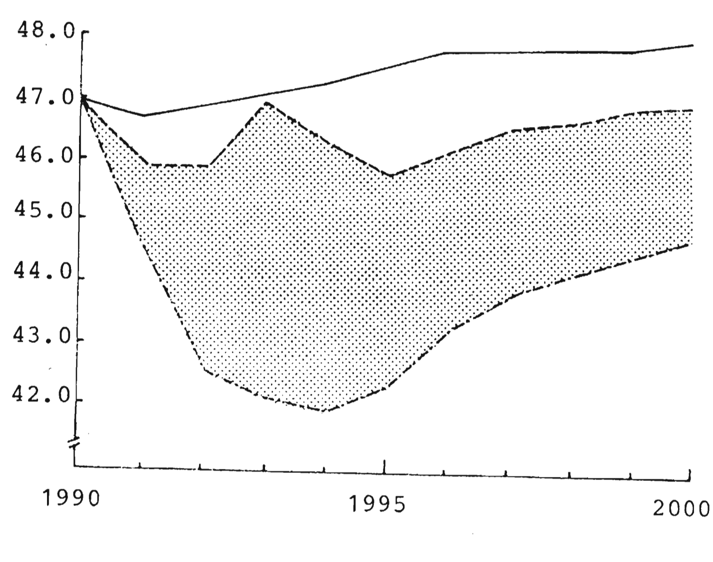
Figure 5.7 Policy measures to reach target values in an oil crisis

Reference case (———)
Oil crisis with reference case policy (-----)
Oil crisis with adjusted policy (—•—•—)

a) Wage policy: Real wage rate level
(Reference case = 100)



b) Tax policy: Real private consumption share of GDP (percent)

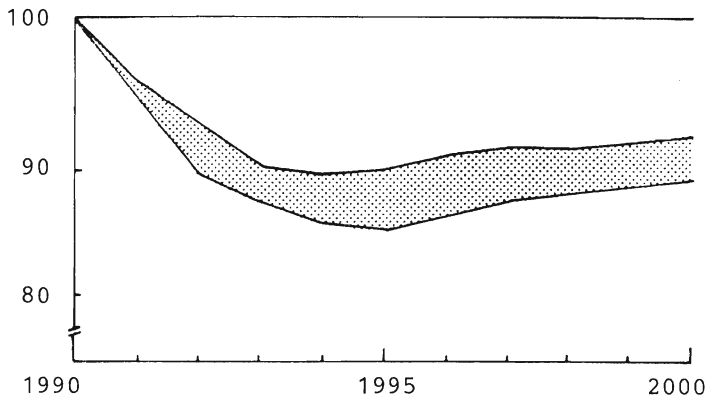


growth path although from a lower consumption level than in the reference case. This difference is a rough measure of the welfare loss incurred by the combined oil price and world market crisis through deteriorating terms-of-trade. It will reach a maximum of 14 percent of the reference case level in 1995 and will on the average be 10 percent.[2]

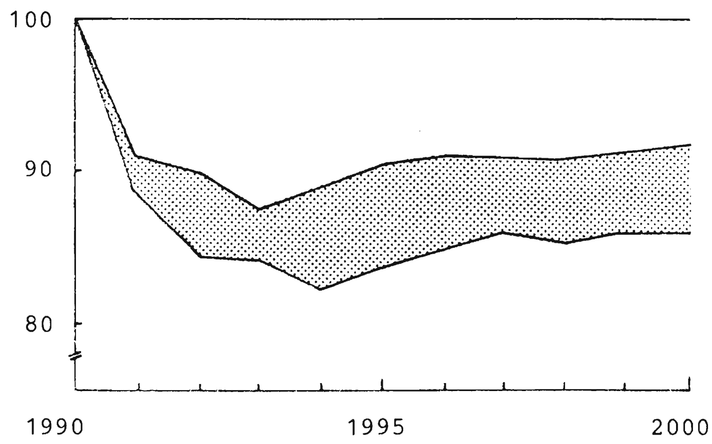
Of course, if all countries would accommodate the oil price hike without deflating their economies, the hardships would be mitigated. As stated above we may approximate such a development - including a balanced trade between oil exporting and importing countries - by assuming that world markets for other goods are unaffected by the oil price rise. This will substantially reduce the necessary changes in policy parameters as well as the persistent loss in terms-of-trade and consumption levels due to stagnating world markets. The difference between the outcome of the two oil crisis cases - with and without world market repercussions - are summarized by the shaded area in Figure 5.8. In both cases targets are reached in 1993 and maintained for the rest of the decade. The figure thus shows direct and indirect effects from an oil price crisis in terms of welfare losses (as measured by private consumption) and policy requirements (as measured by the real wage rate). With the assumed size of the oil price rise and its world market repercussions, the major part of the impact on the Swedish economy - about 3/4 - will consist of the direct oil price effect. However, Figure 5.8b shows that the required real wage adjustment is magnified by the world market effects. While the real wage rate levels in 1995 must be 9 percent below the reference case level when the oil price hike is not accompanied by disturbances in world trade, real wages will have to fall another 7 percent if such disturbances has to be accomodated. During the first two years of the crisis real wages will have to fall by 4 percent as a direct effect on the economy from the oil price rise, while it takes a reduction of real wages by almost 10 percent during these two years to handle the combined crisis. Obviously this will increase the risk of not coping and of therefore incurring further welfare losses.

Figure 5.8 Direct and indirect effects from an oil crisis
(Reference case = 100)

a) Private consumption level



b) Real wage rate level



Effects of Policy Restrictions

So far we have assumed the policy instruments to be completely at the disposal of the policy maker with no restrictions on their use. Policy problems in real life tend to be more complex. There are political trade-offs and the preferences of organized voter groups to take into account. Such interdependencies could be incorporated into the simulation exercises through optimization over some explicit loss-function. For several reasons we have here chosen a much cruder analytical approach. One reason is that such loss-functions are hard to specify and even harder to estimate (cf. Gramlich, 1979). The main reason, however, is technical. Since ISAC is a fairly large model, formal optimization would have added considerably to solution costs.

Instead we will in the following simply discuss the consequences of successively giving up or restricting the use of policy instruments. The gradual shrinking of the policy space will make it impossible to reach both targets in all cases. We have then choosen to meet the external balance target and measure the cost of the restrictions in terms of unemployment.

The experiments are carried out in the following way (cf. also Table 4.4). During the "crisis" period 1991-1993 various restrictions are put on the use of policy variables. The policies pursued still aim at reaching in 1993 both the external balance and the employment target. When both cannot be reached the employment target is abandoned. For the rest of the simulation period, i.e. 1994-2000, no restrictions are imposed and targets are (approximately) attained. By measuring the "harshness" of the policies required in terms of consumption and real wage, we try, in a very rough and indirect way, to estimate the risk of not coping with the crises, of the policies being blocked or impeded.

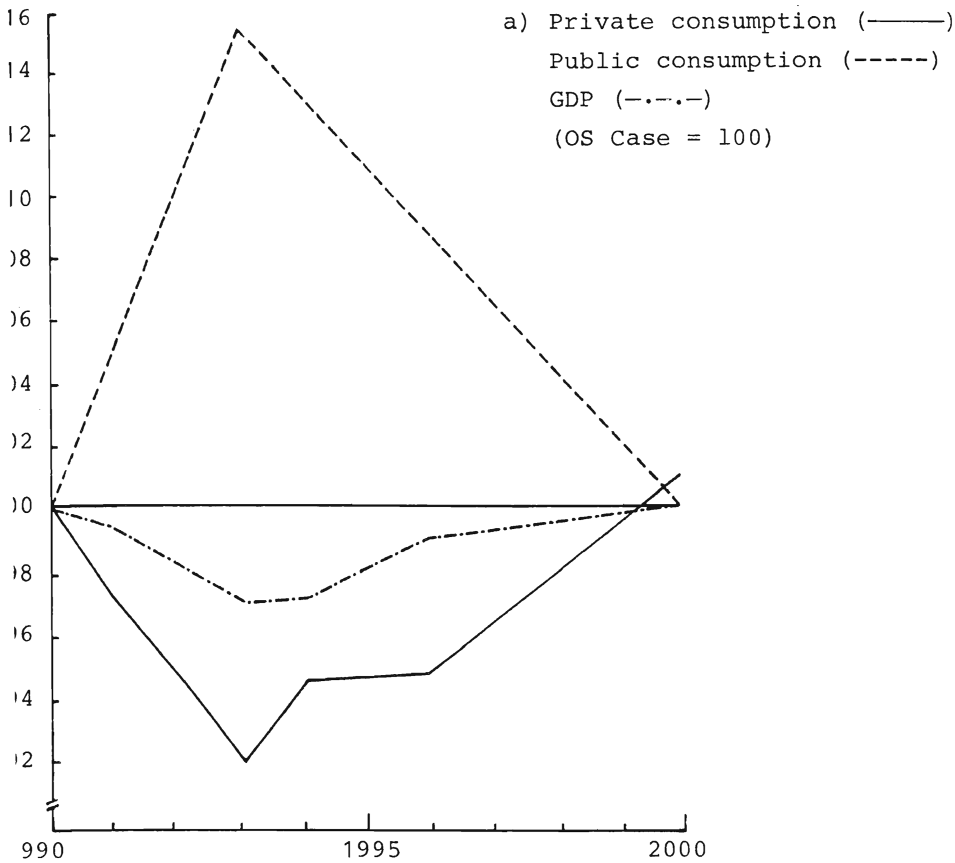
In the first experiment (MW) no wage policy is allowed, i.e. we cannot control the autonomous wage growth. Wages will not only fluctuate according to "market forces" but also develop according to an exogenous long term trend. To reach the targets we must then use the third instrument available - public consumption expenditures. If we cannot improve our competitive position by measures directly affecting production costs, i.e., wage rates, the only way to eliminate the external deficit in the short run without increasing unemployment is to save imports by substituting public for private consumption. This solution is illustrated in Figure 5.9, where all variables are related to the unrestricted oil crises case (OS). Note that the current account target is reached in these experiments and is therefore not shown in Figures 5.9-11.

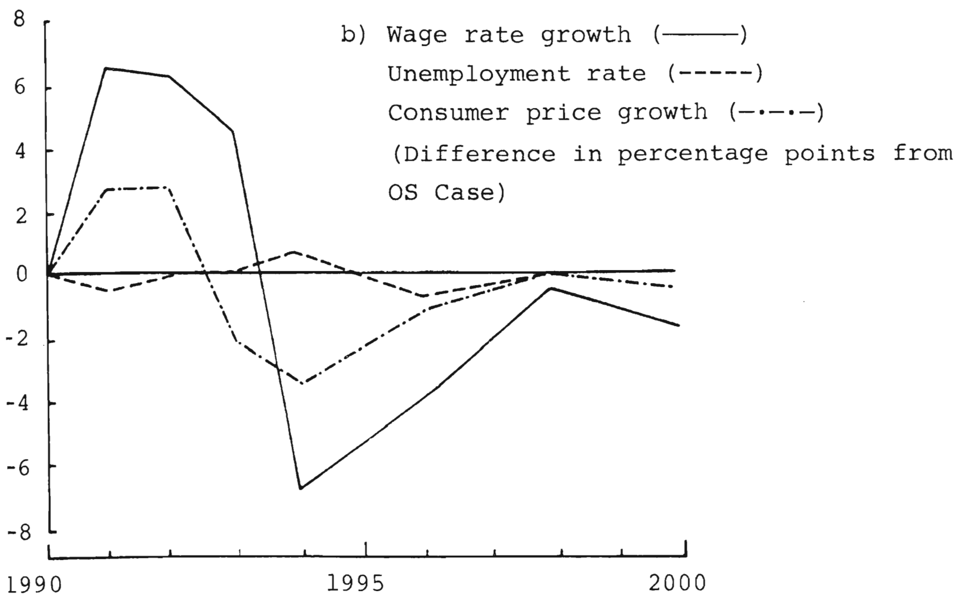
The necessary redistribution between private and public consumption is drastic. Public consumption growth rate must increase from 2.1 percent to almost 7 percent per year during the crisis period 1991-93. To release labor for this public expansion from the rest of the economy, taxes must be raised substantially. As a result private consumption in 1993 is 8 percent below the OS case. Since the private consumption level in the OS case is almost 5 percent below the 1990 pre-crisis level this further decrease implies an average yearly reduction of total private consumption by 4.5 percent during 1991 and 1993. Even though consumption levels will be restored to the unrestricted levels towards the end of the decade it would obviously be difficult to find support for and to execute such wild swings in public consumption.

Inflation will be higher during the crisis period than in the OS-case (cf. Figure 5.9b) since wage inflation is not controlled. Real wage growth will on the average exceed the OS case by 2.3 percent per year between 1991 and 1993, still however implying zero real wage growth from 1990.

In the second experiment (MP) we also assume that rapid shifts in public sector growth are impossible. To make it simple we proscribe that public consumption cannot be used as a policy instrument at all. This leaves us with only one policy variable - tax policy - and with no hope of reaching both targets except by chance. Since we have decided to stick to the external balance,

Figure 5.9 Minus wage policy (MW)



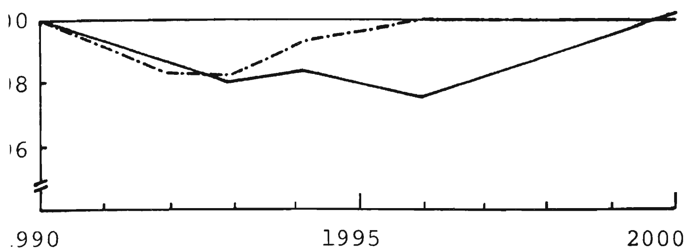


taxes must be raised to make room for the necessary export expansion. The tax raises will save imports through reduced private consumption and depress wages through increased unemployment. Lower wages in their turn increase net exports and improve the current account. As Figure 5.10 shows, private consumption need not be quite as contracted as in the MW case during 1990-1993. At the same time public consumption will be much lower and unemployment almost twice as large. Towards the end of the decade, the economy will again settle on a growth path close to the unrestricted OS case. Real wages will decline during 1990-1993 although not so fast as in the OS case, as shown in Figure 5.10b.

In our final experiment, the MR case, we add, on top of all the preceding policy restrictions, the political prescription that real wages should not be allowed to fall. Strictly speaking this is not a policy restriction in the model but rather an ad hoc restriction on one (or several) of its behavioral equations. Nevertheless we believe that the effects of such a lower bound on real wage rate growth is of great interest, whether it is imposed by central policy makers or by the parties on the labor market. This restriction will reduce the effects of raised taxes on the balance of payments. The resulting unemployment cannot fully exert its downward pressure on wages. Thus the net export expansion that comes from improved competitiveness will be weaker, and it will be left to the income effect on imports to ascertain a balanced current account. This will call for a larger reduction in private consumption and in total demand than in the MP case, as seen in Figure 5.11. Unemployment will exceed 5 percent in 1992 - almost twice the level in the OS case.

.gure 5.10 Minus public consumption (MP)

a) Private consumption (———)
GDP (—·—·—)
(OS Case = 100)



b) Wage rate growth (———)
Unemployment rate (-----)
Consumer price growth (—·—·—)
(Difference in percentage points from OS Case)

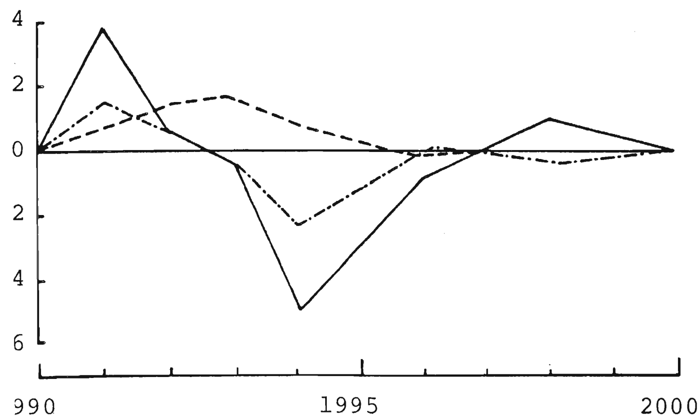
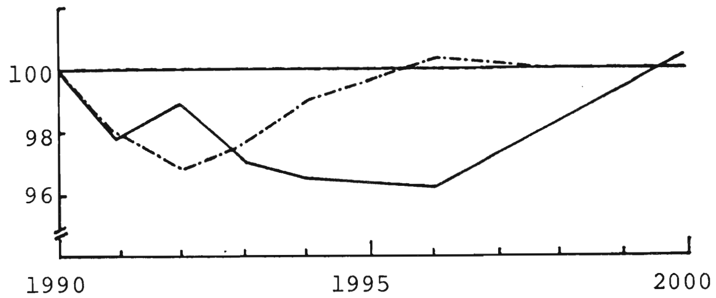
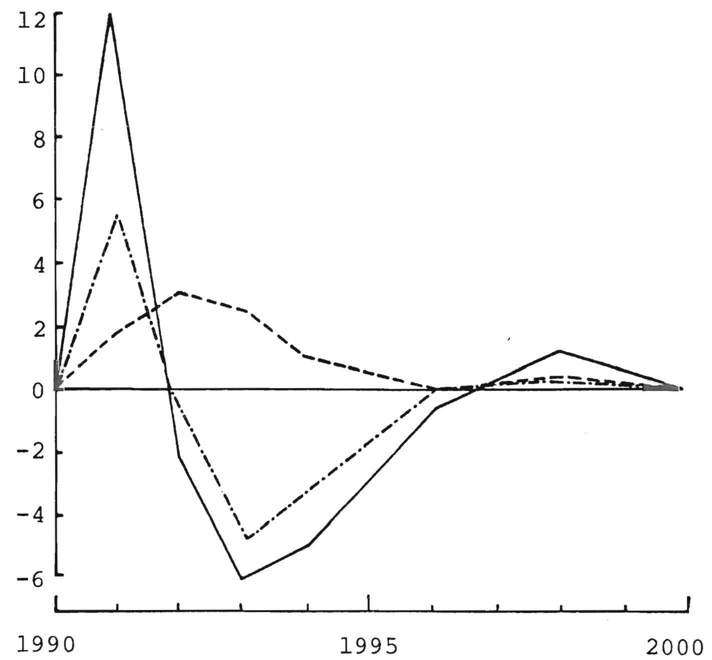


Figure 5.11 Minus real wage adjustment (MR)

a) Private consumption (———)
Public consumption (-----)
GNP (—·—·—)
(OS Case = 100)



b) Wage rate growth (———)
Unemployment rate (-----)
Consumer price growth (—·—·—)
(Difference in percentage points from OS Case)



NOTES

[1] This is the simple "technical reason" for giving the combination wage and tax policy first priority in selecting an "optimal" policy program for two instruments. There are of course other ways of evaluating program packages, and our choice here should not be thought of as indicating any value judgement in this respect.

[2] This case (OS) will be compared to the oil tax case (TOS) in Chapter 6.

6 THE USE OF AN OIL TAX AS INSURANCE

There are many alternative ways in which you can try to insure against the adverse effects of an "oil crisis". Some ways were indeed already suggested above, e.g. improving counter-cyclical measures and preparing for sharp changes in fiscal policy. Another natural suggestion is to force domestic producers and consumers to adjust gradually to an anticipated long term rise in oil price. This could merely mean promoting flexibility in investments involving the use of energy and persuading, by the use of some "indicative planning", investors to tailor their investments to fit expectations of higher future oil prices. As we suggested in our introductory discussion, there may, however, be good reasons for the government to go a step further and extend some kind of guarantee for a slowly rising domestic oil price, both as a way of reducing total risk and as a form of risk-pooling. This can be done in many ways. The example we have chosen to illustrate in our simulation is a rough sort of "oil price insurance" - a cumulative oil tax. The use of increased domestic oil taxation as a means of accelerating energy saving and the use of substitute fuels is a dominant theme in the current Swedish discussion on energy policy.

The oil tax we study has a very simple construction. It is successively stepped-up during the 80s, annually adding an extra oil price increase to domestic consumers, so that by the beginning of 1991 it has raised the oil price altogether 54 percent above international levels - the same as the assumed size of an eventual oil price hike.

If the oil crisis materializes - the TOS case - the tax is used as a buffer, the lifting off of the tax neutralizing the raised import price. We then measure the "benefits" by comparing the resulting development during the 90s with the "uninsured" case OS, assuming the same access to economic policy instruments. If the oil crisis does not come - the TREF case - the oil tax however remains, causing some retardation in growth etc. during the following decade. Simulation experiments show that a major part of these adverse effects could be eliminated if the tax e.g. was successively lifted off during the 90s, ensuring a return to international price levels at the turn of the century. To assume that uncertainty about oil price development should suddenly end in 1991 seems however not only arbitrary but also hard to interpret. The cost of the tax "insurance" is evaluated by comparing with the outcome in the reference case, which, apart from the tax, rests on identical presumptions.

It should perhaps be emphasized that we have chosen this particular tax construction more out of analytical convenience than for its merits as a concrete proposal. The oil tax in our simulation does have the disadvantage of driving up the domestic oil price to a level in 1990 that may be attained in the international markets only 20-30 years later. A more realistic proposal would perhaps be to align the guaranteed rate of increase of domestic oil price with the anticipated long term price trend, so as to make the expected level of international and domestic oil price at the turn of the century, roughly the same. It may also turn out to be impossible for fiscal reasons to make the guarantee absolute. A compromise solution could be to limit the fiscal "risk" to the amount of oil tax, thus setting an absolute floor for the oil price development, insuring effectively against a price slump, but only alleviating the problems for the individual investor raised by a major price hike.

Since our simulations could anyhow only provide an example and never hope to give a proper evaluation of more flexible schemes and proposals, we have chosen the rather extreme case where a full guarantee will work even in the face of a major price hike without involving net subsidies.

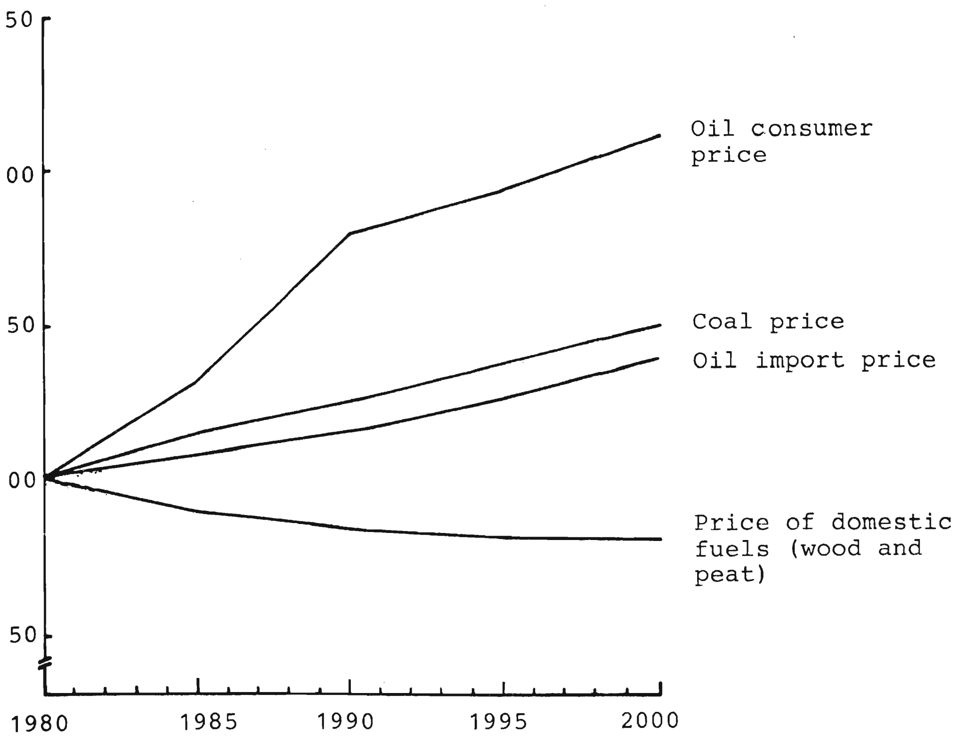
The Cost of an Oil Tax

The oil tax is assumed to affect the price of oil to all consumers at an equal rate, i.e. their buying prices will increase at the same rate compared to the reference case. This will introduce an increasing price differential on the domestic market during the 80s between oil and other primary energy sources as shown in Figure 6.1. In real terms the oil prices paid by consumers will rise steeply while prices of domestically produced fuels will even decline somewhat due to a favorable productivity development as the scale of production increases. This will induce substitution away from oil to a greater extent than in the reference case.

The reduced use of oil will mitigate the inflationary impact of the oil tax but will not eliminate it. Without compensatory economic policy, the oil tax will affect total demand and employment in two ways. To begin with it will raise consumer prices and reduce real disposable income compared to the reference case. Also the industrial sector's international competitiveness will be adversely affected by increased energy costs. The result will be loss of market shares both on foreign and domestic markets. The development through the 80s is given in Figure 6.2. At the end of the decade real private comsumption expenditures will be almost 3 percent below the reference case level. Total exports will be down 2 percent.

The weak export demand will however not bring about a deficit on current account. As shown in Figure 6.2b the external balance will actually improve. There are two reasons for this. Firstly, the substitution away from oil will considerably reduce the cost of imported energy although some oil will be replaced by coal. The savings on import costs will amount to more than 2 percent of the total import bill in 1990. Secondly the deflated private consumption volume will further depress the import need. These two effects combined will prevail over the deteriorated competitiveness in Swedish industry, due to higher oil costs, and lead to an improvment in the balance of payment.

Figure 6.1 Real prices of primary fuels

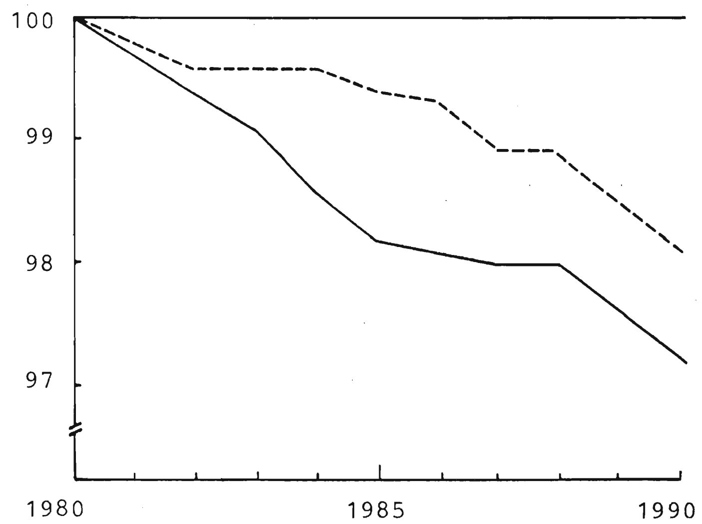


Note: Nominal prices are deflated by the world market price for finished goods. The real price in 1980 is set equal to 100.0 for all fuels.

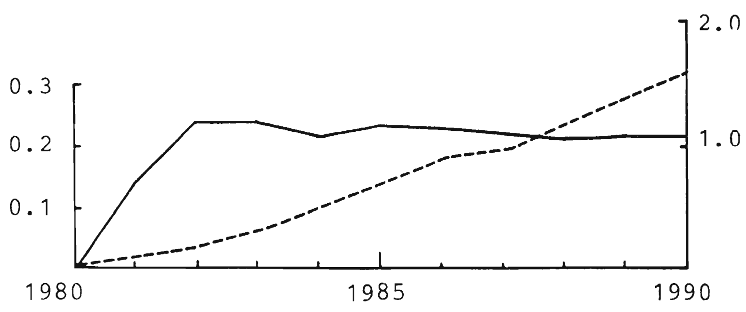
Unemployment will rise somewhat due to reduced demand and at the end of the decade there will be unused resources as well as an external surplus due to the oil tax imposed. This implies that there is room for a more "expansionary" economic policy during the decade, than was carried out in the reference case. It turns out that it is possible to attain full employment and balance on current account by a reduction of income taxes if the long term wage trend is simultaneously adjusted somewhat downwards. The outcome of such a policy change is described in Figure 6.3. From the second half of the 80s and throughout the rest of the

Figure 6.2 Macroeconomic effects of an oil tax without compensatory economic effects

a) Private consumption (———)
Export (-----)
(Reference case = 100)



b) Unemployment (———, left hand scale)
Balance of payment as percentage of GDP (-----, right hand scale)
(Reference case = 0.0)



simulation period the level of private consumption consistent with full employment and external balance will be almost one percent higher if the oil tax is introduced.[1]

Total production in the economy will as expected respond negatively to the oil tax even with compensatory policies being pursued. This is due to substitution effects reducing labor productivity with rising energy prices. The decline in full employment GDP will continue throughout the simulation period due to the gradual introduction of less labor saving technologies compared to the reference case. This reduced production volume, however, permits a higher consumption level, since the export required to balance external transactions is almost 4 percent lower than in the reference case. Again this is possible only because of the improved terms-of-trade of the economy, which will accompany the substitution away from imported oil. Terms-of-trade - the export price index divided by the import price index - in 1990 is almost 3 percent higher in the oil tax case than in the reference case. Ceteris paribus this would allow for a redistribution of 3 percent of the volume of foreign trade to domestic uses. With the large foreign sector of the Swedish economy this is a sizable share of domestic use. It will however to a large extent be offset by the negative productivity effects and increased energy-related investments.

Fixed price GDP for the tax- and non-tax cases are compared in Table 6.1. The loss in productivity does not completely wipe out the positive terms-of-trade effect associated with the oil tax. The lower overall production volume will also somewhat reduce the required investments although the total investment ratio will rise as a consequence of increased energy related investments in the oil tax case.

It is obvious already from the figures given that the factors affecting the consumption difference are nicely balanced. One should therefore be cautious in drawing conclusions from the actual outcome of the simulation examples. The most we can say

Figure 6.3 Macroeconomic effects of an oil tax with compensatory economic policy (TREF)

Private consumption (———)
Exports (-----)
GDP (—·—·—)
(Reference case = 100)

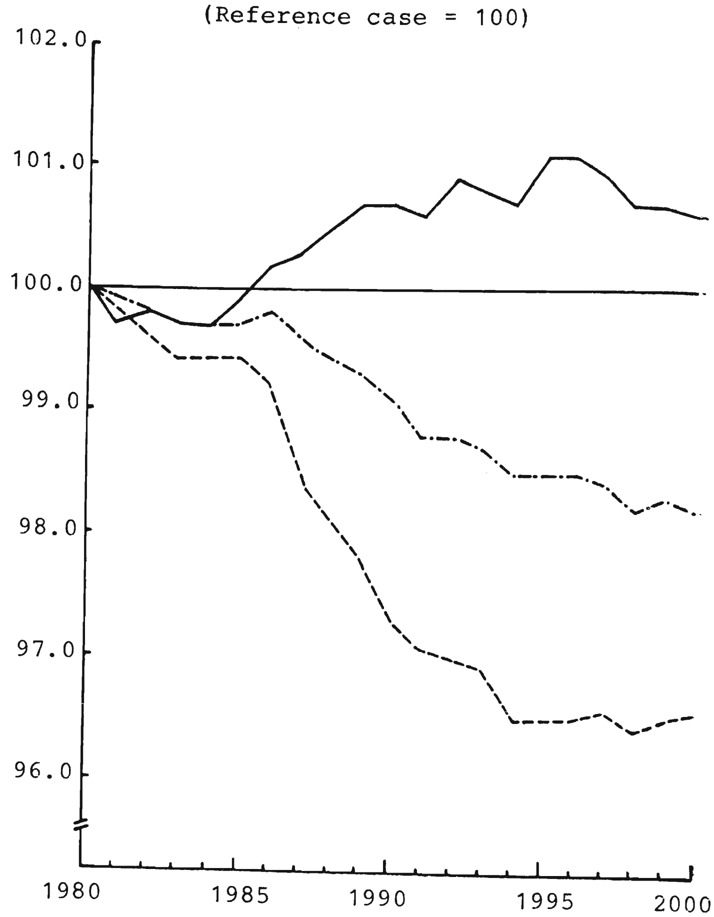


Table 6.1 GDP by expenditure
(billions of SEK in 1975 fixed prices)

	Reference case			Oil tax case minus reference case	
	1980	1990	2000	1990	2000
consumption	164.4	185.9	238.8	+1.3	+1.4
Gross investments	60.5	74.9	92.6	-0.4	-1.4
Export	104.3	163.8	238.4	-4.4	-8.1
Import	97.3	129.9	198.4	+0.2	+0.6
GDP[a]	322.0	396.8	496.5	-3.7	-8.7

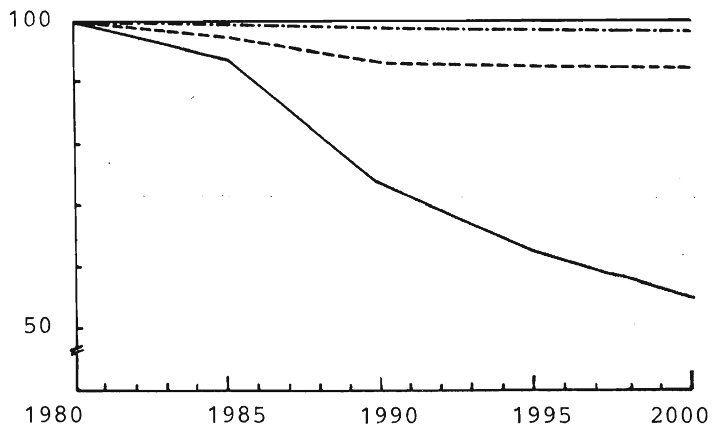
[a] Expenditure items will not sum to GDP since those that do not differ between the two cases are excluded.

is that the expected negative growth effects of the oil tax are more or less neutralized by other factors notably the effects on terms-of-trade of increased economizing in the use of oil. If it is easy and cheap to substitute oil by e.g. domestic fuels, the cost of the oil tax in terms of reduced productivity and increased energy investments will be small and the net effect on private consumption is likely to be positive. The same holds if the price responsiveness of foreign markets to Swedish exports is small. In that case a large oil import is "expensive" since it requires large cuts in relative export prices - or worse terms-of-trade in equilibrium - to make sure of the markets needed to pay for the oil. Reduced oil import will thus give rise to sizable improvements in terms-of-trade.

The energy consumption pattern emerging from the oil tax simulation is shown in Figure 6.4. Compared to the reference case the savings of oil are considerable. The consumption level will be 75 percent of the reference case level in 1990. By the year 2000 oil use will have fallen almost another 25 percentage points relative to the reference case, due to lagged responses to the rising relative oil price. As can be seen from the GDP-curve the declin-

Figure 6.4 Energy consumption in the oil tax case
(Reference case = 100)

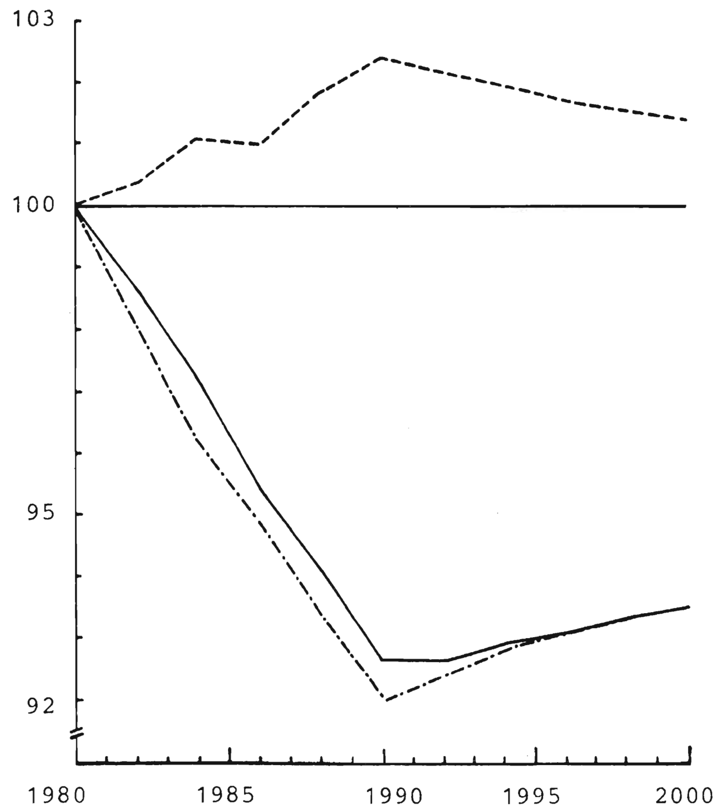
Oil consumption (———)
Energy consumption (-----)
GDP (—·—·—)



ing oil use is not explained by a lower economic growth rate. To some extent it is caused by a larger reduction in total energy use than in GDP compared to the reference case. The lion's share of the oil saving, however, is accomplished by substitution with other types of energy. In our oil tax simulaton oil use is 120 TWh lower in 2000 than in the reference case. 50 percent of this gap is filled by coal, 20 percent by domestic fuels (wood and peat) and the rest by what is usually called savings, i.e. substitution with other factors of production and changes in the composition of consumption of goods and services.

Figure 6.5 <u>Oil tax vs oil import price increase</u>
(Oil tax case = 100.0)

Private consumption (———)
Exports (-----)
Terms-of-trade (—·—·—)



Effects of an Oil Tax Compared to an Import Price Increase

The oil price on the domestic market is determined by the import price and oil taxes. We saw earlier that the economy as a whole may benefit from an oil tax due to savings on import expenditures. If the domestic oil price increase was caused instead by rising prices on the world market, oil savings would take place to the same extent. However, terms-of-trade would then deteriorate, thereby shrinking the room for domestic private and public consumption if external balance is to be maintained.

The result of a simulation where oil import prices are raised to establish the same domestic oil price as in the oil tax case is shown in Figure 6.5.[2] Although there will be oil savings they will not be large enough to prevent a substantial loss in the economy's terms-of-trade during the 80s. This loss emanates from two sources. First there is the impact of the oil price on import prices. Secondly, there will also be a need to lower relative export prices to gain market shares abroad to pay the increased oil bill. This is done in the simulation by adjusting wage increases. Export volumes will then become higher than in the oil tax case, but at the same time export prices, and hence terms-of-trade, will be lower. The result is a level of private consumption during the 90s which is about 7 percent lower than in the oil tax case.

If, however, we compare instead the gradually rising import price case with a sudden oil price hike, the big advantage of a gradual price rise is of course the absense of stabilization problems and the ensuing political strains. A gradual rise will also be anticipated and planned for, and will therefore avoid the costs of misguided investments that are incurred by a sudden and unanticipated price jump.

The Benefits of an Oil Tax

The cost of an oil tax, in terms of consumption forgone, does not seem very frightening. On the other hand one would expect the benefits to be substantial if an oil crisis occurs. The reason is twofold. First the oil dependence of the economy will be much less. Hence the penetration of an oil price hike will be less severe. Second, if the oil tax is used as a buffer, the inflationary impulse may be contained, reducing the risk of a self-sustained wageprice spiral in the aftermath of the oil price hike. This will greatly facilitate the conduct of economic policy since adjustments in terms of wages and taxes need not be quite so drastic.

How domestic oil price develops in the price hike case when oil is taxed and when it is not, is measured in Table 6.2. We see that the price increase felt by consumers during the crisis year 1991 is considerably less in the oil tax case, when the tax is used as a price buffer. Of importance to the stabilization problems that will follow in the wake of the crises, is the reduced oil dependence of the economy. Measured as percentage of GDP (at factor cost) the oil import bill in the non tax case is 7.0 in 1990 but only 6.1 when the extra oil tax is imposed during the 80s.[3] Furthermore, due to the forced export drive, necessary to pay for higher oil imports in the non tax case, the economy will be more vulnerable to a slow world trade growth during a crisis. The oil tax will thus reduce the exposure of the economy to world market disturbances on the import as well as on the export side.

Table 6.2 **Oil prices paid by consumers in the oil crises case.**
(Average annual growth rate)

	1989/1990	1990/1991	1991/2000
Oil tax case	12.8	8.0	8.0
Non tax case	8.0	66.3	8.0

The implications for stabilization policy of the oil tax is illustrated in Figure 6.6. To regain full employment and external balance by 1993 a very harsh policy is needed in the non tax case as already described in the previous chapter. Real wages must fall by 2 percent a year instead of the 3 percent growth that is possible in the undisturbed (reference) case. In 1991, according to the model, even nominal wages will have to fall - despite a 9 percent growth in consumer prices - to accomplish the necessary accomodation. Taxes must be raised to depress private consumption and to make room for the export expansion and import substitution.

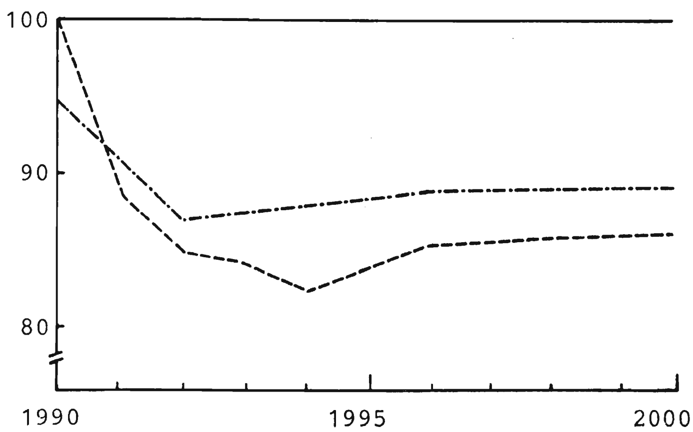
By comparison the strains imposed by the crises in the oil tax case seem more manageable. Real wages may in fact still grow during the adjustment period. The private consumption share of GDP will fall drastically during the crisis with or without oil taxes. In the latter case, however, this fall is accompanied by a slow GDP growth, making the consumption level fall by 5.5 percent during 1991 and 1992. In the oil tax case unemployment will be more easily contained and GDP growth will be higher. The fall in consumption level will therefore be limited to 3.5 percent during 1991 and 1992.

During the latter part of the 90s the differences between the tax and non tax cases in consumption levels, real wage growth etc. will even out. This is simply due to the construction of the simulation examples. We have assumed that balance in the economy is attained by 1993 and have compared the necessary measures. However the value of the oil tax may also be estimated in terms of the risk of having the economy go out of control and the welfare losses this could imply. If - in the non tax case - stabilization policy fails and we get a persistently high inflation and, after some years, increasing unemployment, how would e.g. the level of private consumption compare to a balanced oil tax case? Our experiences of oil crises have indicated that these losses may be severe. However, to construct such cases for the 90s might stretch the capacity of the model and the imagination of the reader a bit too far.

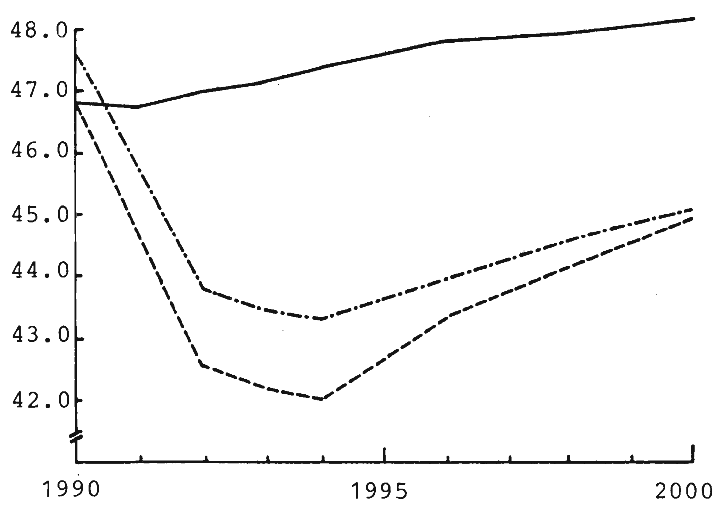
Figure 6.6 Oil tax with oil price hike - consequences for stabilization policy

Reference case (———)
Oil crisis without oil tax (-----)
Oil crisis with oil tax (—·—·—)

a Wage policy: real wage rate level. (Reference case = 100)



b Tax policy: real private consumption share of GDP (percent)



NOTES

[1] As stated above the tax rate will increase gradually during the 80s to reach 54 percent in 1990 and remain on that level for the rest of the period.

[2] This simulation is very much like the one discussed in the beginning of the previous chapter. However, in that case coal prices were as usual assumed to follow oil prices on the world market. To show only the "partial" oil tax-import price difference we here let coal prices remain unaffacted.

[3] The use of primary oil energy in 1990 is reduced by 26 percent in the oil tax case. The oil import bill, however, is reduced by only 15 percent. The difference is explained by a shift towards more refined products in the total oil import along with a general shift towards more refined products. With a more detailed treatment of the domestic refinery sector in the model, likely shifts in the composition of oil imports could of course have been incorporated into the calculations.

7 CONCLUSIONS

This study starts out from the assertion that instability and price uncertainty in the oil markets is one of the main problems confronting - and indeed calling forth - energy policy.

The first part of the study is devoted to tracing the impact of a representative oil price hike on the Swedish economy. Our simulation experiments yielded i.a. the following conclusions.

1. The long-term development of oil prices are indeed an important determinant of the rate of growth of the Swedish economy. Stagnating real prices up to the turn of the century may, as shown in the simulations, add a half percent of annual growth, compared to the case with a slowly rising (1.5 percent/annum) oil price.

2. Even more important is the instability of the oil market. Judging both from the experiences of the 70s and from simulation results, the size of the indirect effects of an oil price hike via world market repercussions may be half or more of that of the direct impact on the economy.

3. An "oil crisis" is for Sweden to a large extent a problem of economic stabilization. What makes an unexpected oil price hike so much more dangerous than a correspondingly large but gradual price rise, is the risk of not being able to cope with these problems. A fast but efficient adjustment of domestic policies can reduce the welfare losses considerably.

4. The chances of coping efficiently with the stabilization problems can be shown to depend critically on the flexibility of available policies. The more the government is tied down by varios commitments, which limit the use of policy instruments, the more extreme - and therefore the less likely - will the required policy changes be.

The second part of the study deals with possible policy devices aimed at reducing and sharing oil price risks. Our experiments with a government price guarantee supported by a cumulative oil tax used as price buffer, indicated i.a. the following.

5. The cost of such an oil tax in the case when no oil price hike occurs may be smaller than commonly supposed and could even turn out as a net profit. With appropriate policy changes the ensuing gains of terms-of-trade may be large enough to more than offset the deterioration of international competitiveness. We will however enter the next century with a smaller industrial capacity.

6. The "benefits" of smoothing the domestic oil price development, when a major oil price hike occurs, is considerable and due both to the enforced increase in total oil saving and to the pooling of price risks. The chances of efficiently dealing with the stabilization problem of an oil crisis are enhanced substantially by the early introduction of an oil tax and an oil price guarantee.

It should again be stressed that we have not been able in this simulation study to treat the general problem of oil price instability and price stabilization. The simulation results are more like a point estimate of a stylized and rather extreme case. We do think however that the results indicate fairly well both the mechanisms and the magnitudes involved and allow for some general conclusions to be drawn as to the desirable direction for future energy policy.

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Energy and Economic Adjustment

The two papers collected in this volume are both concerned with the economic consequences of instability and uncertainty of energy prices. The policy options available in Sweden for dealing with the problems are discussed. Both papers report on simulation experiments carried out on macro-models for the Swedish economy, specially designed for this purpose at IUI and the Stockholm School of Economics respectively. These simulations, covering the period up to the turn of the century, exemplify the possible impact of future oil price hikes and the effects of policies aimed at easing the domestic adjustment.

Apart from the particular insights and policy recommendations to be drawn from these simulations, the integration of energy policies with the wider problem of macro-economic stabilization should prove both instructive and helpful in avoiding many of the pitfalls encountered in more specialized energy studies.

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