MINERAL COMMODITY EXPORTS, EXCHANGE RATES AND GROWTH:

A CASE STUDY OF GOLD AND OTHER MINERALS IN SOUTH AFRICA

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Abstract

This thesis aims at assessing the role of mineral exports for a developing economy, with a focus on commodity prices and supply, exchange rates, and growth. The study is especially concerned with the case of gold in South Africa, which is considered within a broader theoretical and empirical framework, encompassing other minerals and countries.

The contradictory effects of a large mining sector, alternatively seen as a blessing or a curse for economic development and policy-making (or, rather, as a mixed blessing), provide the thread underlying the study. A growth model of a mineral developing economy is initially proposed, and tested over a 25-year period. A double *weak-convergence* equilibrium, and related differences across countries, are found to be partly explained by the performance of international prices of the main export minerals.

A literature review draws attention to other development issues, with emphasis on exchange rate analysis. The picture is one of controversial hypotheses and empirical findings, which are largely explained by objective differences in such aspects as mineral, country, and period analysed. Within this context, the thesis subsequently evaluates the role of the gold price for the South African real and nominal exchange rates in the 1980s and early 1990s. Results, based on econometric techniques applied to

monthly observations, point to the gold price as a determinant of both exchange rates in South Africa, even if with some variation over the sample period.

A recursive equation model is constructed to link South African gold mining to a macroeconomic framework. This model allows reconsideration of the above results with a new approach, employing a different time period and observation frequency (1970-1994 annual data), and draws implications in terms of real exchange rate misalignment and economic growth. The results highlight the potential for a moderate recovery in gold mining and the need for adequate development strategies for the mining sector in South Africa, in view of the challenging requirements of the near future.

The last part of the study turns to examine company-level statistics for gold and other minerals, so as to test hypotheses on the supply behaviour of mines which are ignored, or at best presumed, by studies exclusively relying on macro data. Results, based on pooled data, suggest the relevance of microeconomic, geological and, in some cases, institutional factors to account for different mineral supply responsiveness.

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Unless otherwise specifically indicated in the text, this thesis represents my own original work, and has not been submitted for any degree at any other university.

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Abbreviations and units of measurement

Abbreviations

AAC	Anglo-American Corporation Ltd.
ADF	augmented Dickey-Fuller (DF)
ADL	autoregressive distributed lag
ARIMA	autoregressive integrated moving average
ARMA	autoregressive (AR) moving average (MA)
BIC	Bushveld Igneous Complex
BoP	balance of payments
CBA	cost-benefit analysis
CIS	Commonwealth of Independent States
CSO	Central Selling Organisation
CDV	Cuddy and Della Valle
CPI	consumer price index
CSS	Central Statistical Service
CUSUM	cumulative sum (test)
CUSUMSQ	cumulative sum of squares (test)
CVRD	Companhia Vale do Rio Doce
DW	Durbin-Watson
EASy	Economic Analysis Systems (database)
ERER	*equilibrium* RER
ESSA	Economic Society of South Africa
GEIS	General Export Incentive Scheme
GFSA	Gold Fields of South Africa Ltd.
GPUSD	gold price in US dollars
ISIC	International Standard Industrial Classification
LDCs	less developed countries
LME	London Metal Exchange
NEER	nominal effective exchange rate
NER	nominal exchange rate
NERUSD	nominal exchange rate of the rand with the US dollar
NICs	newly industrialising countries
MUV	(World Bank) manufacturing unit value index
OFS	(Orange) Free State
OLS	ordinary least squares
PGMs	platinum group metals
PPP	purchasing power parity
REER	real effective exchange rate
RER	real exchange rate
RERUSD	real exchange rate of the rand with the US dollar
RGDP2	Summers-Heston PPP-converted real per capita income
RMG	Raw Materials Group (database)
rms(se)	root-mean-square (simulation error)
SARB	South African Reserve Bank
SOEs	state-owned enterprises
VAR	vector autoregression
ZCMM	Zambia Consolidated Copper Mines Ltd.

Units and conversion table

t	(metric) tonne	1000 kg (=1.102 sh.tn., and 0.984 l.tn.)
kt	kilotonne	1000 t
Mt	megatonne	1000 kt
oz.	troy ounce	31.1035 g

Other units of weight (not used in the analysis): short ton (sh.tn.), long ton (l.tn.), avoirdupois pound (lb., 0.454 kg), avoirdupois ounce (avdp.oz., 28.35 g).

1. Introduction

1.1 Background

The economy of South Africa continues to be heavily dependent on the export of gold and other minerals. In 1993 gold accounted for nearly 30% of total South African merchandise exports (Minerals Bureau 1994a: 5). Other exported minerals which provide substantial foreign exchange earnings include platinum and other platinum group metals, coal, uranium, diamonds, copper, iron ore, manganese, chrome, nickel, silver, asbestos, fluorspar, alumino-silicates, such as andalusite, and heavy minerals (titanium, vanadium, zirconium). Minerals other than gold have tended to contribute to foreign exchange earnings to the extent of a further nearly 20% of total commodity export receipts over the last few years. The direct contribution of the mining sector to the South African GDP in 1994 is estimated to have been about 9%, while the indirect multiplier effects raise this share to 18% (Chamber of Mines 1995: 58).

South Africa is estimated to hold more than 70% of world reserves of platinum group metals, manganese ore, and chrome ore, while for most of the other minerals listed above the country occupies a top position in terms of world reserves. The supply and export of these minerals hold world rank positions similar to those of the reserves. However, the respective shares tend to diverge significantly from the corresponding percentage figures of world ore reserves (Table 1.1). Allowing for constraints in data comparability, the large positive gap between estimated shares of supply and reserves, in the case of a few particularly relevant minerals, highlights the possibility of a sustained development of the mining sector in South Africa. This applies to a greater extent than it would in countries with a more limited mineral resource base. Gold and platinum are minerals for which South Africa's share in world supply has tended to lag behind the country's relative importance in estimated world reserves. Figures

1.1 and 1.2 illustrate these shares for gold. Reserves estimates for China are not known, but South Africa's share in world supply would still remain far below its share of world reserves if China's supply is not included (Table 1.1).

In spite of some downward pressures on the international gold market in the early 1990s, prospects for the gold industry worldwide are believed to be moderately favourable in the medium to long term. Similarly, world demand projections for most major minerals point to improved growth prospects, or at least to maintenance of the average attainments of the last two decades (World Bank 1992: 5), although uncertainty is associated with future sales of suppliers such as the CIS (ADB 1995: 211). In South Africa, known gold reserves are considered to be approximately equivalent to what has already been mined over more than a century (Chamber of Mines 1993, No. 4: 2). The extent to which this growth potential can be effectively exploited, will depend on the net effect of a number of factors, such as the international gold price, the exchange rate, the mineral working costs, the tax structure and institutional environment, and the development of new technologies.

Aside from the growth prospects for mining in South Africa, one should consider the implications of an enduring relevant role of gold and other minerals for the economy. To this purpose, attention should be paid to both the positive and the negative effects which have been attributed to the presence of a large mining sector. In the case of South Africa, gold exports have protected the economy against otherwise more unfavourable terms of trade over the 1970s and 1980s, and, according to some authors, have even smoothed cyclical fluctuations. Nevertheless, the high mineral export dependence is believed to have become, directly or indirectly, a constraint on the policy objectives of improving the international competitiveness and diversifying towards a greater share of high value added goods.

An indirect effect in this regard is related to the linkage with the exchange rate policy in South Africa. Gold and platinum producers are considered to have benefited from a significant degree of volatility in the exchange rate until the late 1980s, the argument being that this volatility tended to follow the course of the gold price, thus significantly insulating gold and platinum producers and exporters from world price fluctuations in dollar terms. The instability of the exchange rate, together with other factors such as trade sanctions and the skilled labour shortage, probably undermined the expansion and strengthening of industrial exports, despite the manufacturing export promotion pursued over the 1980s (Kahn 1992; Black 1992). Besides the *nominal* exchange rate volatility, sudden international price upturns in gold and other minerals may have weakened the development potential of other export sectors, by contributing to misalignments in the *real* exchange rate (South African Reserve Bank 1990).

1.2 Scope and objectives

In this study the term *mineral* is applied in its broadest and most common sense. Thus it includes not only natural metallic and non-metallic chemical elements, or compounds, characterised by a crystalline nature and formed as a product of inorganic processes, but also non-crystalline hydrocarbon chemical compounds of inorganic origin. The latter compounds, namely coal, petroleum, and natural gas, are technically defined as mineraloids (Vogely 1985: 181). Mining is defined as the sector concerned with the extraction and, in the case of certain minerals such as gold, the primary treatment of the ore (Lombard-Stadler 1980). Other key concepts, such as *mineral economy* or *real exchange rate* (henceforth RER), are defined as they first occur in the text.

The study of the linkages between trends and fluctuations in leading mineral commodity exports, on the one hand, and performance of the mineral-dependent economy, on the other, has attracted a substantial amount of research. However, further investigation seems to be necessary, in view of both unclear theoretical underpinnings and controversial empirical evidence. Among other topics within this area, the relationship between mineral commodity and exchange rate markets stands out as a relatively little developed area of research: the bulk of econometric studies tends to be focused either on issues of impact assessment of mineral prices and exports other than the exchange rate, or on possible explanations of the RER disconnected from, or only indirectly connected with, mineral commodities. In addition to these deficiencies, empirical research is most often limited to annual and aggregate macroeconomic data, thus failing to measure some aspects of the problem.

Price, demand and supply instability in mineral commodities is mainly a short- to medium-term problem, but some of its implications for economic growth can be similar to those of a structural decline in the terms of trade. Domestic investment and import capacity tend to be hampered by both a terms of trade deterioration, and high fluctuations in export earnings. Furthermore, the policy response of mineral-dependent economies to sudden commodity price and demand changes has often been inadequate. Among other effects, the lack of an adequate adjustment has, in the case of several countries, operated to fuel domestic inflation and failed to redress distortions in trade and exchange rate policies.

Besides these general considerations, on a number of issues no unanimous view is to be found among studies on mineral commodity production and trade. Does, for instance, a high dependence of a developing economy on minerals tend to hinder or to facilitate (despite the above remarks) the achievement of sustained rates of growth and other macroeconomic objectives? Supposing that the answer is formulated along the lines that it depends on a variety of possible circumstances and factors, which of these circumstances and factors actually account for different patterns, according to various minerals and mineral-dependent economies?

More systematically, the main questions addressed by this study can be synthesised as follows:

i. What is the role of a significant endowment in mineral resources in the long-term growth of a developing economy? What have been the implications of such an endowment, and mineral production and export specialisation, along with other possible determinants, for patterns of long-term convergence or divergence within mineral economies (as opposed to non-mineral economies) in the pace and level of economic development? Within this theoretical and empirical framework, which is the specific position of South Africa?

ii. What are the indications of other studies on the effects of a large mining sector on various macroeconomic and policy-related aspects in a developing economy, with particular reference to South Africa and the exchange rate policy? How can some of the underlying hypotheses of these studies, especially those concerning mineral supply and prices and the RER, be tested in econometric models?

iii. Is the increased foreign exchange inflow in periods of rising gold prices responsible for RER misalignments, and is there any link between these prices and the volatility in the nominal and real exchange rate in South Africa? Have these misalignments and this volatility seriously undermined the potential for expansion of non-mining export sectors in South Africa? In a wider context, how do the international gold price and the exchange rate interact with other variables, related to both the economy as a whole, and gold mining?

iv. At a more disaggregated level of analysis, what are the most relevant determinants of mineral supply responsiveness by gold and platinum mining companies? Do institutional characteristics of the mine matter more than macroeconomic, policy-related, or mineral market-related features? What is the supply behaviour of South African mines in gold and other minerals, particularly with respect to supply responses to international and domestic mineral commodity prices? Do prices of these minerals tend to vary, in terms of trends and medium-term fluctuations, in phase, with amplifying effects on the economy, or to offset each other?

1.3 Structure of the study

The logical sequence followed by the study traces the objectives outlined above. A brief description of each chapter is provided here.

Endogenous growth theories have paid little attention to patterns of growth within sub-groups of developing countries. Partly drawing on these theories, a mixed endogenous growth-technology diffusion model is formulated in **chapter 2**, with regard to developing mineral economies. This model envisages an S-shaped pattern of double convergence long-term equilibrium. In view of a likely greater government misallocation and production inefficiency, and fewer incentives to human capital formation at low levels of development for mineral economies, the flex point is predicted to lie above the corresponding point for non-mineral economies. The performance of a mineral economy is assumed to depend on growth and instability of its main mineral commodity export price, human capital formation and government policy responses. The model is tested on cross-country data. Within this framework, the econometric analysis tries to identify the relative position of sub-Saharan African mineral economies and South Africa.

A literature survey is provided in **chapter 3**, which throws a *bridge* between the general long-term framework of chapter 2 and the specific analyses presented in chapters 4, 5 and 6. These analyses are aimed at deepening and testing a number of arguments introduced in chapter 3. The survey initially reviews controversial interpretations of the role of mining in a developing economy. The analysis is extended to include aspects other than aggregate growth, such as individual components of aggregate demand, business cycles, sectors of the economy other than mining, regional and economic imbalances, inflation, and the exchange rate. The survey thereafter turns to examine a specific area which embraces some of these aspects and is of particular concern to this study, that is (i) possible determinants and implications of changes in mineral commodity prices and quantities, and in real and nominal exchange rates, and (ii) econometric models dealing with these topics.

Some studies regard mineral export prices as a relevant macroeconomic *fundamental*, which, among other factors, can explain the performance of nominal and real exchange rates in a mineral-dependent economy. Other studies point to the need to study the time series properties of these variables individually, independently from the structural features of the economy concerned. **Chapter 4** investigates the impact of the gold price on the South African real and nominal exchange rates in the 1980s and early 1990s, including a possible structural change in the late 1980s. Results are obtained from alternative procedures for co-integration analysis applied on monthly data. These results are compared with those of (i) stochastic time series models for these variables, and (ii) time-varying parameter models applied to the behavioural relationships. The analysis is finally broadened to include possible implications for aspects such as inflation and manufacturing exports.

The relationship between the international gold price and the RER in South Africa is further addressed in **chapter 5**, which explicitly returns to the issue of economic growth. In this chapter, the use of annual, instead of monthly, data over a longer period (1970-1994) allows the reassessment of the same hypothesis in a different perspective and through an alternative approach, also made possible by the availability of a wider set of statistical information. A recursive equation model is constructed, so as to link a sector-specific framework, related to features of South African gold mining, to the wider context of the domestic economy. Besides testing other hypotheses, results of the regressions are used (i) to examine whether RER misalignments and volatility have been associated with lower growth attainments, and (ii), conditional on forecasts and projections of the exogenous variables, to simulate the model over the medium term (1995-1999).

In order to gain some insights into the supply response of mines to changing market conditions, **chapter 6** shifts the focus of the analysis into mining company statistics. This level of disaggregation allows the examination of determinants of mineral supply, which could hardly be assessed with macroeconomic data only. Besides mineral commodity prices in international and domestic currency, different supply determinants have been identified in: the ownership and control pattern; institutional and policy-related elements such as the tax treatment; geological characteristics; the scale of mining operations; and other features of the macro and microeconomic environment. These factors are believed to influence the objectives of the mines, such as giving priority to foreign exchange earnings rather than profit maximisation, and their ability to achieve these objectives. Subsequent to a review of the hypotheses, which supplements the survey of chapter 3, statistical and econometric tests are applied on (i) partly pooled cross-country mine-related data (1984-1992), limited to major gold and platinum producers, excluding industrial countries, and (ii) partly pooled cross-mine and cross-mineral data (1984-1993), for gold and other major export minerals in South Africa.

Conclusions in **chapter 7** focus on the main results of the study, pointing both to its possible contribution to research undertaken on the subject, and to limitations of and controversial aspects surrounding these results and some of the econometric techniques applied by the study. The chapter concludes by examining the implications of some of the results for growth prospects of the South African economy, and by considering recent policy issues.

The statistical information has been obtained from international and national sources. The former are mainly publications of the World Bank and the IMF, and of a specialised information service institution for minerals (Roskill, London). More detailed statistics for South Africa have been available thanks to publications of various national institutions (Central Statistical Service, South African Reserve Bank, Chamber of Mines, Minerals Bureau). These and further supplementary statistics have partly been collected from computerised databases (IWTAB, attached to Summers-Heston 1988; World Bank-Social Indicators of Development; Economic Analysis Systems, i.e. EASy, Pretoria; Raw Materials Group, henceforth RMG, Stockholm). Throughout the study, specific comments are made on the reliability, coverage and methodological problems associated with some of these data. Except for few insertions within the text, tables and figures are presented at the end of each chapter.

Table 1.1 - South Africa's world shares and ranks in mineral reserves, production and exports (1992-1993)

mineral commodity	reserves % [rank]	production % [rank] (1994 update)	exports % [rank]
platinum group metals	88 [1]	54 [1] (79)	39 [1]* #
manganese ore	83 [1]	12 [3] (13)	25 [2]*
chrome ore	72 [1]	33 [1] (34)	37 [1]
vanadium	45 [1]	46 [1] (47)	79 [1]
gold	39-43 [1]** 50^ **	27 [1] (26) 29**	NA [1]
alumino-silicates	37 [1]	35 [1]	51 [1]*
zirconium^^	26 [2]	33@ [2] (23)	26 [2]*
uranium	8 [5]***	5 [8] (5) 6***	NA
fluorspar	12 [3]	7 [5]	13 [2]*
diamonds	NA [4]^^^	10 [5] (11) [3]	NA
titanium	10 [4]	21 [2] (20)	10 [3]*
nickel	10 [5]	4 [6] (4) [7]	4 [7]*
coal	10 [5]	5 [6]	14 [3]
iron ore	6 [7]	3 [8] (3)	5 [6]
silver	2 [7]	2 [13] (1.5)	0.4 [12]*
copper	2 [12]	2 [13] (2) [12]	2 [13]
asbestos	NA	4 [7] (4)	11 [3]*

. percentage shares refer to either of the two reference years, unless otherwise indicated
. in square brackets: ranking
. in parentheses, for production data (if available): 1994 update from RMG database (followed by indication of ranking if changed) (for PGMs the 1994 figure refers to platinum only, and it is therefore not comparable with Minerals Bureau information)
. NA: not available, i.e. classified, unknown or unreported information, for South Africa and/or other major producers

* 1991 figure (# minor exporters excluded) (Minerals Bureau 1994a)
** reserves of the People's Republic of China are unknown (** for production: excluding China)
*** CIS reserves are unknown (*** for production: excluding the CIS)
^ including by-product gold (Roskill 1995: 3)
^^ unofficial estimates (official statistics are confidential) (Minerals Bureau 1994a: 79-80) (@ US production NA)
^^^ Chamber of Mines 1995b: 2

Sources: Minerals Bureau 1994a; Chamber of Mines 1995b; Roskill 1995; RMG database

Figure 1.1

GOLD MINING

Producing countries in 1994

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Figure 1.2

GOLD

World reserves in 1990

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(countries with six most important reserves; China NA)

2. Mineral resources and growth: towards a long-term convergence?

2.1 Introduction

In spite of not being explicitly accounted for in most theoretical formulations, the conventional view on the role of mineral resources tends to see these resources as a critical factor of growth, especially at initial low-income levels of development. Improvements in other factors, particularly human capital and technological know-how, can partly replace the need for these resources in a later stage. The postwar experience of developing countries seems to contradict this view: in spite of the increased availability of foreign exchange revenues and potential for easier resource-based industrialisation, mineral economies appear to have often underperformed as compared to non-mineral economies at similar levels of development, in terms of economic and social indicators (Auty 1993: chs. 1-2). Obviously, this does not imply that the presence of a large mining sector as such can be harmful to growth, but that the potential assets deriving from this presence have often inadequately been used by developing countries.

The determinants of these misachievements are attributed to deficiencies in the domestic allocation of resources in mineral economies, with (i) an excessive capital-labour ratio, (ii) a large presence of foreign capital and a significant proportion of export earnings flowing out of the country to service debt obligations, and (iii) relatively weaker inter-sectoral production links. Even when governments have tried to keep large shares of the mineral rents[1] for internal purposes, these windfalls have frequently been misused and insufficient attention has been paid to the need to increase the international competitiveness of other sectors of the economy. Sudden mineral price upturns have led in many cases to RER appreciations and temporary overexpansion of the mineral sector, undermining the competitiveness of non-mineral sectors. Subsequent unexpected commodity price or demand downswings have seen governments of several mineral-rich countries unprepared, the only short to medium term response being inflationary or foreign-financed public deficits and protectionist trade policies. An excessively rapid absorption of mineral rents during boom periods, and delayed or failed adjustment in slumps, is considered a reason for a supposed greater difficulty of mineral economies in dealing with commodity price volatility than non-mineral economies (Wheeler 1984). Also in this case, however, some empirical evidence is brought against the hypothesis of negative effects of commodity price instability on policy goal attainment in developing countries (Behrman 1987).

Among authors supporting this hypothesis for mineral commodities, no consensus seems to exist as to which countries have been relatively more damaged by inadequate domestic policy responses to export commodity fluctuations. According to Auty (1993: 27, 50), in middle-income mineral economies the bias against agriculture and industry of an excessively mineral-dependent growth is likely to be more acute, although the presence of a larger domestic market may have favoured a diversification of production and can contribute to reduce the dependence of the economy on mining. An opposite view sees low-income mineral economies as more vulnerable to external forces, and more likely to use the mineral rent for unproductive purposes and for the postponement of needed structural changes, such as agricultural reform or strengthening the competitiveness of the manufacturing industry (Bomsel 1992; UNCTAD 1994).

In view of these controversial views and empirical findings, and the scarcity of theoretical formulations, there seems to be a need for further research. More precisely, the following interrelated aspects should be examined: (i) the role of endogenous technological progress and education, as a complementary or, vice versa, a substitute factor vis-à-vis mineral resources; (ii) the pattern of growth and instability of mineral commodities and policy responses of local governments; and

(iii) the links between the mining sector and other sectors of the economy. In general terms, these aspects can be assumed to constitute a major problem for small, poor and scarcely diversified mineral economies, such as Niger, Guinea or Mauritania, as opposed to Chile or South Africa. Beyond these differences, a higher dependence of the economy on mineral export receipts will obviously also entail a relatively greater importance of these aspects. For instance, copper accounts for nearly 90% of Zambian exports, while it amounts to one third of Zaire's exports; furthermore, the share of exports in GNP has tended to lie between 30 and 40% for Zambia, whereas it is close to 25% for Zaire (World Bank 1993, 1993a, 1994).

While leaving the treatment of specific topics related to this subject to later chapters, the following analysis focuses on selected problems of the above outlined aspects. In section 2 new theories of growth are considered, by paying attention to most relevant factors of growth and conclusions in terms of long-term performance in cross-country growth patterns. Based on some of the theoretical contributions of these models, a simple (partly endogenous) growth model for a mineral economy is then developed in section 3. Section 4 deals with testing the implications of this model with an econometric analysis, distinguishing between mineral and non-mineral economies. This analysis tries to overcome a few of the drawbacks encountered in similar statistical applications and criticisms which can be raised towards these applications. In section 5 conclusions are drawn with regard to the theoretical framework and empirical results.

2.2 New theories of growth and related empirical results

Models of growth such as those formulated by Solow (1956) and Meade (1960), or Kaldor (1957), envisage that, in the absence of technological change and following decreasing returns to capital, output per capita would converge to a steady state value, with no per capita economic growth. Provided that a unique rate of exogenous technical change exists and countries are characterised by the same rates of domestic savings and population growth and similar production functions, under steady state growth conditions there would be no difference in income growth between countries, independently from their initial level of development. This equalization of economic growth *rates* would be achieved through a process whereby the country with a relatively lower and less efficient capital endowment, i.e. lower capital-labour and capital-output ratio, is able to progressively bridge its development gap thanks to medium-term faster growth rates due to higher marginal productivity of capital. However, Chatterji (1992: 61-62) points out that the resulting convergence is of a weak kind, in the sense that it does not assure a long term equalization of per capita income *levels*[2]. An overview of these and alternative (endogenous) growth models, examined hereafter, is provided by Table 2.1.

Empirical applications geared to test the neoclassical growth model are presented in Mankiw *et al.* (1992) and Barro and Sala-i-Martin (1992). Despite their stated aim, these contributions are usually referred to as belonging to the endogenous growth literature since they allow for country-specific elements, such as human capital or technology (van der Ploeg-Tang 1992; Romer 1994)[3]. Mankiw *et al.* (1992) extend the neoclassical hypothesis of decreasing returns to physical capital also to human capital: the rate of return to schooling is higher in poor countries, since this rate is measured as "the percentage increase in wage resulting from an additional year of schooling" (*ibidem*: 432). These authors moreover maintain the hypothesis of exogeneity of the rates of savings and population growth. Technology is also assumed to grow exogenously, but country-specific factors, e.g. institutions, climate, resource endowments, affect its initial level (Mankiw *et al.* 1992: 409-411). Results on productivity data over the period 1960-1985 show *unconditional* convergence only for OECD countries, while for a more heterogeneous set of countries convergence is conditional to accounting for differences in population growth, investment rate, and education levels.

According to the authors, this would support an *augmented* Solow model, as opposed to more narrowly defined endogenous growth models with non-decreasing returns to scale, since the latter models would generally predict a lack of a steady state level of income and no convergence (*ibidem*: 423-424).

In Barro and Sala-i-Martin (1992) the hypothesis that relatively poorer regions or countries tend to experience faster rates of growth than richer ones is tested for the United States over a period of nearly one and a half century and for a sample of 98 countries over 25 years. In the presence of heterogeneous conditions in technology and preferences in the latter country sample, a negative relationship (i.e. weak convergence) appears between initial levels of development and average growth rates over the whole period only if some additional variables are held constant. These variables include initial primary and secondary school enrolment and the ratio of government consumption to GDP, which are considered by these authors as proxies for the steady state value of output per worker and the rate of technological progress (Barro and Sala-i-Martin 1992: 246). Although not distinguishing them empirically, the authors conclude that cross-country convergence can be due to both strictly neoclassical *closed economy* factors (diminishing returns to capital and imbalances among types of capital), and further possible determinants in an open economy context (partial international mobility of capital and labour, and technology diffusion).

The assumption of exogeneity of technical progress does not allow a more realistic interpretation of processes of catch-up or even reversal of gaps in development levels between countries. Arrow (1962) and Uzawa (1965), as early contributions towards a relaxation of this assumption, stressed the importance of improved technological knowledge and education for increased labour efficiency. Under the influence of these contributions, Lucas (1988) constructs a model embodying human capital accumulation and distinguishing between different production specialisations, which tend to vary according to the specific human capital endowment of a country, among other factors. Calling h(t) the skill level of the labour force, which can grow at a maximal rate δ, and u(t) the working time allocation, Lucas adopts Uzawa's formulation relating linearly the growth of human capital in a society to the level already attained and the efforts devoted to acquire more skills:

$$\Delta h(t) = h(t)\delta[1 - u(t)]$$

Regarding the human capital accumulation process of a finite-lived individual, the learning potential on any particular goods is considered to decline with the amount produced. Hence, the growth potential of learning-by-doing for an individual country can be maintained or enhanced particularly if the country is able to continuously modify its production and export specialisation towards new products. This is especially true if these products face a high demand in importing countries, such as the often quoted case of South East and East Asian countries (Lucas 1988: 41). In this regard, an interesting point of Lucas's analysis is the consideration that, in an open economy, rapid technological change does not guarantee as such a relatively higher real growth rate, unless the assumption of high substitutability between goods is made. *Ceteris paribus*, if two goods are poor substitutes, the production of a *high-learning* good will have positive effects on productivity, but negative terms of trade effects, as a consequence of a faster rate of supply. If the terms of trade effects were to outpace the direct productivity effects, 'immiserizing growth' would paradoxically follow (Lucas 1988: 32-33).

Similar to Lucas's concept of human capital, other theories of endogenous growth use the stock of knowledge as an input in production. Paul M. Romer (1986) rejects the neoclassical assumption of upper bounds to the growth of per capita output following diminishing returns to capital and absence of technological change. According to Romer, even with other inputs held constant, per capita income growth can continue unaltered or even accelerate, due to increasing marginal productivity of factors of production resulting from changes in the stock of knowledge. Empirical evidence is provided of long-run upward trends in productivity growth and real per capita income growth of the few countries with available information running backwards over more than two centuries (Romer 1986: 1008-1009). Furthermore, Romer argues against a neoclassical assumption of a unique long run convergence equilibrium, by relying on statistical evidence for the period 1950-1980 showing how "growth rates appear to be increasing ...as a function of the level of development' (Romer 1986: 1012). This result would envisage the possibility of multiple convergence equilibria, or no convergence at all. In this way, Romer also refuses to adopt the rigid interpretation of the models of *technology diffusion* stating that the country with the highest level of productivity is bound to gradually lose its competitive edge in the long term growth process vis-à-vis its technological followers. Based on similar hypotheses, Krugman (1991) formulates a dual equilibrium model with two steady state levels determined by both historical conditions and expectations.

In contrast with Romer and Krugman's assumption of increasing returns to scale, another strand of endogenous growth models does not remove the neoclassical assumption of constant returns to scale, but it allows for constant returns to a broad definition of capital, i.e. including physical and human capital, and zero returns to other (labour and non-reproducible) inputs (Barro 1990: Rebelo 1991). According to the latter models, emphasis should not be laid on the presence of imperfect markets or positive externalities, as done by the majority of endogenous growth models, but rather on different government policies, leading to permanent differences in cross-country growth rates. While leaving for future research the study of the influence of market distortions and political instability, Barro (1990: 122-124) analyses the role of productive government expenditures as a factor stimulating economic growth. Productive government expenditures are defined to include resources for property rights enforcement and activities directly entering the production function, such as transport, electric power, or water supply. In this respect, a high proportion of public investment in total investment, supposed to be a proxy for the relative importance of productive government expenditures, is found to be associated with higher growth rates. In close resemblance with Barro's hypothesis of a growth-hampering role of excessive government consumption, Rebelo (1990) shows how a high rate of income tax, along with low protection of property rights, can reduce the rate of return on investment in the private sector, thus decreasing the rate of capital accumulation. Solow (1956: 89-90) had already reformulated his model to take into account the effects of income tax on growth, by distinguishing between the growth-inducing effects due to the use of tax proceeds to enhance investment, and opposite effects if these proceeds are used for consumption.

The neoclassical assumption of exogeneity of technical progress has also been revised and replaced by hypotheses which are only partly coinciding with those of the endogenous growth framework. Some theoretical and applied contributions explain the apparent strong convergence in productivity levels for a group of countries and certain periods in terms of technological catch-up. An early contribution in this regard is represented by Gerschenkron (1962). According to Abramovitz (1986), given one country as a *leader* in technological advance and other countries as followers, the potential for productivity increases is higher for the followers than for the leader. During a phase of replacement of technology, while the productivity increase for a leader is limited by the advance of knowledge occurring between the installation and the replacement of the "old" capital, for the followers there is greater scope for productivity improvements due to the larger technological gap. However, the catch-up process will be self-limiting, since the possibility of large *leaps* decreases over time during the process of gradual convergence to the leader. Furthermore, to provide an explanation for changes in leadership and, more broadly, for the capacity of a country to catch up, Abramovitz (1986: 389) uses the concept of *social capability* as a vehicle for endogenous growth and successful exploitation of the cross-country diffusion of technology. Social capability includes such aspects as openness of the economy to international competition, organisation of firms, or content of education.

The *technology catch-up* (or technology diffusion) hypothesis is tested by Abramovitz using estimates of product per worker for sixteen countries over almost a century (1870-1979). As a support to the hypothesis, a negative rank correlation appears between initial levels and subsequent growth rates. The author admits there may be sample selection bias, since all selected countries are characterised by favourable educational and institutional features. However, he also believes that the potential for increased growth is shifting towards LDCs in Asia and Latin America. Besides an advanced level of social capability, the presence of abundant natural resources, including minerals, and a large size of the economy would explain the prolonged leadership of the United States (Abramovitz 1986: 397).

Another empirical test on this hypothesis is carried out by Baumol (1986), who uses a larger country sample with shorter time series, limited to the period 1950-1980. His findings highlight the possibility of more than one *convergence club*, and suggest that the poorest LDCs may not have benefited from technology diffusion, thus providing a case of diverging pattern. The latter result complies with subsequent theoretical refinements of the technology diffusion hypothesis. While maintaining Gerschenkron's and Abramovitz's framework of technology diffusion for a number of countries, Gomulka (1990: 150-159) assumes a *hat-shape* relationship between productivity growth rates and productivity growth gaps (from the leader) across countries: in the absence of a sufficiently developed absorptive capacity, defined by physical infrastructure and educational standards, LDCs with severe technological backwardness are unable to catch up. This backwardness then becomes a disadvantage. Similar to Baumol's analysis and relying on the period 1950-1985, Dowrick and Nguyen (1989) extends the analysis of cross-country convergence to include some middle-income countries, besides a group of industrial countries. In view of the heterogeneity of the sample, population growth and investment ratios are introduced as *ceteris paribus* variables. Results point to no convergence in income levels, but existence of catch-up in total factor productivity for all countries except those with particularly low investment rates and high population growth[4].

Instead of or along with the hypothesis of an *international* catch-up, some authors have tried to explain the process of technology diffusion in terms of *internal* catch-up and inter-sectoral shifts in resources. While Feder (1986) has stressed the role of a dynamic manufacturing export sector, Dowrick and Gemmel (1991) have examined the role of inter-sectoral labour allocation for GDP growth. These authors assume that productivity advances in industry may feed through to the agricultural sector, so that technological catch-up in agriculture tends to be to a large extent indirect. Over the 1960-1985 period, these authors find convergence in productivity levels to be limited to high and middle-income countries, both within and between groups, in the industrial sector and, after 1973, in agriculture as well. By contrast, low-income countries show some catch-up in agriculture in the 1970s and early 1980s, but are subject to within and between-group diverging tendencies in industry. These sectoral patterns would help explain the heterogeneous performance of per capita income growth among middle-income countries, with some of them lacking sufficient technological spill-over from industry into other sectors, and the performance of the relatively poorer LDCs.

The assumption of a structural poverty threshold implicit in some technology diffusion models is reconsidered in a study by Chatterji (1992), which combines aspects of these models with some elements of endogenous growth theory. While retaining Gomulka's hypothesis of a unique leader, Chatterji constructs a model embodying a double equilibrium level, for two sets of countries. The presence of a unique leader would allow weak convergence in the long run for all countries, but lack of sufficient absorption capacity prevents a group of countries from achieving strong convergence to the leader (*ibidem*: 64; note 2). The result would be the coexistence of a stronger and a weaker club, each characterised by countries reaching similar growth rates in the long run, but possibly diverging between them in average per capita income levels. By applying the model to 1960-1985 cross-country data, Chatterji (1992: 65-66) finds evidence in support of this interpretation, identifying the threshold in an initial (1960) real per capita income level equivalent to one sixth that of the United States.

Although the bulk of new models of growth has concentrated on the role of human capital, technical progress and government intervention in specific areas, some recent contributions have dealt with other related issues, such as demographic patterns, income distribution or trade specialisation (Pio 1993). Becker *et al.* (1990) formulate an endogenous growth model embodying Malthusian and neoclassical features. While the neoclassical hypothesis of a declining rate of return on investment in physical capital is maintained, for investment in human capital the authors assume an increasing rate of return (differently from Mankiw *et al.* 1992), at least until the stock of human capital becomes large. The reason for this would lie in the especially high intensity of skilled inputs in education and other sectors producing human capital, as opposed to sectors producing physical capital or consumption goods[5]. Furthermore, by raising the discount on per capita future consumption in the intertemporal utility function of households, higher fertility discourages investment in human and physical capital; vice versa, greater human and physical capital per worker discourages fertility by increasing the cost of time devoted to child care.

As a consequence of these assumptions a dual equilibrium framework is constructed, with an undeveloped or *Malthusian* steady state, characterised by high birth rates, little human capital and low rate of return on human capital, co-existing with a developed steady state, with low birth rates, large human capital and high rate of return on human capital. The position of a country and the possibility for it to converge to either of the two equilibria, or to switch from one equilibrium to the other, would depend on its initial relative level of human capital and technology, as well as on subsequent changes and shocks, such as productivity improvements. Between the two convergence equilibria there is a point of instability, graphically represented by the flex point in an S-shaped function of human capital per worker. While before this point a Malthusian positive interaction between fertility and income prevails, immediately beyond this point a *take-off* period would follow, with a quick drop in fertility and rapid growth in human and physical capital.

Based on a model of politico-economic equilibrium growth, Persson and Tabellini (1991) formulate an endogenous growth model attributing to income inequality harmful implications for growth, within a democratic country framework. Higher inequality would reduce the scope for growth promoting activities, such as capital and knowledge accumulation. Even once certain factors are controlled, i.e., besides income distribution, education, skills and other structural variables (urbanisation and industrialisation levels), the model does not predict any convergence. In practice, however, evidence of some convergence is found for a sample of 56 countries over the period 1960-1985.

With reference to open economy models, Rivera-Batiz and Romer (1991) develop a two-industrial country model leading to higher rates of growth as a consequence of better exploitation of increasing returns to scale in the R&D sector, and Grossman and Helpman (1990) highlight alternative implications of trade specialisation on growth, depending on each country's relative efficiency in R&D-intensive activities. A country's long-run growth prospects are not always enhanced by opening up to foreign trade, even if welfare gains from trade are maintained (Grossman-Helpman 1991; Grossman-Helpman 1994: 41): natural resource-rich countries with relatively smaller efforts devoted to R&D activities may be induced to specialize further in resource-based production activities, thus giving up their potential for innovative and technology-intensive production. In this respect, economic integration may divert R&D-linked resources away from R&D-poor countries, and induce them to specialize in technologically backward productions. This rationale supports an infant industry argument for R&D activities.

2.3 A mineral economy model in an endogenous growth framework

2.3.1 Mineral resources and long-term growth

On the whole, the assumptions underlying the endogenous growth models can be considered to be realistic for LDCs, with a few cautious remarks (Pio 1993: 4-5). Constant or increasing returns to accumulable inputs, i.e. human and physical capital, can easily be hypothesized in an economy with relative scarcity of these resources. These resources can also be associated with externalities, except for very poor LDCs lacking sufficiently developed infrastructural networks. Other assumptions which can be seen as acceptable for a small open developing economy are the presence of imperfect markets and, in some cases, increasing returns to scale, once a process of export expansion has started. An assumption subject to criticisms is the supposed constant proportion of labour force in total population, with the latter variable exogenously determined and used as a proxy for the former. In this regard endogenous growth theories do not differ from the basic neoclassical framework, with the exception of Becker, Murphy and Tamura's attempt to endogenise population growth, although an early treatment of this issue is already present in Solow (1956: 90-91).

Natural resources and labour, thought as non-reproducible factors, are mainly attributed zero returns in endogenous growth models. Moreover, given their supposed static nature, natural resources are usually even disregarded, similar to the early model by Meade (Meade 1960; Rebelo 1991). According to Davis (1993: 44-

45), the conversion of mineral resources into revenues artificially inflates the actual growth path of a country, since this is derived from a gradual depletion of a non-reproducible asset and is dependent on the speed of mineral extraction and sales. Recent literature contributions have raised the need to adjust national income statistics, so as to take into account the impact of the process of depletion of non-renewable resources, in terms of lost *natural capital stock* on future consumption opportunities (Winter-Nelson 1995: 1508). Besides having controversial policy implications, considered in chapter 3 (sub-section 2.2), and methodological difficulties (*ibidem*: 1509), the *depletion* argument does not support the exclusion of mineral resources from possible factors of growth, since the long-term performance of a mineral economy will to a large extent rely on the potential to use these resources to build up and broaden more stable sources of growth.

Some authors do mention the possible relevance of different natural resource endowments, among other factors, to account for different steady state values and lack of long-run cross-country convergence (Barro and Sala-i-Martin 1992: 243). In Maddison's study on the determinants of growth in various historical epochs, natural resources can be *augmented*, or its progressive exhaustion be slowed down, by technical progress and education, similar to the concept of increasing returns to capital and labour with embodied stock of knowledge. This process would occur through new discoveries, eventually stimulated by commodity price rises, and substitution effects (Maddison 1982: 5, 47-48).

Among recent empirical studies on determinants of growth, cross-country analyses by Lal (1993) attribute differences in economic growth achievements to partly endowment-related policies, besides factors such as level and efficiency of investment, and outward-orientation. Land-abundant, as opposed to labour-abundant, LDCs appear more liable to suffer growth collapses, mainly in coincidence with excessively expansionary fiscal policies and balance of payments crises (*ibidem*: 355), and are found to register lower growth rates on average over the period 1950-1985. In this respect, Lal's analysis is however limited to a distinction between three factors, namely physical capital, labour and arable land, thus failing to consider e.g. the mineral resource endowment.

Based on cross-country Baumol-type regressions on conditional long-term growth convergence (see sub-section 4.1 on methodological issues), Sachs and Warner (1995) reach similar conclusions as Lal. Alternative proxies for relative abundance in natural resource endowment in the initial year (1970), including the share of mineral production in GDP, are found to be negatively related to PPP-adjusted average per capita income growth in the period 1970-1989. The authors attribute these adverse growth impact mainly to *direct* dynamic Dutch disease elements[6]. Except for a relatively more inward-oriented trade policy, no strong *indirect* effects on growth appear to be exercised by the abundance of natural resources through other growth determinants, such as standards of bureaucratic efficiency and the investment rate.

With reference to African countries, a pooled econometric analysis by the ADB (1995: 254-255) finds no strong evidence of an either negative or positive influence of the degree of export concentration in primary commodities prior to 1965 on per capita income growth achievements over the period 1965-1989. While no distinction is drawn in terms of average performance of the principal export commodities over that period, human capital and structural characteristics other than primary commodity dependence are found to matter relatively more. Similarly relying on pooled data on African LDCs, Winter-Nelson (1995) shows how results of this kind of econometric studies can be substantially altered by environmentally-adjusted production statistics for mineral economies. Disincentives to productive investment, as proxied by real exchange rate misalignments, are however found to negatively affect economic growth per capita, irrespective of the income measure used (*ibidem*: 1514). In this analysis, per capita income adjustments concern the real purchasing power, and results should be assessed by bearing in mind these different methodological approaches.

2.3.2 A theoretical framework

Drawing on some contributions of the endogenous growth literature, a non-formalised model can be constructed aimed at interpreting the different growth performance and growth potential of mineral economies, as opposed to non-mineral economies. Unlike the neoclassical approach, inputs of production are not assumed to be exogenous: they can rather be thought to depend on structural features of the economy. Among these features, particular attention is paid to the role of the mining sector. Moreover, technical progress can be considered as partly exogenous and partly endogenous, if one adopts the concept of social capability of the technology diffusion theories. While the partial exogeneity can be represented by a factor efficiency parameter linked to time (t), endogenous technical progress relies upon the development of local human resources through education and infrastructural development. Along with and as an outcome of technical progress, human capital (H) can be added to physical capital (K), labour (L), and (currently exploited) mineral resources (MIN) in a production function for the mineral economy:

$$Y = f(K,H,L,MIN,t).$$

This function can be reformulated by distinguishing between mineral resource endowment and mining policies:

$$Y = f(K,H,L,R,t),$$

where R represents the rate of extraction or utilisation of the mineral resources and can therefore be considered as largely policy-determined. Given any particular growth target for the future (t+k), R is set to maximise growth in the long term, subject to each country's specific conditions in terms of other (short- or long-term) policy objectives, such as balance of payments equilibrium, and obviously taking into account the constraints imposed by the available stock of mineral resources. If the latter variable at an initial time 0 is indicated by S_0, this condition can be analytically represented (Dasgupta-Heal 1979: 154):

$$S_{t+k} = S_0 - \int_0^{t+k} R_\theta d\theta \geq 0$$

Moreover, mineral resources can be distinguished according to their *essentiality* to long-term growth: these resources can be considered unessential if there is a feasible long-term production programme whose success does not depend on their foreseen exhaustion. This is more likely to happen when (i) mineral resources can be easily replaced by reproducible capital as a growth factor, i.e. in the presence of a high elasticity of substitution between K and R, and (ii) the rate of savings and capital accumulation is sufficiently high, so as to maintain or increase the level of output in spite of declining availability of mineral resources.

For a developing economy with a high reliance on mineral production and exports the issue of essentiality of these resources is hardly to be questioned. A more relevant problem arises in terms of (i) the structural links between mineral resources and other factors of production, and (ii) the pattern of growth and instability of mineral commodities and the connected policy response by the local government. In chapter 3 these topics are considered more extensively, by comparing controversial views on the role of mining in developing countries, with reference to different theories and hypotheses, features of the economy, historical periods and types of minerals. Here attention is limited to a broad and schematic framework, which can constitute a basis for an empirical analysis of long-term growth.

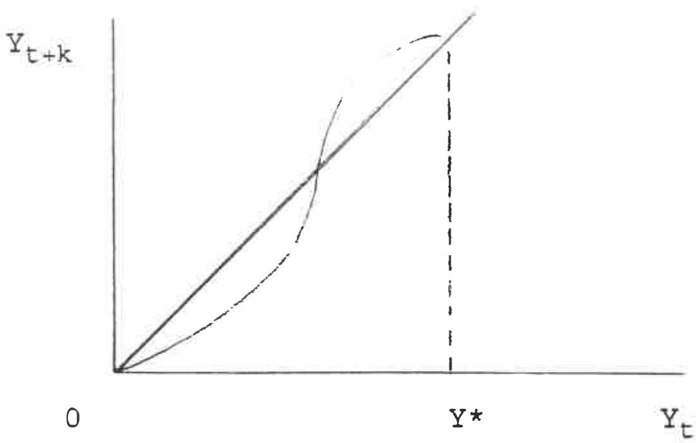
In terms of the linkages with and spill-over effects on human and physical capital and labour, alternative conditions can be assumed. As a first approximation, terms of trade shocks and different growth patterns in mineral markets can be disregarded. For low levels of infrastructural development and low inter-sectoral links, the social rate of return on investment in minerals (defined as in the standard *social* CBA) is likely to be lower than the discount rate on future consumption (defined as a social time-preference rate, i.e. the rate at which society trades off present and future consumption) (Pearce-Nash 1981; Brent 1990). The economy will present a more marked dual structure, with a largely foreign-controlled mineral sector along with an underdeveloped agricultural or small manufacturing sector. Therefore, for very low levels of human capital and technological development, generally coupled with high fertility rates, the mineral economy will not be able to draw substantial benefit from its resource wealth, because of (i) the smaller bargaining power of the local government vis-à-vis foreign investors, (ii) the larger immediate consumption needs, and (iii) the lower indirect employment effects in other sectors. The above inequality can be expressed as:

$$[a(n,h)]^{-1} > R_{min} ,$$

where R_{min} is the social rate of return on mineral investment and the discount rate on future consumption is implied by the left-hand term. This rate is inversely related to a factor [a(n,h)], which depends negatively on fertility (n) and positively on human capital formation (h). As compared to other developing economies, human capital formation in mineral economies could paradoxically be retarded by the presence of mining rents, despite the potential growth edge which these economies may have, *ceteris paribus*, on naturally less endowed countries. Especially at a low level of production diversification, these rents may also provide less stimulus for an upgrading and restructuring of the local production structure. More broadly examined, developing mineral economies may suffer to a relatively greater extent than other LDCs because of a lower degree of international integration, due to a less diversified (resource-based) and more prolonged inward-oriented industrialisation. These constraints may affect the capacity of a country to endogenise technological progress (Holden 1993).

As long as the amount invested in minerals does not provide a scope for the local economy to draw sufficient economic rents for the development of human capital, technology and inter-sectoral links, there will be a tendency for the economy to remain below a steady-state growth line $Y_t=Y_{t+k}$ (Figure 2.1: 45^o line), with Y measuring the level of economic development, e.g. income per capita. Similar to Becker *et al.* (1990) and Chatterji (1992), there will be two stable steady states, one at $Y_t=0$ and another at $Y_t=Y^*$. The latter condition arises since, beyond a certain level, or *threshold*, of mineral exploitation and human capital development, the rate of return on investment in both factors increases at declining rates and eventually approaches a saturation level, due to absorption capacity constraints[7]. The inflexion point will determine this threshold, so as to distinguish between low-income low-growth mineral economies converging to a lower equilibrium level, and another group of relatively successful and more diversified mineral economies, converging to an upper equilibrium level.

Figure 2.1 - A dual convergence equilibrium framework for mineral economies



In order to assess the potential of a country to switch from one equilibrium condition to the other, it is necessary to introduce the possibility of positive or negative shocks. Limiting the analysis to mineral commodity-related shocks, these shocks can include long-term (near permanent) and medium-term changes in demand and price trends, temporary changes around these trends, and different policy responses. Long-term changes can be determined by such factors as substitution effects between minerals, a change in international market structure, or a technological shock (Radetzki 1989).

Distinguishing between two sectors producing tradables (a mineral commodity and a non-mineral commodity, e.g. manufacturing) and one producing non-tradables, the *Dutch disease* model (Corden-Neary 1982; Corden 1984) highlights the possible de-industrialisation, or, generally formulated, contraction of the non-mineral tradable sector, indirectly determined by a temporary mineral commodity boom. This outcome would derive from both a resource movement effect, out of other sectors into mining, and a spending effect. The latter effect would bring about a RER appreciation, due to the lack of responsiveness of supply of non-tradables to increased demand, and a worsening in the foreign trade balance. Furthermore, in the presence of real wage resistance or even attempts by wage-earners in the *lagging* export sector to keep unchanged their relative position as compared to the booming (mineral) sector, higher real wages in the latter sector would spread to the rest of the economy and be accompanied by higher unemployment (Corden 1984: 370).

Beyond short and medium-term effects, in the long run a commodity boom, if lacking adequate policy adjustments, acts as a constraint to such objectives as production diversification and export competitiveness, inflationary control, and employment creation. This is likely to occur if loose fiscal and monetary policies are excessively biased towards non-productive sectors and continue to be implemented once the boom is over, when the government may try to maintain the expenditure programme pursued under the boom. In this context, a temporary decline in the non-mineral tradables sectors can lead to a permanent lower growth path compared to what may have happened otherwise, especially if these sectors hold a significant potential for endogenous human capital building (van Wijnbergen 1984; Nyoni 1993: 16) and the scope for development and diffusion of technological capacity by the mineral sector is limited.

Besides foreign exchange instability caused by world market changes, a mineral economy can also be affected by the instability in investment planning and implementation, due to the *lumpiness* of investment in this industry. If this irregular pattern is not offset and supplemented by investment activities in other sectors, negative implications would follow for the rest of the economy (Cathie-Dick 1987: 48-50).

Summarising and seeking an analytical expression for the above arguments, the rate of growth of a mineral economy *g* can be represented by the following equation, where some of the symbols have been used in the preceding treatment:

$$g = Uk(R,f,td) + Vh(GP,R,td) + W_o l_o(E,n) + W_{min} l_{min}(R,f,n) + ZR(S,G,GP,td)/f + tx \ ,$$

which shows economic growth as a weighted average of the growth in the stock of physical (k) and human (h) capital, the growth in the labour force (l) in the non-mining and mining sectors, and the rate of extraction and utilisation of the minerals (R), each factor being weighted by its marginal importance in the productive process, plus the rate of growth of an exogenous component of technical progress (tx). Fluctuations in the rate of extraction and/or external demand of the mineral (f) will negatively affect the stability of other parameters, particularly physical capital formation.

Technical progress and technology choices can partly be endogenised (td), and be considered affecting the rate of physical and human capital formation and the rate of extraction of mineral resources. This includes the possibility to widen the scope for mining activities towards the surveying and exploitation of lower grade seams and new mining sites. The rate of mineral extraction and utilisation will also be subject to the available mineral stock (S), geological factors (G), such as ore quality, and government policies (GP).

A high pace of mineral extraction, following a prolonged commodity boom period, may in turn induce a pro-physical capital bias in the growth process. In *enclave*-type mineral production activities, higher physical capital formation could be accompanied by relatively lower efficiency of this production factor. Moreover, a possible connected real appreciation of the domestic currency (E) may imply negative effects on the development of other sectors, thus hampering employment creation in these sectors, unless fiscal measures are taken to avoid these effects. Implications for human capital formation are less easy to assume, depending on the inter-sectoral linkages in the economy and the capacity and willingness of the local government to use part of the mineral rents to this end. However, the above mentioned factors retarding or hindering human capital formation and endogenous technological progress can be hypothesized, associated with a misuse of mineral rents, especially for scarcely diversified economies.

The purpose of the following section is to test the relevance of specific factors of growth, i.e. the role of human capital development and mineral exports, for a group of developing mineral economies. The sample is first examined within a broader cross-country study focused on developing economies for the period 1960-1985, then analysed separately for individual mineral country and commodity cases. Should the size of the mineral sector, as proxied by the degree of dependency on mineral commodity exports, account for different growth achievements between groups of countries over a sufficiently long time period, other conditions held constant, it would then be possible to attribute predominantly net positive or negative implications to the specific features above highlighted, as opposed to the *standard* case of a developing economy.

2.4 An empirical analysis

2.4.1 Methods and data sources

Statistical tests of alternative growth theories have to face a number of problems, concerning the selection and appropriateness of the variables, the functional form, and the estimation procedure. According to Levine and Renelt (1992), these tests are often not sufficiently robust, since results are sensitive to the explanatory variables chosen for the regression estimations. Moreover, these variables, such as the investment rate, can often be considered endogenous, and regressions generally ignore the changes in the sectoral composition of output (Pack 1994: 68). In order to test endogenous growth theories, human capital is reflected in only an approximate way by indicators such as secondary schooling rate or literacy rate (Boltho-Holtham 1992).

In terms of the suitability of available data, even in the presence of long time series it is extremely difficult to find appropriate criteria geared to filter cycles out of the data, so as to use estimates more closely reflecting long-run trends (Romer 1986: 1008). Particularly in the case of LDCs, the averaging of growth or percentage rates over long time series is likely to conceal substantial and sudden changes, caused for instance by a more unstable political setting (Lucas 1988), or by other exogenous shocks. This procedure will therefore be affected by the choice of the initial and final year, for such policy indicators as the rate of government investment, trade orientation, parallel market premium, and inflation (Easterly *et al.* 1992: 30). The choice of different model specifications, historical periods, and country samples may also lead to different conclusions.

Baumol (1986: 1076) has pointed out the risk of a pro-convergence bias in the regression of cross-country long-term growth rates on initial levels of per capita income or productivity. This bias would arise from (i) the backward extrapolation of growth rates in the case of time series dating back to the last century, and (ii) the implicit presence of the same variable on both sides of the regression equation, given the average compounding of growth rates. However, the first argument seems to have relevance only if backward-reconstructed trends are such as to strengthen the inverse relationship between initial levels and growth, while the second argument does not appear to be sufficiently substantiated by the author[8]. A more convincing argument pointing to a pro-convergence bias in some studies refers to the country sample selection, for analyses limited to countries with relatively high and homogeneous levels of development at the end of the period (Dowrick-Nguyen 1989: 1010).

As an alternative to Baumol-type regression specifications, some empirical analyses have tried to test the convergence hypothesis by looking at the behaviour of measures of dispersion of per capita income or labour productivity levels over long time spans, using the coefficient of variation, the variance, or the standard deviation of the (log)level variable (Romer 1986: 1012; Dowrick-Nguyen 1989: 1012-1013). The main drawback of both procedures is the lack of a clear distinction between weak and strong convergence (Chatterji 1992, as defined in note 2) and the inability to identify sub-samples of countries with different convergence or divergence patterns. For these reasons, regression specifications other than the standard Baumol-type model have been preferred here, as described in sub-section 4.2.

As far as the regression models used for the sub-sample of mineral economies are concerned, variables for growth and instability of mineral commodity prices were used. Details on the estimation procedures are presented in sub-section 4.2 and Appendix A. Instability is measured in terms of fluctuations around the trend. In general terms, an *a priori* selection of trend model specifications was avoided. On the one hand, the use of the simple coefficient of variation (i.e. the ratio of the standard deviation of a series to its mean) can provide an unbiased estimate of instability only for non-trended or de-trended series, since otherwise it would lead to an overestimation of instability (Cuddy-Della Valle 1978). On the other hand, the use of more flexible measures, as proposed in Cuddy and Della Valle (1978), can also lead to biased estimates, if insufficient attention is paid to the choice of the trend model, including the possibility of changes in the direction of the trend.

In cross-country studies on convergence including LDCs, oil-producing countries have in some cases been omitted from the analysis because of the specific nature of their growth process, pulled by the extraction of existing resources rather than by value added creation, thus not complying with standard growth models (Mankiw *et al.* 1991: 413). In the present analysis only relatively richer and lesser populated oil-producing countries have been excluded, while oil-producers such as Indonesia or Gabon have not been regarded as problematic cases, to the same extent as producers of other minerals. The selected country sample included 70 LDCs, regionally distributed as follows: 36 in Africa (including South Africa), 12 in Asia (including Israel), and 22 in Latin America. Within this sample, 26 countries were identified as *mineral economies* according to the criterion of a high reliance (40% or more) of export revenues on mining[9]. In turn, among mineral economies so identified, 13 countries can be considered as highly dependent on one mineral commodity, with this commodity constituting at least half of their total merchandise exports (1985-1987 average) (Table 2.4)[10].

As followed by similar analyses, in order to achieve a realistic cross-country comparability in terms of real (1980 prices) purchasing power, data on real per capita GDP were taken from Summers-Heston (1988), choosing the RGDP2 series for this indicator[11]. Summers-Heston data were also used to estimate the 1960-1985 average investment rates for each mineral economy.

Except for uranium and diamonds, data for mineral commodity prices in constant terms were obtained from World Bank (1993; also used for the main mineral commodity share in country total exports: Table 9) and Roskill (1994). Uranium price figures in real terms were available through Radetzki (1981), for the period 1973-1979, complemented for earlier and later years by the graphical information in Battey *et al.* (1987). Corresponding figures for diamonds were taken from Cathie and Dick (1987: Table 3, 47-48), and deflated with the manufacturing unit value index used by the World Bank.

Statistical information for other variables was drawn from various World Bank publications or computerised databases, such as World Bank (1994) for money supply and World Bank (1992: Table 1.3; and 1993b: Table 16) for the share of mining in country total exports. As a proxy for outward-orientation of the economy, reflecting to some degree the extent of price inefficiency or distortions in the allocation of domestic resources, use was made of an index proposed and estimated by Dollar (1992). This index, whose estimation method is outlined in chapter 5 (Appendix), is based on distortions in the RER, as opposed to a situation of *free trade* and after correcting for local endowments. If compared to similar measures of outward-orientation, Dollar's index offers the advantage of being easily applicable to a large number of countries (Grilli 1994).

2.4.2 Results of the econometric analysis

a. *Analysis of weak convergence within the total LDC sample and general comparison with the sub-sample of mineral economies*

The econometric application was geared to check for both weak and strong convergence (as defined earlier on, in note 2), over the period 1960-1985. Summers and Heston (1988) do not provide complete data sets for the selected variables for all countries before 1960. Strong asymmetries in the distributions of per capita income levels in 1960 and 1985 for the whole sample of 70 LDCs suggested to transform both variables into natural logarithms. The scatter plot of the two transformed variables reveals a striking similarity to the S-shaped dual convergence framework adopted by the present analysis. The same pattern is found for the plots of the same variables in original and logarithmic form in relation to the group of 26 mineral economies (Figures 2.2, 2.3 and 2.4).

The OLS regression equations mostly hold significant results in terms of goodness of fit (Table 2.2)[12]. For the whole cross-country sample, the S-shaped pattern is well captured by a cubic function, with the final year per capita income regressed on the corresponding initial year figures and both variables being in logarithmic form. Should the dual convergence pattern be absent, loglinear or log-quadratic functions would then be preferred, thus entailing different convergence or divergence paths over the period (note 8). An alternative specification, which better reflects the saturation level at the upper tail of this pattern, has been the following (Pindyck-Rubinfeld 1986: 478-479):

$y85 = e^{\alpha-(\beta/y60)}$, which is linearised in the parameters, by applying logarithms on both sides:
$\ln y85 = \alpha-(\beta/y60)$.

Regression results with this model specification are very similar for developing countries as a whole and for mineral economies separately considered: the estimated parameter β amounts to 722 and 724, respectively for the two groups of countries. Since the second derivative of the function in y60 is null when this variable is equal to $\beta/2$, the inflexion points in the S-curves are identified in approximately 361 and 362 US$ of per capita income in 1960, for the two country samples respectively, which would nearly correspond to 428 and 459 US$ in 1985 (once constant terms have been taken into account). Countries with per capita incomes higher than these figures appear to converge at least weakly to an upper equilibrium level, while relatively poorer low-income economies tend to remain at a lower equilibrium.

Figure 2.2 - Developing country sample: lny85 vs. lny60

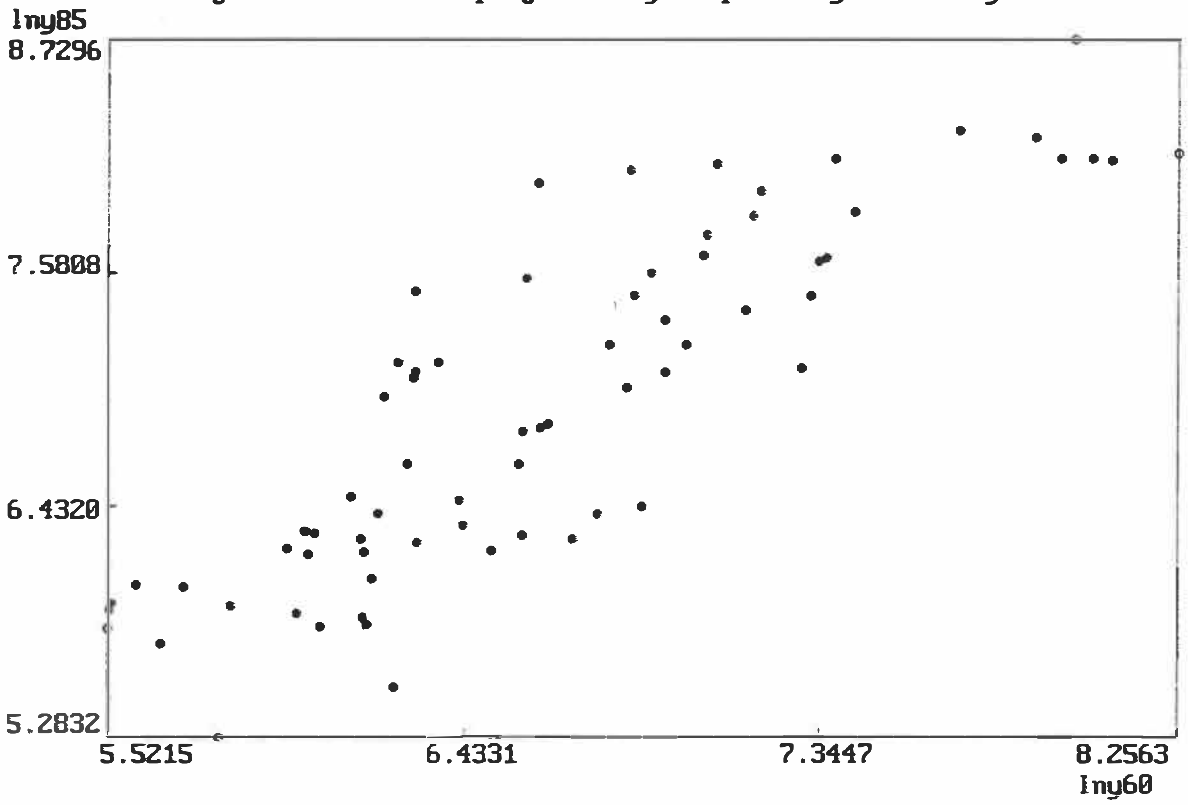


Figure 2.3 - Sub-sample of mineral economies: lny85 vs. lny60

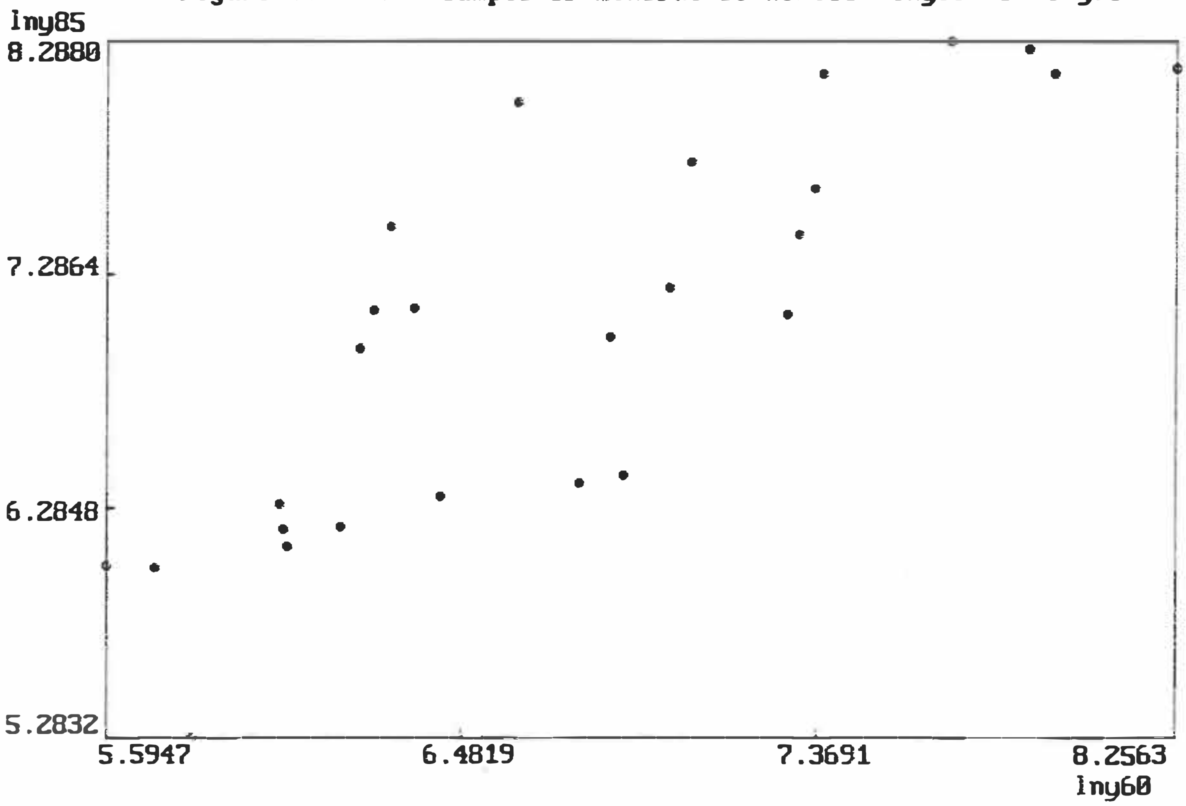
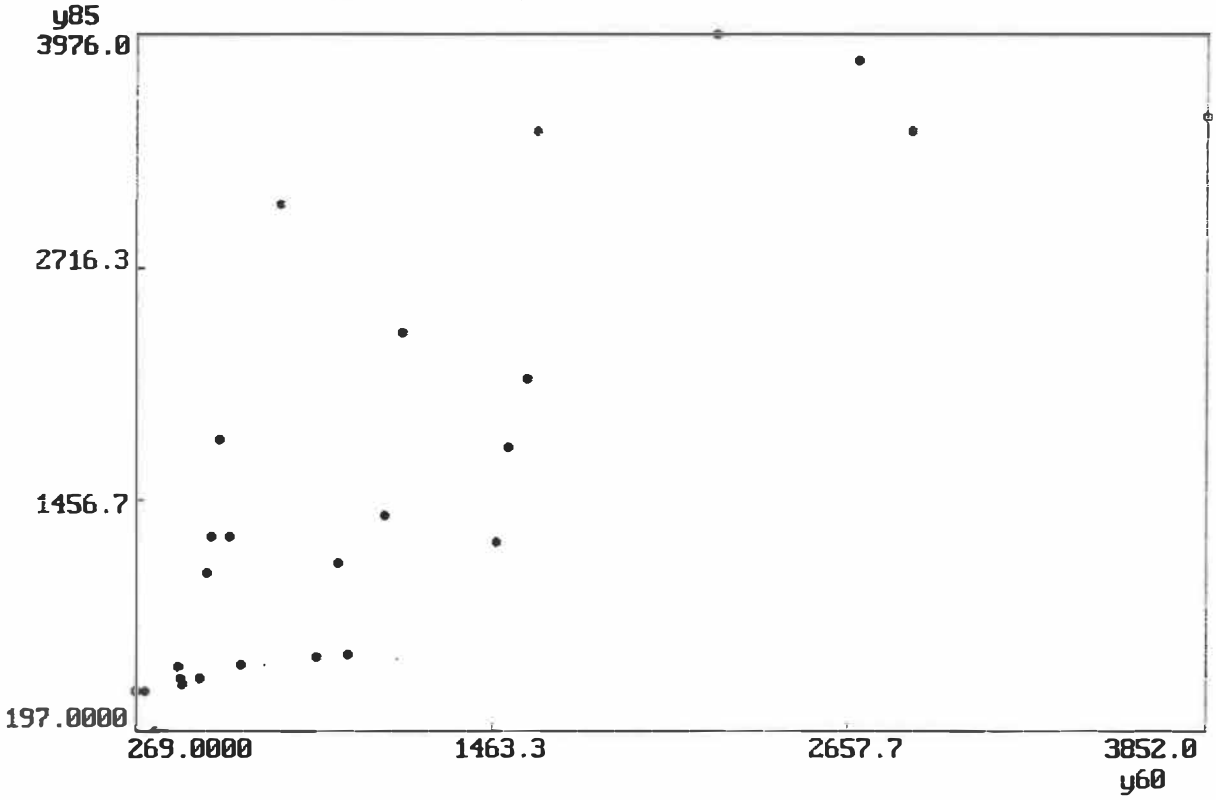


Figure 2.4 - Sub-sample of mineral economies: y85 vs. y60



A further indication that mineral economies are not liable to a different pattern from the standard case of developing economies is provided by the low and statistically insignificant value of the intercept dummy for the former group of economies, once this variable is added to the cubic model (second row in Table 2.2). If the second and third term of the polynomial expression are replaced by the logarithm of adult illiteracy rate, as a proxy for constraints to human capital formation and, partly, social capability, a significant negative coefficient is obtained[13]. The value of the estimated elasticity of the final year's per capita income to the initial year's is 0.89. A t-test indicates no significant difference of this estimate from 1, thus reflecting neither convergence, nor divergence at an aggregate level of analysis.

The controversial hypotheses about factors fostering or hampering growth prospects, in the presence of a dominant mining sector and once differences in initial development level and human capital have been taken into account, prove to be both lacking empirical support on average for the period analysed, with a statistically insignificant intercept dummy for mineral economies. If this dummy is instead used in connection with the illiteracy rate parameter, a small positive value is obtained which turns out to be modestly significant, at a 70% confidence level. This may be interpreted as an indication that growth-inhibiting constraints to human capital formation may have played a lesser role in mineral economies, possibly due to the offsetting presence of mineral rents.

Following a procedure suggested by Persson and Tabellini (1991), besides the mineral country dummy, dummies for different developing regions were introduced. While the dummy for Latin America is significant only at an 85% confidence interval, the Asian dummy is positive and statistically significant, clearly implying a more successful growth performance of these economies as a whole, as opposed to sub-Saharan Africa. This is also revealed by the plot of residuals obtained from the above formulated S-shaped saturation model, and by the improved fit when the same dummies are introduced in this model. A crossing of the regional dummies with the mineral country dummy, in order to check for a different growth pattern of non-mineral *versus* mineral economies and, within the latter, African as compared to non-African mineral-rich countries, does not produce significant results.

Even if no proxies for political instability and warfare disruption have been introduced in the regressions, an ethnolinguistic fractionalization index, based on 1960 information, is considered by Mauro (1995: 693) a suitable instrument to assess potential ethnic conflict and severe corruption practices. With this index ranging from 0 to 100 (*ibidem*: 708-710), in Africa the ethnolinguistic fragmentation appears high in general, and only slightly higher in mineral than in non-mineral economies, in terms of robust measures of average and variation, namely median and interquartile range. The medians are 77 and 70, for the two country groups respectively, and values for the midspreads reflect this slight difference. More clearcut appears to be the difference between African LDCs and the other developing regions, and, within the latter regions, mineral as opposed to non-mineral economies: median values are 47.5 and 20, for the non-African mineral and non-mineral economies listed in Table 2.4.

b. Analysis of weak convergence in the sub-sample of mineral economies and strong convergence in both country groups

A second set of regressions focused on the sub-sample of mineral economies only. Appendixes A and B provide some information on preliminary estimations needed for this part of the study. Both real growth and instability of mineral commodity prices appear to account for the different performance of these economies over the 25-year period: the growth variable has a significantly positive estimated parameter, with an 80% confidence interval, and the instability index assumes a negative coefficient with a 75% confidence interval (Table 2.2). Both regression models explain nearly 65% of the variance of the dependent variable. In Table 2.2 only results based on the relatively more *pessimistic* figures on price instability, with regard to alternative estimates for copper and iron ore, are reported, and the same selection criterion has led to the choice of the growth estimate for iron ore. The alternative estimates are given in Table 2.3.

Regressions using the other estimates for the instability of copper and iron ore prices and for the growth performance of iron ore prices led to similar conclusions and are not reported here. Insensitivity of regression results to alternative estimates was also found with regard to the instability variable in the analysis of strong convergence, considered at the end of this section. For gold the most highly unstable and high-growth picture depicted by the double linear spline was discarded, in spite of a relatively better regression fit, due to reasons explained in Appendix A. An averaging of the fits obtained from the other two models (Table 2.3) was done to calculate the annual growth rate for the gold price. For copper prices the quadratic trend model was not taken into account for the estimate of the annual growth rate, due to an unrealistically low 1985 estimated fit value. While in 1978 copper still accounted for more than 40% of export revenues in Papua New Guinea, this mineral has been overtaken by gold as a major source of foreign exchange receipts since the late 1980s, following the shutdown of the Bougainville copper mine (also producing gold) (IMF v.y.): for this reason, alternative regressions were run replacing the estimates on price growth and instability of copper with those regarding gold for Papua New Guinea, but similar results were obtained and are not reported.

Examining the values of residuals around the estimated fits of the two regressions with the growth and instability indexes, in the regression including the average annual price growth rate the two African copper producer countries, Zambia and Zaire, and, to an even greater extent, Angola and Nigeria lie relatively more markedly below the fit, while the opposite case of positive residual values is observed for Botswana, Gabon, Niger and Surinam. A similar pattern of residual *outliers* appears in the equation with the instability index, with Angola, Zambia, Nigeria, and Guyana faring particularly poorly as compared to the norm, and Botswana, Gabon, Niger and South Africa achieving a higher than *expected* growth performance.

On the whole, therefore, sub-Saharan Africa seems to contain most of the relatively less explained country cases in terms of mineral price growth and instability and initial development level, although the case of Angola can easily be explained by the prolonged warfare. The introduction of dummies for different LDCs' regions does not increase the explanatory power of the two equations and lead to insignificant results. However, if South Africa is considered as a non-African country, in view of its relatively more diversified and advanced production structure, results point to a higher intercept in the equation with the growth variable and a basically horizontal slope in the equation with the instability variable for non-African as opposed to African mineral economies (Table 2.2). These results improve the statistical significance of the growth and instability variables and may imply the existence of relatively stronger growth-inducing factors in non-African mineral economies, after accounting for price trends, accompanied by a relatively lower long-term vulnerability of these economies to mineral price fluctuations.

In view of the above results, one may be tempted to distinguish between mineral economies with a relatively higher export specialisation in one major commodity, and other more diversified mineral exporting countries. In the former case, destabilising effects of unstable trends and short-term fluctuations in mineral prices may be more severe. Meanwhile, given a certain growth path, long-term growth effects are more difficult to foresee, depending on such aspects as the Dutch disease and the inter-sectoral links in the economy. This distinction appears to overlap partly with a regional disaggregation: according to the 50% export share criterion established to the purpose of distinguishing the two sub-groups, two thirds of African mineral countries would fall under the category of mineral economies with a high dependency on one mineral commodity, as opposed to less than one third for mineral economies in the other regions (Table 2.4). However, the insertion of a dummy for this country category does not produce statistically significant results, thus implying that factors other than export concentration in one mineral commodity could better explain different long-term growth performances.

In order to analyse whether loose monetary and fiscal policies may have affected the growth performance of mineral economies, a variable for average annual rate of growth of money supply, defined in broad terms as money and quasi-money[14], was used as a regressor besides the inverse of 1960 per capita income. These policies may have been undertaken as a consequence of a misplaced belief in the long-term persistence of favourable price tendencies in the 1970s, for a few minerals, and of a lack of political will to adjust to sudden commodity price downturns in that and the following decade. Therefore, 1972-1985 was the period chosen for estimating the money supply growth. This variable does not appear to be statistically relevant, except to a very limited extent (nearly 60% significance level) if a regional distinction is made: in this regard, the value of the slope dummy Mnafr (Table 2.2), referred to non-African economies, almost offsets the estimated parameter value for money supply growth. This implies that, if some negative influence of loose macro policies cannot be excluded for African mineral economies, this outcome does not hold to the same extent for mineral economies in other developing regions.

Another distinction, which has frequently been investigated in the literature on economic growth in spite of difficulties in finding suitable indicators, regards the extent of outward-orientation in the economy. The presence of a liberal trade regime and a correct exchange rate management is thought to be associated with a higher capacity to absorb foreign technology and a reduced risk of excessive foreign indebtedness of the economy. Trade openness indicators are criticised for being unsuitable for a measurement of the phenomenon (Grilli 1994: 30-31). Dollar's index of RER distortion has instead been used here, converting the figures (Dollar 1992: 540-542) into natural logarithms. Among developing regions, the average distortion for the period 1976-1985 is found by this author to be relatively higher in Africa and, to a lesser degree, Latin America. This pattern is clearly reproduced if the analysis is limited to mineral economies, with Niger, Nigeria, Sierra Leone, Zaire and Zambia showing the most overvalued currencies[15].

This outward-orientation variable has a significant coefficient, with the expected negative sign implying a growth-constraining effect of overvaluation as a consequence of protection. The addition of the investment rate does not improve the explanatory power of the regression and the statistical significance of its parameter is close to 80% (Table 2.2). This result cannot be attributed to multicollinearity problems, but it seems rather to point to the difficulty to estimate the impact of domestic investment at this aggregate level.

The use of per capita income variables in level form for a cross-country study of long-term growth does not allow a distinction between weak and strong convergence, but just an identification of minimum conditions for (weak) convergence (note 2 and 8). Following the procedure suggested by Chatterji (1992: 65), the cubic model was re-applied, by replacing the level variables with gap variables. The gaps are expressed in logarithm of the ratio of the highest per capita income recorded in the year of reference (1960 or 1985, for the independent and dependent variable, respectively) to the corresponding figure of a specific country, given a selected group of countries. In a similar fashion as with the level variable model, different values for the estimated coefficients lead to alternative interpretations of the growth process across countries (Chatterji 1992: 66).

To the above end, other econometric analyses tend to use the United States as the *leading* economy, in samples covering both industrial and developing economies, because this country shows the highest recorded per capita income over long estimation periods. Since this analysis is concerned with LDCs only, possible *regional* leaders have been searched for. This procedure relaxes the assumption of a unique source of technology diffusion, by presupposing, instead, a potential *chain* of technology diffusion and adaptation from industrial countries, through *regional* leaders, up to relatively poorer economies. The aim is to test whether, besides the scope for weak convergence to an upper equilibrium level for most LDCs, strong convergence patterns can be identified within regions.

In Asia and Latin America it is almost impossible to identify a regional leader, and in terms of per capita income in the latter region there would be a shift from Venezuela in 1960 to Mexico in 1985, according to Summers-Heston data. Attention was therefore focused on Africa, distinguishing between (i) the full 36 country sample, with South Africa as the *potential* leader[16], and (ii) the mineral economies with the exclusion of South Africa because of its structural diversity, with Gabon as the leading economy.

Results for the African country sample discard the need for a polynomial model and point to an elasticity statistically close to unity, thus suggesting a lack of either strong convergence or divergence. With their sample observations corresponding to high negative residuals, Botswana and Gabon stand out for bridging part of the gap from the leader, to a far greater extent than would be predicted by their initial conditions. The unexplained variation for the same equation restricted to the 14 mineral economies is still higher than for the whole sample. An improved fit is obtained, to some extent, when the instability variable is used, which reveals how a relatively greater mineral price instability tends to widen the gap from the mineral leader (Gabon) in the final year (Table 2.2). An analogous result, with the expected opposite sign, is found for the mineral price growth variable, although with a lower significance level. Finally, similar to the analysis of weak convergence, the introduction of an index of outward-orientation reveals how trade-inhibiting RER distortions are likely to have hindered efforts at closing the gap from the leader.

2.5 Conclusions

With few exceptions, recent contributions to growth theory pay scarce attention to patterns of growth within developing country groupings, distinguishable according to such indicators as mineral endowment and other features of the economy. Partly due to easier comparability and data availability, most empirical analyses focus on industrial countries, eventually extending the assessment to developing countries. In the analysis of the long-term convergence hypothesis, this approach has often been criticised on the grounds of sample selection bias. Furthermore, the use of insufficiently *flexible* regression models does not allow for testing alternative theoretical frameworks.

This analysis has adopted a mixed endogenous growth-technology diffusion model, which has led to test a double convergence equilibrium framework for mineral economies. Similar to models by Becker *et al.* (1990) and Grossman and Helpman (1990), this framework endogenises other elements besides human capital and technical progress, i.e. demographic characteristics and trade specialisation. Given assumptions of (i) a partial substitution effect between mineral resource exploitation and technical progress, or human capital accumulation, (ii) limited inter-sectoral links in the economy, and (iii) vulnerability of the economy to commodity price shocks and fluctuations, the model predicts an S-shaped pattern of cross-country long-term convergence. While the first two assumptions are especially concerning mineral economies with relatively lower levels of infrastructural development, the last point can be serious for both poorer and often scarcely diversified economies, and middle-income more diversified economies, for different reasons. Given the disincentive effects related to points (i) and (ii), the inflexion point of the S-shaped curve might be expected to lie above the corresponding figure for non-mineral developing economies.

The econometric analysis, based on cross-country data which account for purchasing power parity (PPP) and refer to the period 1960-1985, supports the dual growth pattern as long as weak convergence is concerned, for both developing countries as a whole and, within them, the group of mineral economies. Contrary to expectations of the model, the flex points are found to be nearly equal for both groups of countries. More interesting is perhaps a comparison of these results with those of another study on long-term growth convergence. While for Chatterji (1992) the *threshold* level would lie at nearly 1/6 of the US per capita income, for this analysis flex points would correspond to only 7% up to 9% of the *leaders'* per capita income achievements for the total sample (the leaders being Venezuela and Israel, for 1960 and 1985 respectively), and 9% up to 12% for the sub-sample of mineral economies (with Venezuela and Mexico identified as *leaders*, for the two years respectively)[17]. One should bear in mind, however, that, apart from using the same observation period, the two analyses differ in coverage. Chatterji's analysis includes developed and developing countries, and tests directly for strong convergence (which the above flex point refers to), thus assuming weak convergence for all countries.

While the growth-inducing role of human capital formation and social capability is clearly revealed by a negative coefficient for adult illiteracy rate in logarithmic form, statistically less significant evidence seems to support the hypothesis of partial *substitutability* of human capital formation with mineral exploitation in mineral economies, for their growth strategies. According to econometric results, the illiteracy rate may be less of a constraint to growth for mineral economies. However, similar to the above results, the limited statistical significance suggests closeness in the weak convergence paths between the two country groups.

Whereas on the whole, for the overall country sample, regional distinctions appear to matter, the cross-mineral economy analysis provides a more articulated image. After accounting for growth and instability of mineral prices, African countries, except South Africa, appear to follow a *disadvantaged* growth path, in terms of both long-term trajectory and vulnerability to price shocks. The reasons for this poorer performance, however, seem to lie in aspects other than excessive mineral export concentration, or size and openness of the local markets. This is also revealed by the residual plots around the estimated regression fits: Angola and Nigeria stand out as particularly negative cases, while Botswana and Niger appear to outperform the average of mineral economies as a whole. A lack of prudent monetary and exchange rate policies in several mineral economies in Africa appears to matter to some extent in explaining this performance. With regard to a higher sensitivity to export *earnings* instability, Gyimah-Brempong (1991: 822) explains it on the grounds that African LDCs are often highly dependent on imported inputs and few export commodities with a limited domestic market. Other possible determinants, related to the institutional environment, are considered in chapter 3. The closer similarity of the South African case, for certain aspects, to non-African mineral economies, rather than the other mineral-dependent countries of the continent, appears consistent with the way in which other studies classify South Africa in this concern (UNCTAD 1994a: 7). This issue is reconsidered in chapters 3 and 6.

The analysis could be extended in various directions, subject to data availability and selection of suitable estimation techniques. Although the role of mining for growth is specifically focused on, no consideration has been given to structural transformation patterns, such as the changing composition of output, for each country. This would need information on the sectoral distribution of output for each country in various years.

Further distinctions may be based on other factors, likely to be responsible for different growth paths and policy responses, such as the stage of mineral exploitation, or the pattern of ownership and control. As far as mineral price instability is concerned, the econometric analysis has estimated the extent of short-term fluctuations around fitted trends, without trying to identify medium-term fluctuations, which could account for even more severe disrupting effects on the local economy. The absence of sufficiently long time series for mineral prices and the arbitrariness of smoothing procedures applicable to this purpose tend to discourage an attempt in this direction.

Table 2.1 - **Some features of recent theories of growth and related empirical models (with specific regard to endogenous growth models)**

main emphasis of the model	nature of growth process	cross-country growth effects (income per capita or productivity levels)	sources
. savings rate, population growth and technical progress	exogenous	. weak convergence conditional to similar cross-country structural features (preferences, capital and population growth)	Solow 1956 Meade 1961
. capital goods . learning by doing . human capital	endogenous (education and training)	. no need for convergence . possibility of multiple convergence equilibria	(Arrow 1962; Uzawa 1965) Lucas 1988
. stock of knowledge and technology	endogenous (R&D)	. no need for convergence . possibility of multiple convergence equilibria	Romer 1986 Krugman 1991
. material and immaterial infrastructure	endogenous (public goods; fiscal policy; education policy)	. weak convergence conditional on some variables held constant (e.g. productive government expenditure; income tax rate; education)	Barro 1990 Rebelo 1991 Mankiw *et al.* 1991 Barro-Sala i Martin 1992
. technology transfer (between countries) . *social capability*	partly endogenous/exogenous (technology diffusion)	. strong convergence for a subset of countries, possibly conditional to some variables held constant (population growth; investment rate)	Abramowitz 1986 Baumol 1986 Gomulka 1990 Dowrick-Nguyen 1989
. technology transfer (between and within countries)	partly endogenous/exogenous (technology diffusion and inter-sectoral shifts)	. strong convergence for a subset of countries, excluding countries below a threshold level of infrastructural development	Feder 1983 Dowrick-Gemmel 1991
. stock of knowledge and technology . technology transfer (between countries)	partly endogenous/exogenous (*combined* strictly endogenous- technology diffusion approach)	. weak convergence . strong within-group convergence in a dual convergence equilibria framework	Chatterji 1992
. demographic variables	endogenous	. (strong?) within-group convergence in a dual convergence equilibria framework	Becker-Murphy-Tamura 1990
. income distribution and kind of political setting	endogenous	. no need for convergence	Persson-Tabellini 1992
. human capital and stock of knowledge . trade openness and sectoral specialisation	endogenous	. no need for convergence	Rivera-Batiz and Romer 1991 Grossman-Helpman 1990

Table 2.2 - Growth and per capita income convergence in mineral and non-mineral developing economies: econometric estimates (1960-1985)

analysis of weak convergence (dependent variable: lny85)											
const.	lny60	$(lny60)^2$	$(lny60)^3$	dmin	lnil	lnilmin	dasi	dlat	recy60	χ^2 (1) F	R^2 n
developing country sample (mineral and non-mineral economies)											
69.7 (1.69)	-30.76 (-1.68)	4.79 (1.77)	-0.24 (-1.80)							0.39 67.6	0.74 70
68.3 (1.65)	-30.17 (-1.64)	4.71 (1.73)	-0.23 (-1.77)	0.07 (0.66*)						0.18 50.4	0.74 70
1.6 (1.5^)	0.89 (7.4)				-0.18 (-2.0)					0.016 102.8	0.75 70
1.6 (1.5^)	0.89 (7.31)			0.06 (0.53*)	-0.18 (-1.97)					0.001 67.9	0.74 70
1.65 (1.5^)	0.89 (7.33)				-0.19 (-2.11)	0.03 (1.11#)				0.01 69.2	0.75 70
1.67 (1.62)	0.83 (6.75)				-0.13 (-1.4^)		0.43 (2.92)	0.23 (1.44^)		0.49 58.5	0.77 70
8.06 (69.2)									-722.2 (-11.4)	0.68	0.66 70
const.	g	dnafrsa	lx	lxnafrsa	M	Mnafr	lndist	inv	recy60	χ^2 (1) F	R^2 n
sub-sample of mineral economies											
8.13 (43.9)									-724.3 (-6.89)	0.03	0.66 26
7.97 (36.9)	0.026 (1.31^)								-694.0 (-6.54)	0.03 25.3	0.66 26
7.38 (19.2)	0.034 (1.75)	0.52 (1.82)							-479.7 (-3.09)	0.17 19.7	0.69 26
8.33 (33.1)			-0.013 (-1.17#)						-725.0 (-6.95)	0.05 24.8	0.65 26
8.05 (28.4)			-0.029 (-2.07)	0.029 (1.79)					-529.6 (-3.59)	0.03 19.2	0.68 26
8.25 (35.3)					-0.012 (-0.9*')	0.01 (0.8*')			-653.7 (-4.27)	0.017 16.5	0.67 24**
12.1 (8.54)							-0.86 (-2.83)		-538.2 (-4.75)	0.97 34.7	0.73 26
11.7 (8.27)							-0.86 (-2.88)	0.02 (1.36^)	-494.1 (-4.26)	0.71 24.6	0.74 26
analysis of strong convergence (dependent variable: z85)											
const.	z60		lx				lndist			χ^2 (1) F	R^2 n
African country sample and sub-sample of African mineral economies											
0.35 (1.2#)	0.93 (5.45)									2.45@	0.46 36
0.79 (2.58)	0.78 (1.82)		0.03 (1.63^)							2.95@ 4.1	0.32 14
-8.12 (-1.97)	0.68 (1.82)		0.04 (2.28)				1.69 (2.17)			4.62@ 5.23	0.49 14

Sources: Summers-Heston (1988), Roskill (1994) and World Bank data (see text)

Notes for Table 2.2

t-statistic in brackets under the estimated parameters

*	less than 70% confidence interval (' ca. 60%)
#	70-80% confidence interval
^	80-90% confidence interval (in all other cases, at least 90% confidence interval)
@	null hypothesis of homoscedasticity rejected at 85% confidence interval or more
**	Angola and Guinea excluded
χ^2 (1)	heteroscedasticity test (Lagrange multiplier)
F	F test
R^2	R^2 is adjusted for degrees of freedom in multiple regressions
n	number of observations (the sub-sample of African mineral economies used for the analysis of strong convergence does not include South Africa)

List of variables

dependent variables

lny85	real per capita income in 1985 (y85, 1980 US$), in logarithm
z85	logarithm of the ratio of the maximum value of y85 to the value of y85, for each country

independent variables

const.	constant term
lny60	real per capita income in 1960 (y60, 1980 US$), in logarithm
dmin	dummy for mineral economies
lnil	adult illiteracy rate, in logarithm (% pop. age 15+, 1985; earlier years for Ethiopia, Tanzania and Nicaragua)
lnilmin	lnil multiplied by 1 for mineral economies, 0 otherwise
dasi	dummy for Asia
dlat	dummy for Latin America
recy60	$(y60)^{-1}$
g	mineral commodity price growth (average compound rate on initial and final fitted values: Appendixes A and B)
dnafrsa	dummy for non-African mineral economies + South Africa
Ix	mineral commodity price instability (Appendixes A and B)
Ixnafrsa	Ix multiplied by 1 for non-African countries + South Africa, 0 otherwise
M	money supply growth (average compound rate, 1972-1985; M3, or M1 if quasi-money is not available: see note 14)
Mnafr	M multiplied by 1 for non-African countries, 0 otherwise
lndist	logarithm of Dollar's trade orientation index (1976-1985)
inv	investment rate (% of GDP, period averages)
z60	logarithm of the ratio of the maximum value of y60 to the value of y60, for each country (except Angola and Zambia: see note 16)

Table 2.3 - Growth and instability of mineral commodity prices: econometric estimates (1960-1985)

mineral	trend model	coeff. of variation	$\surd(1 - R_a^2)$	I_x	g
aluminium	double-log	14.4	0.92	13.23	-0.14
bauxite	double-log	17.5	0.71	12.52	+0.6
copper	quadratic cubic	39.05 39.05	0.70 0.54	27.21 21.1	-5.0 +0.07
diamonds	log-lin (1963-1984)	20.0	0.57	11.38	+2.45
gold	no trend (1971) + quadratic no trend (1971) + linear spline (1981) double linear spline (1971, 1981)	2.92 + 29.74 2.92 + 29.74 69.5	1 + 0.74 1 + 0.75 0.54	24.99 25.37 37.68	+4.55 +3.08 +5.06
iron ore	linear spline (1974)	14.32	0.63	8.97	-0.94
iron ore 2	linear spline (1974) no trend (1974) + quadratic	6.95 2.24 + 4.7	0.54 1 + 0.35	3.78 3.91	+2.11 +1.09
petroleum	linear spline (1974)	19.5	0.35	6.89	+10.76
phosphate rock	quadratic spline (1975)	40.45	0.82	33.14	-1.33
tin	linear	22.35	0.71	15.84	+2.18
uranium	(no trend: Appendix B) + quadratic	46.1	0.38	17.37	+1.41

(the years in parentheses indicate the break year, except for diamonds where they refer to the sample period; for symbols see text and Appendixes A and B)

Sources: Cathie-Dick (1987): diamonds; Battey *et al.* (1987) and Radetzki (1981): uranium; Roskill (1994): gold, iron ore 2; World Bank (1993): aluminium, bauxite, copper, iron ore, petroleum, phosphate rock, tin

Table 2.4 - Country list, with main mineral export reported for mineral economies

Africa	Asia	Latin America
non-mineral economies		
Benin Burundi Central African Republic Chad Ethiopia The Gambia Ghana Ivory Coast Kenya Madagascar Malawi Mali Morocco Mozambique Rwanda Senegal Somalia Sudan Tanzania Uganda Zimbabwe	Bangladesh India Israel Jordan Malaysia Nepal Pakistan Philippines Sri Lanka Thailand	Costa Rica Dominican Republic El Salvador Guatemala Haiti Honduras Nicaragua Panama Argentina Brazil Colombia Paraguay Uruguay
mineral economies		
Angola (petroleum *) Botswana (diamonds *) Cameroon (petroleum *) Congo (petroleum *) Gabon (petroleum *) Guinea (bauxite *) Liberia (iron ore *) Mauritania (iron ore) Niger (uranium *) Nigeria (petroleum *) Sierra Leone (bauxite) South Africa (gold) Togo (phosphate rock) Zaire (copper) Zambia (copper *)	Indonesia (petroleum) Papua New Guinea (copper, gold)	Jamaica (aluminium) Mexico (petroleum *) Bolivia (tin) Chile (copper) Ecuador (petroleum) Guyana (bauxite) Peru (copper) Surinam (aluminium *) Venezuela (petroleum *)

* high export concentration in the main mineral commodity: at least 50% of export revenues represented by one mineral commodity, 1985-1987 average (almost 50% for Cameroon and Mexico)

Sources: World Bank data (see text)

Notes

(1) A mineral rent is defined as a surplus earned by a mineral deposit over and above the minimum earnings necessary to attract the various factors of production needed for a mining operation to take place (Bomsel 1992: 62).

(2) Given long time series of real per capita income or labour productivity for a set of countries, Chatterji defines as *weak* convergence the existence of a negative relationship between initial levels and average growth rates over the period. While showing how this type of convergence cannot be considered a sufficient condition for a long term reduction of the absolute gap, he defines *strong* convergence as a dynamic process leading to equalization of real per capita income to a common (e.g. worldwide) steady state level.

(3) It has even been noticed that most empirical work linked to endogenous growth theory actually tends to test the neoclassical model assumptions (Park 1994). Moreover, the distinction between the two strands of growth theory is often not clearcut: Solow regards some subsequent interpretations of his model as misconceptions, denying the acceptability of assumptions of constant, erratic, or completely exogenous technological change (Solow 1994: 88).

(4) Total factor productivity growth is derived as a residual component of growth once account has been taken of contributions of individual factors of production. South Africa is mentioned as a case of a middle-income country showing lack of convergence.

(5) The authors draw a comparison with the benefits from additional knowledge through the learning process, whereby learning of relatively more advanced materials is more efficient whenever basic concepts are mastered (Becker *et al*. 1990: 16).

(6) Surprisingly, the terms of trade volatility, measured as the standard deviation of the log of barter terms of trade, is not found to be relevant to explain different growth achievements. This result may be partly explained by the authors failing to de-trend this variable.

(7) The rate of return on mineral resources and human capital can be assumed to increase at least until the process of mineral exploitation and human capital formation allows a sufficiently articulated and sustained development (e.g., for mining, more solid production links with other sectors of the economy; for human capital: note 5).

(8) Given the regression equation generally used to test the convergence hypothesis, i.e.

$$\ln(Y_t/Y_0) = \alpha + \beta \ln Y_0,$$

this expression can be rewritten as: $\ln Y_t = \alpha + (\beta + 1) \ln Y_0$. An estimation using the latter expression would possibly indicate (i) divergence, (ii) (at least weak) convergence, or, as a theoretical case, (iii) reversal of positions if β is respectively (i) positive, (ii) between -1 and 0, and (iii) lower than -1.

(9) Nankani (1985: 2) and Auty (1993: 3) define *mineral economies* as LDCs with mining accounting for at least 10% (8% for Auty) of GDP and 40% of export earnings. A similar approach is followed by UNCTAD (1994a: 7) and Bomsel (1992: 59), although both studies exclusively refer to non-fuel minerals and total merchandise exports (ignoring the GDP). This seems to be a better selection than the extremely broad definition adopted by other studies. For the choice of a dummy variable, Wheeler (1984) defines as non-mineral economies in Africa only countries with a complete lack of mineral exports, thus including in the group of mineral economies countries where the contribution of mining to the local economy is not substantial.

(10) With regard to the criterion used in this analysis, apparently contradictory estimates of the share of mining in merchandise exports can be observed for Sierra Leone and Togo (World Bank 1992 and 1993b): this can at least partly be attributed to high annual fluctuations in mineral export receipts. For both countries the higher estimates were taken into account (in Sierra Leone mining exports represented 80% of total exports in 1989, and the corresponding figure for Togo in 1991 was 49%), so that both cases are included in the sub-sample of *mineral economies*. According to more recent estimates, both countries would be classified as mineral economies: the export share of minerals in 1993 was 45% and 52%, for Sierra Leone and Togo respectively (World Bank 1995: Table 15).

(11) Other measures of per capita GDP proposed by the authors do not correct for changes in base-year price weights, so as to render long term comparisons more unreliable (Summers-Heston 1988: 13).

(12) Except for the analysis of strong convergence, which relies on relatively small samples, no heteroscedastic pattern in the residuals is detected by the Breusch-Pagan LM test (Stewart 1991: 159) applied to a regression of squared estimated residuals on squared predicted values of the dependent variable (Table 2.1). If a quadratic functional form is used, however, the Glejser test applied to the residuals from the first regression reported in Table 2.2 does reveal a diverging followed by a converging conical shape in the residuals plot. This is also detectable from a careful observation of Figure 2.2. Although parameter estimates of this regression equation are therefore not efficient, this problem is not serious enough as to impinge upon the indications of the analysis.

(13) In strict terms the regression should have used 1960 figures or an average over the 1960-1985 period. However, due to the lack of a thorough coverage for the entire country sample, the final year was preferred, assuming that a substantial stability in the cross-country pattern would persist for this specific variable in the period considered.

(14) For Botswana, Liberia and Papua New Guinea a narrower concept of money supply was used, in view of the absence of available information in World Bank (1994). The average rate of government expenditure (as a percentage of GDP) was not included as a proxy for fiscal policy, in view of its excessively aggregate nature and high instability during the period examined for most LDCs.

(15) One should notice that overvaluation in Dollar's study refers

to a RER distortion as a result of trade protection. Given a country's factor endowments, a ratio of domestic to foreign prices substantially higher than the cross-country regression fit (see Appendix to chapter 5) would indicate overvaluation, since this would be sustainable only with a consistent protectionist trade policy (Dollar 1992: 524-526). This concept is different from the most commonly adopted definition, which refers to RER misalignments out of its (long-term) sustainable equilibrium, determined by macroeconomic fundamentals such as the trade policy itself.

(16) In spite of the peculiar features of South Africa as compared to African economies, the selection of another country would not have been appropriate, because, similar to Latin America, significant shifts in relative positions of countries in terms of real per capita GDP over the period analysed impede the identification of an alternative *potential leader*. In the analysis on mineral economies South Africa could more easily be disregarded due to the presence of a clearer pattern: excluding South Africa, in terms of per capita GDP, Gabon lies in the third position in 1960, close behind the figure for Zambia and Angola, and stands out as a definite *leader* in 1985.

(17) Here the term *leaders* merely refers to the LDCs with the highest PPP-adjusted per capita incomes.

Appendix A

Problems in the analysis of growth and fluctuations: measures of instability and selection of trend models

In several studies on commodity unit prices or commodity export earnings the coefficient of variation is used as an indicator of instability (Cuddy-Della Valle 1978). If multiplied by 100, it can be expressed as follows:

$$CV = (100/\bar{Y}) \sqrt{\Sigma(Y_i - \bar{Y})^2/(n - 1)} \qquad [1]$$

where Y_i is an observation of the time series and $\bar{Y}$ is the corresponding mean value.

Other studies, also quoted in Cuddy-Della Valle (henceforth CDV) (1978), more correctly opt for applying the coefficient of variation to the estimated fit of a linear trend or exponential trend model, i.e. by replacing the mean value under square root with the fitted values of the estimated regression. This allows to avoid an overestimation of instability whenever a trend exists. These studies generally fail, however, to take into account the number of degrees of freedom in the estimation of the standard error of regression (CDV 1978: 80). CDV warn against the use of these methods, for being not sufficiently general and suited to measure the phenomenon, except for the simple coefficient of variation in the absence of a trend. They propose a modified coefficient of variation, adjusted so as to account for any possible correlation between an estimated trend and the actual data series. This index is defined as:

$$I_x = CV \sqrt{(1 - R_a^{2})} \qquad [2]$$

where CV is the coefficient of variation multiplied by 100 and R_a^2 is the adjusted R^2 of the regression equation chosen for the estimation of the trend. The formula for I_x is arrived at through the following procedure. Given a regression estimation with *k* number of estimated parameters, the error sum of squares can be defined in terms of R^2 and total sum of squares:

$$\Sigma(Y_i - \hat{Y})^2 = (1 - R^2)\ \Sigma(Y_i - \bar{Y})^2 =$$
$$= (n - k)\ (1 - R^2)\ [(n - 1)/(n - k)]\ [(\Sigma\ (Y_i - \bar{Y})^2/(n - 1)]$$

The last term of the right-hand side part of the equation is the variance of Y. Dividing both sides of the equation by (n - k) and extracting the square root, one obtains an expression for the standard error of regression (SER), in terms of the standard deviation of Y (SD) and the R^2:

$$SER = \sqrt{\Sigma(Y_i - \hat{Y})^2/(n - k)} = SD \sqrt{(1 - R^2)[(n - 1)/(n - k)]}$$

Given the expression in [1] and similarly standardising the SER by the mean value of variable Y (thus assuring a cross-variable and cross-sample comparability), and taking into account the formula used for the adjusted R^2, equation [2] can therefore be rewritten as:

$$I_x = 100\ (SER/\bar{Y}) = CV \sqrt{(1 - R_a^{2})}$$

The authors (CDV 1978: 82-84) suggest to use I_x whenever the adjusted R^2 is found to be statistically significant. Should the regression equation have a perfect fit, with an adjusted squared multiple correlation coefficient equal to 1, then there would be no instability. On the opposite extreme, should this coefficient be statistically close to 0 (or even negative, in rare cases), then the expression under square root should be ignored and the appropriate index would be the unadjusted coefficient of variation. In the latter case, the trend model does not contribute to explain part of the variance in Y, so that the original observations can be directly used for the analysis of instability.

According to CDV (1978), a significantly low R^2 would be sufficient to discard the need for a trend model, thus opting for the unadjusted coefficient of variation as a measure of instability. In this analysis however preference has been given to the significance of the individual trend parameter estimate, thus applying the CDV procedure also in the case of a slight but statistically acceptable trend. For the same reason, at the opposite extreme, unlike CDV's approach to trend model selection, preference has not been given to an estimated equation with the best fit, if this was not accompanied by a good statistical significance in individual parameter estimates of the trend(s). Such a case was found for the double linear spline function applied to gold prices, where the *first period* trend coefficient appears significant only at a 74% confidence level.

Another major flaw in CDV's application of the formula in equation [2] lies in the arbitrary choice of the trend model. For instance, the authors propose to test between two alternative specifications, i.e. a linear and a log-linear model, and to choose the model with the highest explanatory power, provided individual parameters are statistically significant. An even more rigid approach is adopted by other authors: Gyimah-Brempong (1991), and Singer and Lutz (1994), opt for a log-linear model, and the latter authors discard the possibility of a presence of a trend if the t-test on the slope parameter does not exceed 1.5 in absolute values (*ibidem*: 100, 119). In this way, in some cases the unadjusted coefficient of variation (or a similar measure of variability) may be preferred not because of an absolute absence of a trend, but as a consequence of a lack of correct modelling of this trend through more flexible regression specifications. If justified by a supposed or apparent change of direction in the trend (e.g. 1974 for certain commodities), a break year variable or the use of a spline function may even be necessary. A more flexible modelling of instability is proposed by Kenen and Voivodas (1994), with a first order autoregressive model with a random walk process: this model is however liable to misspecification biases due to the choice of the lag structure.

For the above reasons, in the case of two adjacent sub-periods, e.g. one with no well defined trend and a following one with a trend, a weighting procedure in the application of CDV's index is suggested here and has been applied to prices of iron ore (Table 2.3: iron ore 2) and gold. Instability over the whole period is measured as a weighted sum of the coefficient of variation for the first sub-period and the I_x index for the second sub-period, both indexes being weighted by the relative length of each sub-period in the time series. Similarly, copper prices show a clear peak in 1966 (Figure 2.4). Their I_x index could therefore be calculated both directly, through the CDV procedure, and indirectly, through a weighted procedure on the coefficients of variations for the two sub-periods. In this case very close results are obtained with the two methods, and only those obtained from the direct CDV procedure are presented in Table 2.3.

To the purpose of model selection, apart from a heuristic approach based on the inspection of the scattergram and comparison of regression results obtained from different functional forms, the Box-Cox procedure can hold useful indications (Dufour 1986; Godfrey 1988: ch. 4). For the analysis of mineral commodity prices in sub-section 4.2*b*, this procedure has been used to check for the suitability of (i) a linear as opposed to a lin-log (*steady state*) trend model, and (ii) a double-log as opposed to a log-lin (exponential) trend model. For case (ii), i.e. after transforming the commodity price time series (y) into natural logarithms, the procedure consists in estimating the following non-linear model:

$$\ln(y) = \alpha + \beta\ [(t^{\gamma} - 1)/\gamma] + u$$

with t being the time trend variable and u the error term. For $\gamma \rightarrow 0$, it can be shown that, solving in terms of derivative of the function t^{γ} in the origin, the right-hand side term of the equation converges to: $\alpha + \beta \ln(t) + u$. For $\gamma = 1$, instead, the equation would assume the log-lin form. Since alternative functional specifications are compared while maintaining the dependent variable in the same mathematical form, there was no need for a preliminary transformation of the variable *y*, following the Zarembka scaling (Dougherty 1992: 132-133; Spitzer 1982: 310).

The regressions were performed by using the non-linear least squares estimation provided by the Mfit computer package, and testing for *zero* and *unit* null hypotheses on the γ parameter estimate.

Appendix B

Analysis of growth and instability of mineral commodity prices

In order to proceed with estimates of closer concern to the group of mineral economies separately considered (sub-section 4.2*b*), it was necessary to examine the performance of their main export commodities in terms of price trends and instability. The choice of trend models was based on graphical inspection, comparison of statistical fits of alternative regression equations and application of the Box-Cox procedure, as outlined in Appendix A. These models were applied to constant unit prices in US dollars over the period 1960-1985, apart from shorter periods for diamonds and uranium, for each mineral representing the most relevant export commodity of a developing *mineral economy*, as defined in the text. Diamond prices were deflated with the manufacturing unit value (MUV) index, as defined and used by the World Bank as a deflator for primary commodity prices (World Bank 1993: section 1 and Table 20). Instability was measured with CDV's instability coefficient, applied in a more flexible way than these authors do (Appendix A). Average compound growth rates (g) were calculated based on the initial and final fitted observations of the trend regressions for the price series, except whenever no trend was detected, in which case the actual (initial) figure was preferred (Table 2.3).

Real prices of aluminium and bauxite presented a very unstable performance over the period, as witnessed by the high adjusting factor for the coefficient of variation, especially for aluminium (0.92). Aluminium underwent moreover an almost imperceptible long- term negative trend, captured by the presence of a significant t-statistic associated with the estimated trend coefficient in the loglinear model, in spite of a substantially low explanatory power of the model (the R^2 is only 0.18, and the adjusted R^2, used in this case for the estimation of instability even for bivariate trend regression models, is 0.15: see Appendix A in this concern). Bauxite seems to have followed a *steady state*-type growth, with an estimated elasticity coefficient equal to 0.16. An alternative lin-log specification for bauxite offers less reliable results.

The London Metal Exchange (LME) copper price has an even higher coefficient of variation than aluminium and bauxite prices, but its trend can be better modelled, through a cubic trend function. As shown by Figures 2.5 and 2.6, the copper price variable tended to increase up to 1966, and thereafter to decline with a fluctuating pattern which tends to even out towards the last part of the period. Between 1966 and 1985 copper suffered a deterioration of nearly -6% p.a. on average in its real price. However, some recovery has taken place in more recent years, with the 1989-1990 unit price level being equivalent to the mid-1970s value. Besides the presence of a better fit result, these latest trends have supported the rationale for preferring the cubic instead of the quadratic function as a base for an estimate of instability and growth of copper price, although the more pessimistic instability estimate obtained from the quadratic trend model has also been used.

For diamonds, distinctions can be made between (i) an initial period of unstable and tendentially increasing prices, until the mid-1970s, (ii) a price boom in the late 1970s, with a 13% annual average real growth in the period 1976-1980, and (iii) a subsequent period of contractionary tendencies in the early 1980s, apart from a recovery in 1985. An exponential (log-lin) function was applied over the period 1963-1984, in view of the availability for that period of a consistent set of price figures (sub-section 4.1). In a relatively similar pattern, gold prices kept roughly constant values up to 1971 in real terms, they increased afterwards up to the 1980 peak (which coincided with an 80% increase relative to the 1979 value), and finally faced a second break in 1981, with a decline until the mid-1980s. For this reason three alternative regression specifications were applied to gold prices: a piecewise linear model with two structural breaks (1971 and 1981), a simple one break-piecewise model with the estimation covering the 1971-1985 period, and a quadratic model, again excluding the pre-1971 period. An examination of the fitted plot suggested to adopt the simple spline function for the estimation of price instability, while the growth rate (+3.88) was calculated using the mean of the fitted values obtained from the last two models.

Discrepancies in the figures for iron ore according to two different sources are likely to be due to strong differences in international markets for this mineral: World Bank (1993) refers to Brazilian f.o.b. figures, whereas Roskill (1994) to US Bureau of Mines figures. For the first set of data a linear spline function with 1974 as the break year was justified by the more clearcut V-shape distribution of the price variable over time. For the second set, the application of such a function proves to be less effective in tracing the trend, because of an almost *flat* price behaviour before 1974 and a more marked curvilinear upswing thereafter, with a peak in 1981. A quadratic trend model starting from 1974 fitted the Roskill data better, although for an estimate of annual price growth (+1.62) the same averaging procedure (between fitted values of the quadratic and linear spline functions) as used for diamonds was preferred.

The petroleum price was relatively well-fitted with a spline function which takes into account the 240% jump in 1973-1974, so as to substantially reduce the upward bias in the instability estimate measured according to the simple coefficient of variation. Similarly, the sharp spike experienced by phosphate rock prices around 1974-1975, coupled with *wave*-shaped movements before and after that period (especially if years outside the sample are considered) was modelled with a quadratic spline trend (Suits *et al.* 1978) (Figure 2.6). These prices refer to the Moroccan market (World Bank 1993: 94). The only mineral economy particularly concerned with this commodity in the country sample here analysed, Togo, presents high instability in export revenues in this mineral over the estimation period, with export shares ranging from nearly 20% in years such as 1970, to more than 40% in e.g. 1973.

Tin prices similarly showed a highly unstable performance, with peaks in 1965, 1974 and 1979, and an overall positive linear trend. The Box-Cox procedure holds uncertain results in terms of the choice of a lin-log as an alternative to a linear model, and similar statistical results are obtained for the two regressions. The lin-log would definitely be a more realistic selection for purposes of short and medium-term projections, and even more so would be a quadratic model, in view of the slackening tendencies in tin prices following the 1986 price breakdown. However, the linear model was given preference since it avoids an apparent upward bias in the estimate of the growth variable in this case.

Finally, for uranium prices, only the 1973-1979 period was available, with graphical and similar descriptive information for earlier and later years: while a relative price stability in real terms seems to hold in the 1960s up to the early 1970s, prices then increased sharply until the 1976 peak and subsequently fell and stabilised around levels close to the 1974 figure from 1981 onwards. A quadratic trend model suits well the actual sample period and appears to adequately forecast the 1980 and 1981 figures. While the instability index was estimated on the base of the 1973-1979 period (a likely overestimation of the *full period* coefficient of variation being offset by the low value of the adjusting factor), the growth rate was calculated on the base of the 1981 forecast, under the assumption of no trend before the early 1970s and after the forecasted observations.

Figure 2.5 - Copper prices: quadratic trend (1980 constant US$/metric tonne)

Figure 2.6 - Copper prices: cubic trend (1980 constant US$/metric tonne)

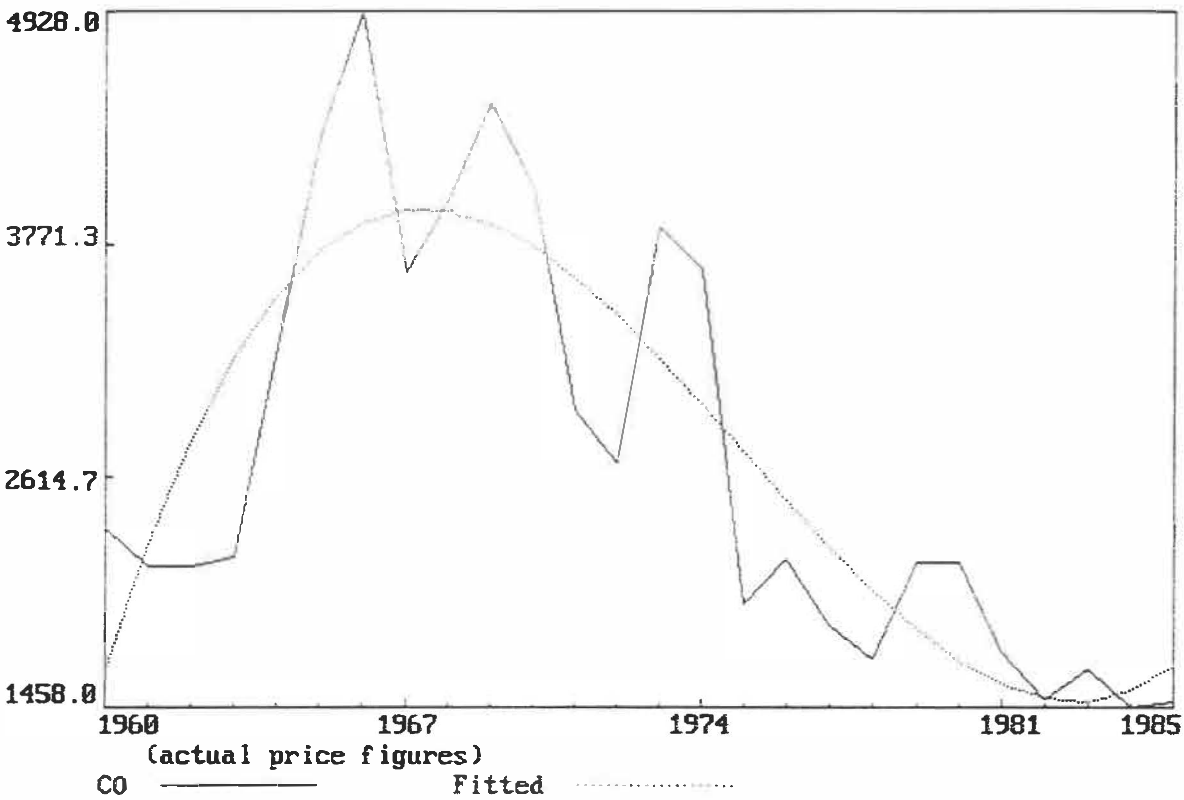
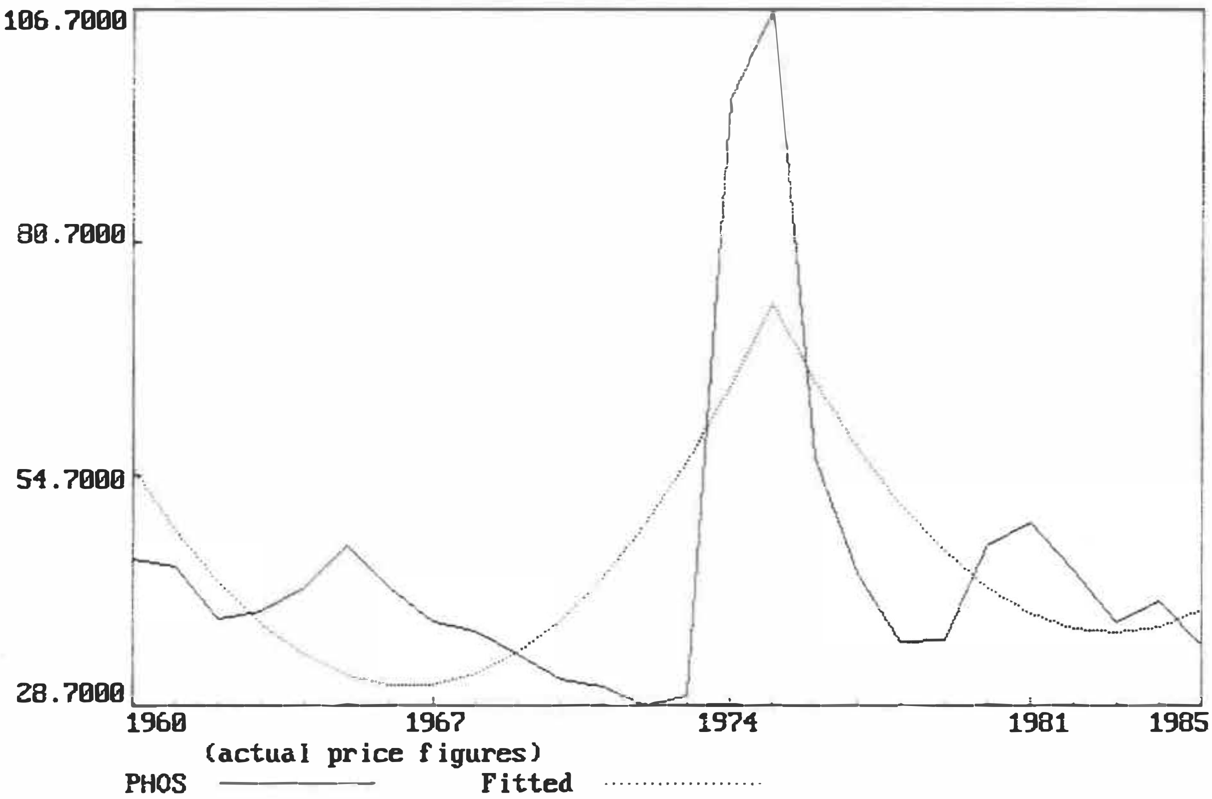


Figure 2.7 - Phosphate rock prices: quadratic spline trend (1980 const. US$/t)



3. Mineral resources, economic development and exchange rates: a survey

3.1 Introduction

The analysis in the preceding chapter aimed at formulating and testing a mixed endogenous growth-technology diffusion model for a developing mineral economy. The scope was aggregate, being an analysis of long-term growth potential. The empirical results highlight a double equilibrium S-shaped growth pattern. In terms of relative position of the *threshold* point, results are substantially similar to those obtained for developing countries as a whole. Even if with limited statistical significance, the econometric estimates do point, however, to an apparently offsetting role of mineral rents in countries with severe human capital constraints. This seems to imply the possibility of a disincentive effect for human capital development at low income levels for mineral economies.

According to these results, moreover, the African region is able to draw fewer of the benefits and runs more of the risks connected with a mineral export specialisation, even if unexplained components appear to be present particularly for some countries of this region. Long-term trends in the location and efficiency of mining production depend on (i) geological factors, i.e. size and conditions of exploitable mineral resources, and (ii) macroeconomic and policy factors affecting mineral exploitation, such as the capacity to attract and manage efficiently investment funds, infrastructural facilities, and the economic growth experienced by the producing country/region or by trading partner countries. According to UNCTAD (1994), the historical process of changes in *leadership* in mining production can be traced back following these two criteria.

Over the last two decades, some regions and countries appear to have increased their share in world mineral production to a significant extent (Australia, China, Latin America). Most industrial countries involved in mining have been facing production constraints, in terms of geological resource availability, energy costs or environmental controls. While still largely untapped in its potential for mineral resource exploitation, the shrinking relative position of the African region in terms of world mining production can instead be attributed to a greater extent to factors related to the second of the above criteria. Supply projections for the next few years indicate a continuation of this negative trend for African mineral production compared to other regions (World Bank 1992: 5). South Africa can be considered to be a special case, with the overlapping of problems of different types of producers.

Among the possible factors, the econometric analysis in chapter 2 suggests a relatively heavier negative impact of imprudent macroeconomic policies in most African mineral economies as an explanation for the underperformance of several mineral economies in Africa, compared to other developing regions. The exchange rate policy assumes a relevant role in this respect, especially in view of the possible links with commodity price fluctuations, and the implications for the production specialisation of a mineral economy. The following analysis broadens the scope investigated in chapter 2, with a view to examine in greater detail a set of interrelated topics, partly empirically tested in later chapters. Among these topics, particular attention is devoted to literature contributions which can help to study the relationships between mineral exports, exchange rates and development.

The analysis first considers controversial views as to how a predominant mineral resource endowment can influence individual aspects of the economic development of a developing economy. These controversies can partly be explained by features of the mineral, mining operations, country and period analysed. In this regard, an attempt at categorisation of African mineral economies according to various criteria is included in section 2. Section 3 first addresses a major area of research concerning some of the above aspects. This area, namely the variability and trends of mineral commodities in prices and quantities, had already been a core point for the analysis in chapter 2, and is reviewed here in the light of the controversial literature evidence. This section then switches into a survey of analytical approaches, econometric models and empirical results related to mineral markets and exchange rate determination, by once again highlighting alternative hypotheses and statistical evidence. Conclusions are drawn in section 4.

3.2 The role of mining in mineral-dependent developing economies

3.2.1 Effects on the local economy and domestic policies: an overview

Mining plays a crucial role in several LDCs, in view of its implications for external trade relations. The assessment of the influence of a large mining sector in a developing economy has produced partly controversial views. Some authors tend to highlight more positive implications, while others have focused on negative effects on the local economy and policy measures. Obviously, no view is completely positive or negative, but distinctions can be drawn according to individual aspects concerned and different minerals. The analyses of the economic impact of mining have focused on (i) impact on growth performance of a producer country as a whole and of other sectors of the economy; (ii) effects on the business cycles; (iii) inflation and exchange rate policy; (iv) income distribution and employment creation. Each of these areas has certain aspects overlapping with the others and includes some related specific topics, such as impact on investment, savings, external indebtedness, or education. Although still maintained at a general level, attention is especially paid here to the role of gold in South Africa.

a. *Growth effects*

In general terms, the controversy about the role of mining for an LDC economy can schematically be distinguished between neoclassical and structuralist interpretations (Daniel 1992). The former view tends to see this sector and its contribution to exports as functional to closing the internal and external financial *gaps* and to achieve a more efficient allocation of domestic resources. The structuralist view, instead, highlights problems associated with production, consumption and fiscal linkages of the mining sector, and the international distribution of mineral rents. Recent studies often contain a combination of elements of both interpretations.

According to an early study by Houghton (1973), gold mining contributed to income generation and stimulated the development of other sectors of the South African economy. This took place through a *trickle-down* of technical and management-financial progress to industrial sectors, and, indirectly, through heavy taxation on gold mines, with mining bearing the cost of heavy protectionism for other sectors. At an early stage of industrialisation in South Africa, in the inter-world war period, mining exports assured an inflow of foreign exchange needed to support the industrialisation process. Paradoxically, they had meanwhile to bear the costs of a highly protectionist import tariff structure (Davis 1993: 21).

Contrary to this view, other authors have stressed the disruptive effects of excessive investment programmes in sub-Saharan mineral producing countries, leading to overproduction in some minerals, and contributing to the slack and unstable trend in prices of many mineral commodities. These misachievements, coupled with the need for more flexibility of investment and for easier recovery of financial requirements, have led in some cases to a shift away from large-scale operations and an increasing interest towards small-scale mining (Salvatore 1989: 219). Moreover, with regard to its relations with the rest of the economy, the high dependence of an economy on minerals can become a constraint to the policy objective of improving international competitiveness and switching towards a greater value added production specialisation.

This negative impact can be felt especially in relatively less diversified economies: except for South Africa, all African mineral economies are more dependent on mining activities than major mineral producing countries in other developing regions (Yachir 1988)[1]. Statistical comparisons of non-fuel mineral with non-mineral economies suggest that this growth constraint may have affected both the industrial potential, and the agricultural sector. A frequently deteriorating performance in both sectors, accompanied by relatively higher and even increasing food import requirements in mineral economies, contrasts with substantially stable conditions in non-mineral economies (Nankani 1985: 42-46). Possible explanations for this deficiency include the agricultural labour shortage created by the sharp dual-wage pattern of mineral economies, trade regimes with an anti-export diversification bias, and price policies with an anti-agricultural and food production bias (e.g. government subsidies for food imports) (Bomsel 1992). The issue of implications for this and other sectors of the economy is controversial and intertwined with policy measures such as the exchange rate policy, which is examined below.

In terms of effects on domestic consumption, mineral economies are believed to have tended to consume above their long-term possibilities, under the illusion of a near-infinite horizon in their mineral rents. Closely related to this aspect and to the export earnings instability (briefly considered under *b* and *c* below and assessed in greater detail in section 3), a relatively higher international indebtedness is attributed to these economies, *ceteris paribus*. As far as non-fuel mineral LDCs are concerned, statistical evidence for the last two decades seems to support the above hypotheses, with a worsening performance of these economies in terms of propensity to save and to accumulate foreign debt, as opposed to other LDCs (Nankani 1985: 20-22, 49-

50; UNCTAD 1994a).

The effectiveness of a mineral-led growth strategy can be seen in broader terms as a dilemma between two partly alternative theories of mineral demand, both to some extent supported by empirical evidence (Vogely 1985: 161-179). According to one theory, first proposed in 1974 by an OECD study on steel, the amount of mineral consumption per GDP unit, defined as *intensity of use*, tends to vary along different levels of development following an inverted-U pattern. In this regard, income elasticity of demand of different countries is supposed to decrease from values higher than one to values lower than one, with increasing levels of income. The inverted-U hypothesis of mineral demand rests on the assumptions of (i) a progressive replacement of minerals by other products, because of changes in relative prices, (ii) a decrease in mineral-intensity of production, due to mineral-saving technological innovations, and (iii) a supposed reduced reliance of a service economy on minerals, compared to the needs of a growing industrial sector. On the other hand, a *life cycle* hypothesis of mineral demand suggests the presence, for an individual mineral, of cycles of growth, maturity and decline, followed by new upturns as a consequence of new demand and technology requirements.

b. Business cycle effects

A similar distinction, as made in the preceding sub-section, can be drawn with regard to implications for cyclical fluctuations. According to Houghton (1973), the stability of the gold mining industry has proved to be particularly useful during recessions, assuring significant inflows of government revenue. The argument of a stabilising role of gold mining can however be sustained only as long as gold prices were fixed independently of business cycles, before the 1971 breakdown of the international adjustable-peg system of exchange rates, while production costs varied accordingly. The net outcome tended to be an inverse relationship between changes in profit margins and in business cycles, thus stabilising the economy.

Besides Houghton, the argument of an anticyclical effect of gold mining has also been defended by Lombard and Stadler (1980). According to the latter study, mineral exports have tended to exercise an anticyclical influence on the rest of the South African economy also in the 1970s. This pattern would have been determined by the high dependence of mineral exports on overseas cycles, which have tended to precede South African business cycles.

Following alternative interpretations, in a relatively small and open economy such as South Africa, the high dependency on gold exports and the large share of mining within the overall economy have been a major factor contributing to the vulnerability of the economy to fluctuations in international markets, once gold stopped being sold at a fixed rate in the early 1970s (Abedian-Standish 1992a: 20; Müller 1992: 262-265).

Obidegwu and Nziramasanga (1981) identify some rigidity and asymmetrical responses in domestic investment and government spending programmes faced with unstable mineral export earnings. These rigidity and asymmetries imply a lack of adequate and efficient adjustments of the local economy to unexpected changes in international business cycles, and negative effects on the economy especially during recession periods. A windfall in commodity export receipts is often not fully used to increase productive investment and tends to fuel public consumption expenditures. By contrast, unexpected downward changes in world demand tend to disrupt local investment projects and are not followed by equivalent cutbacks on public expenditure programmes, thus possibly strengthening pressures on government borrowing and inflation.

According to a study by Dobozi (1990) on the copper industry, the common presence of a large state-owned mining sector in LDCs even implies procyclical effects on the economy. State mineral enterprises are likely to have a lower price elasticity of supply than private mining companies, possibly due to (i) their functional role for social and commercial policy objectives of the government, (ii) their greater involvement in countertrade arrangements and long-term supply agreements, and (iii) the protection against the effects of slumps in international prices for minerals granted to them by comparatively lower costs of production, deriving from lower energy costs, economies of scale, and higher average grade deposits.

Dobozi's results seem to support especially the first of the three explanations, with an unexpectedly negative supply elasticity: according to this author, this behaviour is explained by the pressing foreign exchange needs of many mineral-exporting LDCs, coupled with the pursuit of social objectives such as employment protection. Balance of payments and foreign indebtedness problems tend to worsen in phases of decline in mineral prices, thus forcing producer countries to increase the supply which is under direct state control, in an attempt to offset this negative trend. Negative mineral supply elasticities, associated with state mining enterprises, transmit even higher instability to world mineral prices and could explain the more stable mineral output levels attributed to the group of producer countries concerned.

If these countries hold a large share of the world mineral market, the mid-term effect on the economy can be considered procyclical, because of the unfavourable effects on international prices implied by downward-sloping supply curves. However, in view of the declining trend of the copper price for most of the period considered, Dobozi leaves open the possibility of an asymmetrical response of governments to balance of payments changes. This asymmetry would be evidenced by greater sensitivity and *perverse* effects in mineral supply during phases of deterioration. This pattern would contrast with a possible return of the copper mining supply to a standard behaviour, once a price is reached corresponding to a *minimum target* revenue (necessary to sustain serious balance of payments disequilibria), where the copper mine supply curve could take a normal shape. Other authors dismiss the hypothesis of relevance of the ownership pattern, by highlighting other factors supposed to lower the mineral supply elasticity, namely a lower level of economic development and a higher degree of dependence on mineral export receipts (Markowski-Radetzki 1987).

c. *Price and exchange rate effects*

The effects of a large mining sector on inflation and the exchange rate have also been subject to different interpretations. In South Africa the presence of gold is believed to have possibly saved the country from the experience of a progressive currency decline and high levels of inflation experienced by other developing countries: in view of the above outlined price-costs relationship, the lack of control on inflationary pressures would have seriously affected the profitability and output of gold mining in the country (Houghton 1973). Only following the breakdown of the gold parity system in August 1971 and the subsequent realignment of currencies, including a devaluation of the US dollar, was the devaluation of the rand seen as a necessary measure to maintain stability in, or reinforce, the official rand price of gold.

Later studies have stressed the destabilising effect of gold on South Africa's exchange rate, as pointed out in the beginning of this study. In this view, until the late 1980s, South African exchange rate policy is believed to have to some extent supported the mining sector, with the nominal exchange rate (henceforth NER) tending to trace the movements in the gold price especially in periods of a gold price slowdown. South African authorities are considered to have, however, tried to avoid a strong appreciation of the rand in periods of gold price rises. Since the late 1980s the interest of the manufacturing sector is believed to have been more protected, through a more stable RER (Kahn 1992; ADB 1995: 91-92)[2]. In a broader perspective, with a few exceptions, world prices of most mineral commodities are similarly subject to fluctuations which are beyond the control of producing countries. Depreciation has therefore often been undertaken as a measure to offset a decline in profitability of domestic mining production due to negative price changes in foreign currency terms.

According to the South African Reserve Bank (henceforth SARB) (1990), the gold price surges of the 1970s fuelled excessively optimistic expectations on the role of gold as a rescue agent for the South African economy faced with adverse shocks. As a consequence of this overstatement, macroeconomic policies were often too slack or prematurely relaxed, thus indirectly contributing to inflationary pressures. In this view, former favourable price trends for gold have also contributed to a supposed overvaluation of the RER, and hence possibly hampered the development potential of other exports and of import-competing industries. In this regard, a mild bout of Dutch disease is attributed to the role of the mineral sector, and gold particularly, in South Africa (SARB 1990; UNCTAD 1994a: 19).

By contrast to the pro-mining bias and *standard* Dutch disease model entailed for South Africa by the studies by Kahn (1992) and the SARB (1990), another interpretation lays more emphasis on a *non-standard* Dutch disease phenomenon occurring in South Africa. The latter view, expressed by Davis (1993: 45, 124-125), would see a booming and to a large extent inefficient government sector, instead of a booming mineral export sector, and a pro-industrialisation instead of a de-industrialisation effect, with mining actually being the damaged sector. This did not prevent South Africa, according to the latter study, from failing to industrialise beyond levels attained by some Latin American countries, or India. The author seems however to support his hypothesis especially in view of (i) the past fiscal contribution of mining to financing a protected manufacturing sector, and (ii) the market allocation distortions introduced by subsidies under the General Export Incentive Scheme (henceforth GEIS) implemented since 1990 (Davis 1993: 45-46, 118). The performance of the RER, which is at the core of the Dutch disease theory, is disregarded.

An empirical testing of these alternative interpretations is hampered by the interaction of numerous policy aspects. Empirical studies focusing on *primary commodity-oriented* economies highlight the relatively smaller contribution of the manufacturing sector to growth as compared to countries at a similar level of development. None of eight developing countries belonging to this category (including South Africa), considered by Chenery and Syrquin (1986), show a declining share of manufacturing in GDP over the 1950s and 1960s. If the analysis is shifted forward to the period 1960-1980, only two countries undergo such a decline. This result possibly implies that for several primary commodity-oriented countries the supposed constraining effects of the expansion and predominance of this sector for the industrial sector have tended to be offset by accelerated growth in domestic income (Chenery-Syrquin 1986: 99).

Chenery and Syrquin's estimates cannot be considered sufficient to discard a Dutch disease phenomenon, if one accepts that the analysis should take into account the "background of general growth, including technological progress elsewhere, and 'decline' should only be interpreted as a fall in the size of a sector relative to the outcome in the absence of a sectoral boom" (Corden-Neary 1982: 842). Moreover, Auty (1993: 41-42) argues that the extent of the Dutch disease problem may be seriously understated by this kind of analysis, if strong import protection is present, which is frequently the case for LDCs' manufacturing sectors. In this regard, in several developing mineral economies, mineral rents have contributed to the avoidance or postponement of the restructuring of certain sectors, allowing for the maintenance of subsidised domestic manufacturing and for increasing food imports, thus also in some cases crowding out a weak and unprotected agricultural sector (UNCTAD 1994a: 14-17).

The occurrence of long positive rent cycles for many minerals, in spite of frequent negative long-term price trends, can be a disincentive for mineral producing countries to liberalise their foreign trade regimes and eventually adjust their misaligned exchange rates, thus contributing in the medium term to increased production inefficiencies, inflation and unemployment. The resulting level of RER can in some instances suit a mining sector characterised by relatively higher productivity, but it is likely to be overvalued in terms of other sectors of the economy. These conditions have been experienced by countries such as Chile, Zambia and Zaire (Nankani 1985: 53; Norton 1991: 70-73).

With specific regard to inflation, some studies have stressed the cost-push effects on price levels of a large mining sector in a developing economy, coupled with demand-driven inflationary pressures in periods of commodity export booms (Adams-Behrman 1982; Nankani 1985: 38). Cost-push elements in a mineral economy may arise from spill-over effects of mineral wage rates on other sectors and from partly related constraints to domestic agricultural production. An example of unwillingness of the government to sterilise increased capital inflows and maintain financial stability in the early stages of a mineral export boom, with the related Dutch disease phenomenon discussed above, can been seen in the experience of Papua New Guinea (World Bank 1991).

Similarly, indirect (monetary and demand-pull) inflationary effects of inadequate policy responses to sudden falling mineral export revenues have also been examined. In this respect, during downswings in commodity prices, high inflation can persist or even worsen as a consequence of general price stickiness and deficit-financed expenditures faced by governments unwilling to cut expenditure programmes initiated under a previous price upswing (Obidegwu-Nziramasanga 1981: 32-33; Maizels 1992: ch. 4). Finally, a structuralist approach to inflation points to the supply rigidity and limited absorption capacity of a typical developing economy, contrasting with the ambitious investment plans frequently pursued in mineral economies (Nankani 1985: 38).

d. Income distribution and employment effects

In terms of income distribution effects, gold mining has been seen by Houghton (1973) as a relevant source of employment and income for low-income households in South Africa and neighbouring countries. On the other hand, a high dependence on mineral exports can exacerbate the dualistic structure and accentuate the regional differences in infrastructural development and social inequality of a developing country economy. This economy can schematically be characterised by a capital-intensive *enclave*-type mining sector, and traditional low-growth (especially agricultural) production activities, with modest inter-sectoral links (Thoborn 1977: 239; Hopkins-van der Hoeven 1983). Mineral-dependent countries or regions are, in the latter view, likely to show a more skewed distribution in basic needs fulfillment across the total population.

Negative distributional implications would particularly be present whenever the control and ownership of production and access to technology are highly concentrated in a small share of the population. The drain on foreign exchange and the lack of sufficient linkages with the rest of the economy typical of a predominantly foreign-owned mining sector were tentatively redressed with progressive government takeover of ownership and control, such as in the late 1960s and 1970s in Zambia for copper mining. These changes are considered to have contributed to a more balanced production structure and helped the Zambian economy to a greater extent than would have been allowed by previous conditions (Obidegwu-Nziramasanga 1981: 18-21), although this argument is utterly criticised by other authors examining the Zambian experience (Norton 1991; Bomsel 1992). These contradictory views can be partly explained by the coincidence of the nationalisation process with a reverse of the copper sector's fortunes, reflecting wrong expectations by the Zambian government: while the previous favourable copper prices stimulated infrastructural development and migration inflows in the Copperbelt, the price slump of the

1970s and 1980s induced migration out of the mines and weakened the whole economy (ADB 1995: 247-248).

As far as employment is concerned, dualistic models for mineral economies tend to stress the drawbacks of capital-intensive mineral industries for a developing country. A distinction could be drawn between different mineral commodities. For instance, gold mining is more labour-intensive than coal, where mechanisation has been easier to implement. Increasing depth of mining and lower ore grades, among other factors, have however contributed to a decrease in the productivity of South African gold mines, hence affecting the employment capacity of this sector (Greyling 1989). In broader terms, among mineral-based industries, only primary metal processing is considered to be labour-intensive. Besides, many mineral processing activities need advanced technologies and labour skills, often lacking in LDCs. These features of the mining sector may explain why mineral economies have recorded, on average, relatively higher unemployment rates, greater technological and wage dualism, and lower educational achievements (as proxied by school enrolment ratios, at different levels of formal education) (Nankani 1985: 33-35).

If the dualistic model interpretation is correct, the alleged severity of multiplier effects of primary commodity price fluctuations on non-export sectors of the economy (Maizels 1992: ch. 4) would apply to a lesser degree in a mineral economy than in an economy with commodity exports more closely linked to the domestic production structure. A World Bank study has stressed the dominance of the *fiscal linkage*, as opposed to direct market (production or consumption) linkages, in mineral economies (Nankani 1985). In this respect, the overall implications of the presence of a large mining sector for the local distribution of income, provision of public services and development of other sectors would to a great extent depend on the willingness and capability of the government to tax mining effectively and to invest productively in priority development areas.

Besides the direct implications for distribution of income and employment, indirect effects have been analysed, although to a lesser degree, given the difficulty of an adequate assessment. The latter include, for instance, the distributional effects of government expenditures financed by a predominantly mineral export-related source of revenue. In this regard, Adams and Behrman (1982: 24) suggest that export revenue fluctuations, typical of many mineral producing countries, have tended to be relatively more harmful for labour than capital, and for low-income rather than high-income population groups, with cuts in social expenditure during downswings mainly affecting the poorer.

3.2.2 Some structural differences within the category

Beyond the neoclassical-structuralist controversy, the reasons for contradicting interpretations by various authors on the role of mining for a developing economy partly arise out of different features of the minerals and countries focused on by each study. In this regard, it may be useful to draw some distinctions among mineral economies, based on certain criteria. One of these criteria, the ownership pattern of the mines, is mentioned in the preceding analysis (Dobozi 1990). Other criteria are suggested by a World Bank study, which examines general features of the economy as well as particular characteristics of the mineral sector (Nankani 1985), and by a similar UNCTAD study (1994). Among these criteria, the following can be considered:

i. stage of mineral exploitation, as proxied by the ratio of the estimated value of mineral reserves per capita to the value of (present) capital stock per capita;
ii. length of mining history;
iii. mineral wealth per capita;
iv. human resource development;
v. market size (e.g. population);
vi. type of government;
vii. corporate concentration;

viii. pattern of ownership and control (state vs. private participation).

In Table 3.1 a few African mineral economies[3] (excluding North African oil-exporting countries) are classified according to the first two criteria listed here. On the whole, while in terms of the stage of mineral exploitation there seems to be some effort at export diversification in *late* stages, this does not appear to be the case according to the length of the presence of a predominant mining sector in the economy (Nankani 1985). Mineral economies have therefore tended to keep their export concentration in minerals unchanged as long as sufficient reserves are available relative to their level of capital stock.

Table 3.1 - Classification of a few African mineral economies according to two criteria concerning the mining sector

		stage of mineral exploitation		
		early (>10)	middle (5-10)	late (<5)
length of mining history	new	Guinea Liberia	Gabon Nigeria Zaire	Congo Togo
	old	Morocco	Zambia	

Source: Nankani (1985: 63; 80) (in parentheses, for the stage of mineral exploitation: ratio of mineral reserves per capita to capital stock per capita)

Mineral wealth per capita is an indicator of actual and potential relevance of the sector. If considered in coincidence with the other criteria listed above, a number of preconditions for a more effective use of this asset can be hypothesized. These preconditions, partly implied by the analysis in chapter 2 and sub-section 2.1 in this chapter, pertain to policy decisions on (i) the inter-generational welfare distribution, and (ii), given a certain outcome for (i), the domestic resource allocation.

With regard to the first aspect, a correct pace of mineral exploitation should be implemented. Arguments favouring a postponement of mineral exploitation, due to absorption capacity constraints or deferral of potential gains for future generations, have been criticised in view of the risks connected with technological changes (Radetzki 1992). These changes could determine a progressive decline in demand of the mineral, or obsolescence in one kind of extraction in favour of alternative sources (e.g. land-based as compared to deep-sea level mining), partly reflecting the inverted-U hypothesis considered earlier. In the absence of any demand recovery, the decision to slow down the pace of exploitation can prove to be a waste of potential welfare effects.

On the other hand, with reference to point (ii) above, developing mineral economies have often misused their mineral rents. In this regard, a bi-directionality can be hypothesized between the shortage of human resources and the squandering of mineral rents: the former constraint would impinge upon an efficient and full use of the mineral base, while a high dependency of the economy on these rents, especially at low levels of development, may favour their inadequate allocation.

The last three criteria are particularly relevant for an understanding of the problems characterising the mining sector in African countries. The degree of corporate concentration is to a large extent due to geological factors. Because of high grade occurrences and/or small size of deposits, lower barriers to entry or more stringent diseconomies of scale are typical of mineral industries such as gold (although not in South Africa), tin or lead, thus allowing a relatively low degree of concentration. The opposite occurs for other minerals, such as bauxite, copper, and iron ore, for which large-scale opencast mining is more common.

Besides the geological characteristics of each mineral, domestic policies have to a great extent influenced the structure of the mining industry. With the exception of South Africa, African mining is generally believed to suffer from a *missing middle* (World Bank 1992: 6), that is an insufficient presence of small and medium-sized enterprises. While few countries in the region have promoted joint ventures between the private sector and the government (Botswana, Gabon, Ghana, Guinea, Niger), or even allowed full private ownership to mining operations (Namibia, Sierra Leone, Zimbabwe), several African mineral economies have relied on large parastatal mining companies, which have often gradually lost international competitiveness and technological update[4]. The public sector orientation of African mineral economies has been accompanied by a flourishing of informal and artisanal mining and smuggling, and inefficiency of mining institutions, concerned with maximising short-term rent collection rather than long-term objectives. In other regions the public sector has been more able to expand production and improve the local technological know-how, through a better interaction with foreign and local producers (UNCTAD 1994; World Bank 1992).

In terms of medium- and long-term prospects, opposing views are expressed. An optimistic hypothesis suggests a progressive catching up of relatively less developed mineral economies towards the economically more advanced mineral-exporting countries, and an improving performance on average over different stages of mineral exploitation. A pessimistic hypothesis, by contrast, envisages widening gaps in development levels within this group of economies and a persistently poor performance for these economies as a whole, at any stage of mineral exploitation. In terms of long-term growth over the period 1960-1985, the econometric analysis in chapter 2 reveals how only 4 out of 26 mineral economies, i.e. Guinea, Niger, Sierra Leone and Zaire, lie below the estimated weak convergence inflexion point for 1985. Although not guaranteeing a convergence in real per capita incomes, this result implies that for most mineral economies there is a scope for equalization of economic growth rates in the long run.

3.3 Mineral commodities, exchange rates and development: an overview of hypotheses and empirical results

3.3.1 Fluctuations and trends in mineral commodity prices and quantities

In order to examine the relationship between changes in prices and quantities of mineral commodity exports and RER variations, a distinction should be drawn between a short-term and a long-term framework. The former is concerned with problems of instability in demand and supply and possible volatility in prices and exchange rates, while the latter framework is more directly linked to issues such as trends in economic growth and terms of trade. These two frameworks are identified as the two major dimensions of the *commodity problem*, and can be considered connected to some extent.

High short- and medium-term fluctuations render investment planning more difficult and may also discourage risk-averse importers, diverting users towards substitutes and thus contributing to downward long-term pressures on commodity terms of trade (Adams-Behrman 1982: 21). The efficiency of investment is lowered and, besides the disrupting effects on investment projects during sudden unexpected downward changes, no full use of resources for potential investment is feasible after unexpected upward changes, due to the rigidity of economic structures in LDCs (Obidegwu-Nziramasanga 1981). On the supply side, greater price and quantity instability would be reflected in a need for larger foreign exchange reserves than would be required under more stable export earnings, unless imports are also allowed to fluctuate, and in sudden bursts of inflation (Thoborn 1977). The alternative of import restraints is likely to lead to capital input shortages in LDCs. More unpredictable export earnings will also affect government revenues in LDCs, which still heavily rely on this source of revenue for taxation, and consequently induce deficit-related inflation and/or disruption of development programmes (Gyimah-Brempong 1991). Mineral economies' export earnings instability is considered to have also contributed to their higher exposure to foreign indebtedness (Nankani 1985: 49).

Some counterarguments tend to downgrade the relevance of commodity fluctuations as a disrupting element for a developing economy. The common view on an asymmetrical response of investment to upturns and downturns is reversed by some authors in favour of the former (i.e. more investment would be accomplished as a consequence of upswings than discouraged during downswings), who also hypothesize a higher savings propensity in the long-term during periods of higher instability, following a *permanent income* pattern (Adams-Behrman 1982: 21). For the least developed mineral economies, this argument is questionable, since a large share of domestic consumption is at subsistence levels and domestic savings are therefore likely to be affected relatively more.

As briefly considered also in chapter 2, empirical analyses focusing on the link between short-term commodity export *price* instability and growth show controversial results, apart from the destabilising short-term impact (Dick *et al.* 1983). With reference to export *earnings* by sub-Saharan African countries, a pooled analysis on 34 countries over the period 1960-1986 provides empirical support for the view that the non-export sector is stimulated by export growth, and negatively affected by export instability (Gyimah-Brempong 1991). Recently attention has been paid to volatility in the *terms of trade*: if major primary commodity price instability is to a large extent mirrored by a similar pattern in manufacturing commodities, the impact on terms of trade and, according to Singer and Lutz (1994), on the economy of primary commodity producer countries would be "neutralised or greatly mitigated" (*ibidem*: 92). By relying on cross-section econometric estimates on ca. 96-99 countries and adopting a similar functional form as Gyimah-Brempong, these authors surprisingly find a positive impact of terms of trade volatility for certain country sub-groups, such as sub-Saharan and low-income countries, as opposed to a negative growth effect for other categories, such as primary commodity (industrial and developing) producers[5].

As examined in section 2, with regard to the second framework, i.e. long-term aspects, in general terms a consensus seems to prevail on the negative effects on growth of unfavourable tendencies in international demand and prices of these commodities. Nevertheless, some authors have argued against this interpretation, by highlighting the presence of a large base of a certain mineral, such as gold in particular, as a cushion against otherwise declining terms of trade (Standish 1992: 102) and enduring depreciation of the local currency.

The existence of a clear link between short- and medium-term fluctuations and a long-term unfavourable trend seems to be questioned by Maizels (1992: ch. 1): while in the 1970s extremely large short-term price variations occurred because of sudden external shocks or major market shortages, such as in the oil and coffee markets, in the following decade smaller variations were accompanied by a declining trend. Maizels's remark seems however to complement, rather than contradict, the above interpretation. In the 1980s the negative trend in demand of several commodities is likely to have suffered from the combined effects of severe fluctuations in the previous two decades and contingent causes of the 1980s possibly accelerating the relative decline in world demand. The latter causes are thought to have included appreciations in the US dollar exchange rate, higher costs of holding stocks due to sharp interest rate increases (Maizels 1992: 17-18), and the export policies of several producing countries affected by external debt problems.

Low short-run supply and demand price elasticities are generally held responsible for high sensitivity of commodity prices to sudden and sharp changes in demand and supply, respectively. On the supply side, long gestation periods of mines decrease the potential for a quick adjustment to changing demand conditions, especially whenever production capacity is fully used. The exploration and opening up of new deposits, stimulated by increased demand, can even require several years of delay. In cases such as gold the existence of stocks can help smooth down market instability, although stocks are thought to have, in some cases, partly lost their stabilising effects (Daniel 1992).

On the demand side, demand for many minerals is considered to be very elastic to income changes accompanying business cycles, thus also contributing to market instability. Relatively high mineral-intensive sectors, such as capital equipment, consumer durables, transportation and construction, are particularly sensitive to business cycle fluctuations (Vogely 1985: 383-415). An example is represented by the severe contraction in demand for iron ore, and the subsequent decline in production in 1982-1983, following the growth reversal experienced by the steel industry worldwide in the early 1980s (Franz *et al.* 1986).

Of the two sources of instability in mineral export earnings, price volatility is considered to have mattered relatively more for mineral markets not subject to supply arrangements among producers, such as copper and gold. By contrast, whenever these arrangements dominate the mineral market, such as for iron and steel, or diamonds, revenue instability is believed to have mainly been determined by changes in the volumes of sales (Daniel 1992: 84). In empirical analyses, unit prices have usually been found to be a more relevant factor than volumes (Obidegwu-Nziramasanga 1981: 25; Mainardi 1992). Given low short-run price elasticities, large demand and supply shifts bring about much wider price fluctuations than would occur with higher price elasticities. However, in this case price instability would be inversely associated with quantity instability in the short run (Adams-Behrman 1982: 56). Another interpretation of price instability focuses on the declining market power of major exporting countries, which are supposed to have played a stabilising role in world commodity prices (apart from occasional sharp changes).

Besides their volatility, commodity price changes are believed to be characterised by asymmetry, with short and sharp peaks followed by long and shallow troughs. While peaks tend to be associated with temporary commodity booms, price crashes often follow (frequently temporary) breakdowns of cartels, such as diamonds in 1981 and tin in 1986 (Bevan *et al.* 1993).

Many aspects of the above problems are commonly shared with agricultural commodities. However, on the whole minerals, as compared with agricultural commodities, are characterised by:

i. less diversity in ownership patterns and greater presence of integrated oligopolistic markets (multinationals) and in many cases state enterprises, thus implying an easier implementation and administration of taxes;
ii. if *enclave*-type mining activities are predominant, relatively greater relevance of fiscal linkages, as opposed to absence or weakness of production and consumption linkages;
iii. less seasonality in production;
iv. frequently, a market for scrap or secondary mineral;
v. mostly, higher income elasticity of demand (even if distinctions could be made in terms of the inverted-U and life cycle hypotheses mentioned in section 2);
vi. (if compared with tropical agricultural commodities), substantial production occurring outside developing countries (Thoborn 1977; Adams-Behrman 1982; Hirschman 1977; Nankani 1985).

These specific features of minerals should be taken into account for modelling purposes.

3.3.2 Mineral commodity models and exchange rate analysis

a. *A general framework for mineral market modelling*

For the purpose of analysing short- and medium-term fluctuations and long-run trends, formal mineral market models can either focus on one country, or extend their scope to the world market. Moreover, the coverage of the analysis can be limited to functional relations directly concerning the mineral commodity, or encompass interactions with the rest of the economy. The objectives of mineral commodity models are usually identified in (i) studying certain features of a mineral market, as consequences or determinants of some other characteristics of the sector or other sectors of the economy, and (ii) simulating the potential impact of changes in the identified determinants and forecasting future values, such as production or prices (Gocht *et al.* 1988: 179).

Examples of functional relations tested in econometric models applied to minerals are provided in Table 3.2. The table can only represent a schematic and incomplete overview of mineral market models. The wide variety of these models is explained by the different characteristics of the various minerals concerned, such as market structures, nature of end uses, and government policies.

As outlined in Gocht *et al.* (1988: 181), a *typical* mineral market model can consist in a simultaneous equation system with three equations, for demand, supply and price functions respectively, and one identity for mineral inventories (equal to the sum of this variable with one year lag and the difference between current supply and demand). As far as consumers' demand is concerned, other factors held constant, one can assume an inverse relationship with the price of the mineral and of complementary goods and services (e.g. copper and zinc in brass), and a direct relationship with the relative price of a substitute material (e.g. aluminium *versus* copper, or oil *versus* coal) and with level of income or industrial activity.

A similar approach to mineral modelling as in Gocht *et al.* is followed in Vogely (1985: 383-415): minerals can be classified into three groups, i.e. metals, non-metals, and energy minerals. Typically, unwrought metals are not final goods, since the demand for metals is derived and dependent on the possibility of replacement of a metal with other metals and non-metals with similar characteristics. However, in the short-run and at an aggregate level of analysis, major determinants of demand can be identified in level of income and price variables only (Table 3.2). With regard to a mineral commodity characterised by a relatively large presence of stocks, such as gold, Lipschitz and Otani (1977) formulate a second demand function. This function incorporates stock adjustment effects due to speculative demand transactions, which are assumed to depend on expectations on the metal price performance and the rate of appreciation of competing financial and real assets.

Mineral supply functions are generally expressed in terms of price of the mineral, with an expected positive sign, production costs, favourable local geological conditions and government policies, and market structures. The more concentrated the market structure is, the higher will be the mineral's price and the lower its supply. However, the influence of monopolistic or oligopolistic markets can be weakened by the fact that, for certain minerals, the level of mine production is only one aspect of supply. For instance, world supply of gold is also determined by sales and purchases of the IMF and government-controlled financial and investment institutions, and by net sales of the CIS countries. Moreover, similarly to demand functions, a distinction has been drawn between a low short-run price elasticity of supply (due to output and capacity constraints) and higher-than-unitary long-run elasticities (constrained by known deposits). Determinants of long-term supply include such factors as available technology and accessibility of new deposits (Gocht *et al*. 1988: 168).

A non-standard hypothesis on the supply function attributes a negative price elasticity to copper mining, under certain conditions of mine ownership and balance of payments, as outlined in sub-section 2.1*b* above with regard to a study by Dobozi (1990). In the latter study, while no significant value for price elasticity is found for private enterprises in developing countries, short- and long-run elasticities turn out to be negative for state mineral enterprises in countries with severe balance of payments problems. In this regard, mineral output and exports would act as a macroeconomic tool for balance of payments adjustment.

Alternative explanations of a relatively more price-inelastic mineral supply in developing countries than in industrial countries have been based on macroeconomic variables, such as relative importance of mineral export revenues. Supply price elasticities are also found to differ according to scale of mining operations, with smaller long-run price responsiveness in the capital-intensive large scale sector (Adams-Behrman 1982: 152). In chapter 6 this subject is reconsidered in greater detail.

The simultaneous equation model presented by Gocht *et al.* (1988) is closed by relating prices to the ratio inventories/demand. In other models mineral prices are considered exogenous, since mineral pricing is influenced by the presence of international metal exchanges and international cartels or commodity agreements. The realized price of copper export sales in Zambia is estimated by Obidegwu and Nziramasanga (1981: 54) as a function of the LME price, the former being closely related to the latter price. Similar to other minerals, the LME price of copper is characterised by high volatility in the short run, due to changes in stocks, speculative activity, and shifts in demand and supply (Obidegwu-Nziramasanga 1981: 12). The LME copper price is considered as an international reference, representing a basis for negotiations in several countries (Labys 1989: 46).

While the models considered above are mainly sectoral, since they are concerned with individual mineral commodities within a framework of one country or several producer countries, a broader perspective is assumed by multisector models. The latter models extend the scope to other aspects of the economy, with a view to studying in greater detail the links between variables strictly related to mining and the rest of the economy (Obidegwu-Nziramasanga 1981; Adams-Behrman 1982). Particular attention is paid by these models to examining relations such as total government revenues and the performance of mineral exports, or assessing the effects of trends and fluctuations in mineral commodity prices on growth, employment and inflation, in the short and long run. The role of alternative government policies is also taken into account. In the case of Zambia, Obidegwu and Nziramasanga test the model also for possible asymmetric responses of different components of aggregate demand to upward and downward movements in copper export earnings and prices.

b. Real exchange rate analysis: possible background for mineral commodity modelling

Among aspects of the mineral economy considered in multisector models, the impact on the RER has so far received limited attention, in terms of either theoretical contributions or empirical analyses. These analyses broadly focus on possible determinants of the RER and, in turn, effects of the latter for real growth.

b.1 Impact assessment of exchange rate policies

A strand of research carried out in the last few years concerns the role of the exchange rate as an economic stabilisation tool. The problem of variability of exchange rates over the last two decades consists in both volatility, or short-term variability, and misalignment, i.e. persistent departures of the RER from its long-run equilibrium. The latter has often been defined as a RER consistent with PPP or balance of payments equilibrium. Alternative definitions have recently been proposed, as examined in chapter 5.

According to an *orthodox* view of the effectiveness of exchange rate policy in LDCs, exchange rate misalignment can be redressed in a typical LDC case through a devaluation, coupled with a consistent policy coordination effort. At a level of production below full employment, nominal devaluations will stimulate output. The volatility of the NER is not considered to be a serious problem for an economy and is believed to have relatively little impact on the national inflation rate (Goldstein *et al.* 1992: 16-21). However, the authors of the IMF report quoted here highlight how, under the present international exchange rate regime and given the stickiness of prices and costs to changes in nominal exchange rates, the high short-term variability of nominal exchange rates has to a large extent spilt over into real exchange rates. In this regard, RER fluctuations appear to be systematically associated with movements of corresponding nominal rates (Baille-McMahon 1989: 19-20).

The structuralist critique of traditional stabilisation theory stresses the possible negative implications of devaluations for a developing economy, characterised by low price elasticity of imports and exports. These implications include worsening of the trade balance and contractionary effects on aggregate demand, regressive income distribution effects (since overall prices tend to rise more than wages), and, even in the absence of negative net demand effects, possible recessionary and inflationary supply-side effects (Edwards 1986).

Empirical testing of the above controversial arguments has in some cases disregarded the effects of other macroeconomic policies and external shocks, such as terms of trade fluctuations. Mengisteab (1991) does not find any statistically significant evidence of a short-term impact of real devaluations on trade flows of sub-Saharan African countries, while mixed evidence appears on a five-year lag. Broadening the scope of the analysis, in a multivariate regression analysis on pooled data for 12 developing countries, Edwards (1986) estimates output as a function of the RER, proxies for fiscal and monetary policies, the external terms of trade, and a trend variable for output growth (Table 3.2)[6]. Contrary to Mengisteab's findings, the contractionary hypothesis of devaluation is statistically supported only in the very short run (contemporaneous), but the net effect of devaluations on output is shown to become neutral if the second (lagged) year is included. Contrary to expectations, terms of trade effects, measured either in terms of levels or of rate of change, prove to be insignificant.

With regard to primary commodity prices, the impact of movements in the US dollar effective exchange rate has been investigated empirically, but the underlying causal relationship is still not clearly understood. Some statistical findings suggest an above-unit US dollar exchange rate elasticity of commodity prices, while others point to a lack of a robust relationship (Winters-Sapsford 1989). According to Holtham (1988: 237), the effects of the US dollar effective exchange rate variations on minerals and food prices are likely to be indirect: an inverse relationship exists between these prices (with a 2-year lag for minerals) and international real interest rates, and the latter are also responsible for pressures towards depreciation or appreciation in the US dollar.

According to Maizels (1992), there is no simple answer to this question, since the net demand effect of a change in the US dollar exchange rate on internationally traded commodities (mostly denominated in this currency) will depend on the relative shares of the US, as opposed to non-dollar countries' markets in total world consumption for a particular commodity, and the demand elasticities for that commodity in the different markets. In practice, however, the US dollar appreciation against other industrial countries' currencies in the early 1980s is found to have forced many LDCs to apply real depreciations, contributing to downward pressures in US dollar prices of LDCs' export commodities (Gilbert 1989). The depreciating tendency in the US dollar during the period 1985-1987 was still accompanied by a slackening trend in commodity prices, due to oversupply in world markets (Maizels 1992: ch. 1).

b.2 Determinants of real and nominal exchange rate movements

Another group of analyses has considered the RER not as an exogenous, but as a dependent variable, with a view to examining its possible determinants. According to the PPP theory, any deviation of the RER from its long-run trend is random and will reflect some degree of misalignment, since movements in the NER should be exactly offset by opposite movements in price levels of tradables and "potentially" tradables (disregarding tariff policies) (Baille-McMahon 1989: 16). The long-run trend would be determined by an equilibrium year, which identifies an equilibrium RER. The high post-1973 volatility in RERs undermines the possibility of a robust statistical testing of this hypothesis, i.e. that the RER follows a stationary stochastic process (defined in chapter 4, section 2), and tends to cast doubt on its validity in the short and medium term, although the PPP theory strictly refers to a long-run equilibrium. Moreover, even according to this hypothesis the RER is allowed to stray away from its PPP-determined rate as a consequence of such factors as currency speculations and government intervention (MacDonald 1988), and the equilibrium RER can be altered by radical changes in economic conditions and international trade (Cassel, quoted by Officer 1982: 254). Results of most studies on RER in industrial countries do not reject the opposite hypothesis of non-stationarity, although Edwards (1989: 118-127) suggests that this may be due to an insufficient length in the time series analysed.

The PPP hypothesis received support in the 1970s, whereas more recently it is believed to hold true only for countries with hyperinflation or in the very long run. As an alternative to the PPP hypothesis, given a small open economy with perfect capital mobility and perfectly elastic aggregate supply curve, the Mundell-Fleming model views a strengthening of the RER as a consequence of a loose fiscal policy, while the opposite effect would follow from an expansionary monetary policy. In the former case, a RER appreciation would be determined by capital inflows linked to real interest rate differentials, as occurring in the US economy in the early 1980s (but opposite to its experience in the second half of the decade) (MacDonald 1988). The model therefore suggests an expansive monetary policy for the objectives of a trade balance improvement and income growth, through a RER depreciation. Similar to the PPP hypothesis, a mechanism of regressive expectations is supposed to be at work, with short and medium-term deviations from a long-run equilibrium.

More recent interpretations have extended the analysis of exchange rate determination to include the role of expectations by investors and asset holders (Douch 1989). Edwards (1988: 9) distinguishes between macroeconomic fundamentals affecting the *equilibrium* RER, supposed to be real variables only, and real and monetary variables influencing the RER. The PPP hypothesis (or, rather, its "simplest" version) of a near long-run constancy in the equilibrium RER is rejected, by focusing on domestic and external fundamentals which can modify over time a long-run sustainable internal and external position of a country. These factors include the redistribution of government expenditure between tradables and non-tradables, the imposition or relaxation of controls on capital movements, trade and fiscal policy instruments affecting the demand for import/export, permanent changes in the terms of trade, and international transfers such as aid receipts. Short-term frictions or long-term misalignments of the actual from the equilibrium rate can occur because of lack of adjustment of the actual rate to these and other real macroeconomic fundamentals (*structural* misalignment), or as a consequence of inconsistencies between macroeconomic policy variables, such as a fiscal deficit or excess money supply, and the nominal exchange rate (*macroeconomic induced* misalignment) (Edwards 1988: ch. 2). A more detailed assessment of studies on determinants of RER misalignment, and related econometric models, is presented in chapter 5 (Appendix).

Another recent approach has strayed away from the search for macroeconomic *fundamentals* and stresses the presence of a *chaotic* environment allowing the RER to be forecast only for a limited time period. Hence, the "technical analysts" of the RER emphasize the need to study the time series properties of the exchange rate (De Grauwe *et al*. 1993). Similar controversial evidence also seems to concern the nature of the NER behaviour. Some authors assume the NER to follow a non-stationary random walk, determined by largely *unobservable* factors, which are to some extent unrelated to fundamental macro variables and are also responsible for the volatile behaviour of stock market prices and several commodity prices. Others attribute more importance to the role of the Central Bank in adjusting the NER according to changes occurring in some fundamental macro variables, such as the balance of payments position, or the gold price for South Africa (Baille-McMahon 1989; Kahn 1992)[7].

Examples of studies in contrast with the random walk hypothesis on the RER and the NER are presented by Edwards (1986a and 1989: ch. 5). The 1986 study consists of a simultaneous equation model applied to annual data for Colombia, and covers the period 1952-1980. Regression results point to a relevant role of booming coffee prices in determining a RER appreciation, through an insufficiently sterilised accumulation of foreign reserves and the classical Dutch disease-related effects on income and domestic demand. In a later application of a multivariate regression to quarterly data for Chile, subsequently extended to pooled data for a group of developing countries, Edwards (1989) finds that in Chile in the late 1970s a severe terms of trade worsening, associated with declining copper prices and accompanied by substantial import tariff reductions, necessitated a real depreciation, in order to maintain external equilibrium. In the early 1980s, by contrast, a RER appreciation was brought about by high inflows of foreign capital and an anti-inflationary fixing of the NER (Table 3.2). In further developments of the model, the importance of consistent and sustainable fiscal and monetary policies is also stressed, as a necessary element in order to prevent RER misalignment.

3.4 Conclusions

Beyond specific controversial aspects, most empirical studies on the role of the mining sector for a developing economy indicate a number of risks associated with an excessive reliance of local development strategies on this sector. These risks include (i) increased constraints on the development of other sectors of the economy; (ii) unstable levels of domestic savings and investment, coupled with high levels of consumption and foreign debt exposure; (iii) production inefficiencies and misallocation of factors of production; (iv) maintenance or worsening of dualistic structures and distributional imbalances in the economy; and (v) disincentives to liberalise foreign trade and misalignment in the RER. These risks will be higher, or vice versa the possible benefits will be reduced, whenever inter-sectoral production links are weak, the *fiscal linkage* does not operate effectively, and mineral export revenues undergo severe instability, shocks or unfavourable trends. Given its implications for exchange rate policy, this last problem has been examined in greater detail.

Following a broad regional distinction, mining development has been stagnating in several African countries, in contrast with a dynamic performance by Asian and Latin American producers. Technological innovations for improving the exploration capability have been disregarded, for the sake of short-term production goals, especially in countries affected by balance of payments problems and predominance of large mining parastatals, such as Zambia[8]. While the present knowledge of the geology of most countries of the region allows one to presume that major deposits are yet to be discovered and that the geological potential of the continent is underutilised, this lack of adequate developments in the sector hampers a sufficient pace of replacement of known resources by new deposits (World Bank 1992).

While analyses of the evolution of mineral commodity prices over the 1970s and 1980s tend to question an unguarded acceptance of the *structuralist* hypothesis of a link between short- and medium-term fluctuations and long-term trends in these prices, both aspects do constitute two major issues of the *commodity problem*. The survey of sub-section 3.2 has focused on how these and other aspects examined in the first part of the chapter can be modelled in one-sector or multisector econometric models. Finally, as one major and still insufficiently studied issue related to the above listed risks for a mineral economy, the scope for modelling mineral commodity exports and exchange rates has been investigated, by looking at alternative interpretations of the linkages between international mineral prices, real and nominal exchange rates, and other macroeconomic variables. The hypotheses, empirical findings and econometric models surveyed in this chapter can provide a framework in terms of which the South African case may be focused upon.

Table 3.2 - Econometric models of mineral commodities and real exchange rate

dependent variable	explanatory variables	description	source
<u>mineral commodities</u>			
mineral demand	. Y+, p-, p(s)+ . Y+, p-, p(s)+, p(c)-	sector model	. Vogely 1985 (383-415)/ metals . Gocht *et al.* 1988
mineral supply	. p+, w-, E-, str- . p+, G+, GP+, MS . p-/+, BOP+, M-, d-/+	sector model	. Vogely 1985 (383-415)/ metals . Gocht *et al.* 1988 . Dobozi 1990/copper
mineral price	. I/D-	sector model	. Gocht *et al.* 1988
GDP, investment, employment, price level, government revenues/expenditures, imports/exports	. p+, Q+, instability measures of fluctuations in mineral export prices/earnings	multisector model (short and long-run effects)	. Thoborn 1977 . Obidegwu-Nziramasanga 1981; Adams-Behrman 1982/copper
<u>mineral commodities and exchange rate</u>			
GDP	. RER-/+, GE+, ugM+, TOT(+)	pooled cross-country time series model (short and medium-run effects)	. Edwards (1986)
exports/imports	. RER-/+	time series model	. Mengisteab (1991)
RER	. p- (*via* income and monetary effects) . NF-, TOT-, gY+, RER_{t-1}+	time series model	. Edwards (1986a) . Edwards (1989)

symbols:

BOP	balance of payments deficit
d	dummy variables (e.g. strikes, accidents, nationalisations, severe recessions)
D	mineral demand
E	energy costs
G	geological factors (e.g. reserve seam thickness or ore quality)
GE	ratio of government expenditures to income (in nominal terms)
GP	government policies affecting mineral production
gY	real economic growth
I	level of mineral inventories
M	net mineral import
MS	market structure
NF	net capital inflows
p	price of mineral commodity (with lag distribution)
p(s)	price of main substitute mineral (with lag distribution)
p(c)	price of complementary goods/services
Q	mineral production
RER	real exchange rate (note 6)
str	strikes
TOT	terms of trade (ratio of export prices to import prices)
ugM	unexpected rate of growth of money supply (actual vs. expected money growth rate)
Y	level of income/industrial activity (of end users/importing countries)
w	wage rate paid by producers

Notes

(1) No clear relationship is however found between value added produced within the mining industry, and level of development and diversification of the national production. Copper is a mineral for which a higher percentage of processing has taken place in African countries, such as Zaire and Zambia, than in other producers, such as Chile, Peru, the Philippines and Papua New Guinea. For bauxite, on the contrary, African countries have tended to lie behind (Yachir 1988).

(2) According to Stals (1993: 150), however, no deliberate attempt was made to protect the interests of gold mining during sharp decreases in gold prices, since the weakening of the exchange rate was rather the consequence of policy constraints associated with limited foreign exchange holdings by the Reserve Bank. A partly contrasting view is offered by Kahn (1993: 137), who argues that, until the late 1980s, the objectives of the SARB included the protection of the gold mining industry.

(3) Morocco is included as a mineral economy, since, for the 40% export earnings threshold, Nankani (1985: 2-3) considers 1973-1976 as a reference period, when that country was still highly dependent on mineral exports.

(4) Two of these companies (Zairean Gecamines and Zambian ZCCM) are estimated to account for one third of sub-Saharan mineral production, excluding South Africa (World Bank 1992). In 1989, 70% of African mineral production was state-controlled, as opposed to 56% in Latin America and 33% in Asia (UNCTAD 1994: 41). With a view to increasing productivity and competitiveness, Gecamines has recently started negotiations for a possible privatisation.

(5) Singer and Lutz argue that, unlike middle- and high-income economies and despite a higher average volatility in their terms of trade, low-income countries may be protected against negative effects of this volatility by "compensatory effects such as aid".."and also because [in the poorest economies] the income terms of trade are more related to the capacity to service debt than capacity to import" (*ibidem*: 119). However, as discussed in chapter 2, they admit that results are likely to be sensitive to the statistical procedures used to estimate trends and volatility (see Appendix A in chapter 2).

(6) In Table 3.2, an increase in RER implies a real depreciation and vice versa, as according to the most common definition.

(7) IMF estimates point out how the month-to-month variability in major currency nominal exchange rates in the 1970s and 1980s has been on the whole slightly smaller than the corresponding volatility of equity prices and prices of metals and minerals, but much smaller than that of petroleum and gold prices (Goldstein *et al.* 1992: 18).

(8) In view of the present high rate of depletion, known mineral reserves are expected to last at most for two decades in Zambia (Auty 1993: 256).

4. Gold price and exchange rates: an econometric analysis on South Africa

4.1 Introduction

Empirical studies on fluctuations of commodity exports and exchange rates for a developing economy stress the difficulty of pursuing the analysis in greater detail than is permitted by using annual statistics only. According to Adams and Behrman (1982: 123, 148), the lack of sufficient and complete statistical information for periods of less than a year in several LDCs does not represent a relevant constraint to the analysis of commodity fluctuations, since the most serious implications of the latter phenomenon for the performance of the local economy and for policy objectives would not be induced by changes reversed in a relatively short period of time. However, for the analysis of (real) exchange rate changes, Edwards (1986: 507) points to the need to possibly extend the scope of research to intra-year data, in order to assess dynamic effects which can not be captured by analyses based on annual data.

The present analysis primarily aims at identifying possible links between short and medium-term variations in gold price and the corresponding performance of the nominal and real exchange rate in South Africa. More precisely, the analysis tries to identify to what extent exchange rate depreciation has been implemented as a countermeasure against declines in profitability of domestic gold mining, and, vice versa, whether RER appreciations have followed gold price surges in the 1980s and early 1990s. In spite of some technical difficulties, an attempt is made towards a more complete framework, including explanatory variables other than gold prices.

As an alternative approach to the search for macroeconomic *fundamentals* for the exchange rate determination, such as main mineral commodity prices, the presence of a *chaotic* environment and unobservable factors is assessed with the application of stochastic time series models to the main variables separately. Furthermore, a third radically different approach to econometric modelling of the above structural links allows for the estimation of time-varying parameters, through the Kalman filtering technique. This can be seen to some extent as a combination of elements of structural modelling and stochastic time series analysis, although the concept of time variability of parameter estimates is new to both. The latter approach has recently been used for the analysis of exchange rate determination (Joubert *et al*. 1995), and for this reason an attempt is here done in this direction.

Following the literature review in chapter 3, and particularly the review in sub-section 2.1*c* in that chapter, in the specific case of South Africa, gold price-related RER volatility and appreciations may have exercised a negative impact on other sectors of the economy. In this regard, beyond the above outlined relationship, the analysis tries to identify the nature of the relationships between movements in the gold price and the RER and other macro features, such as the price level, the spread between the commercial and financial rand, and changes in the sectoral composition of South African exports in volume terms. In this way, for South Africa some of the hypotheses considered in the preceding chapter are tested.

The econometric application draws on some of the models outlined in chapter 3. The analysis is based on monthly data for the period January 1980-December 1992, compiled from SARB quarterly bulletins. Gold price figures are measured in US dollar per fine ounce (GPUSD). As measures of nominal and real exchange rate, use is made of (i) the nominal and real effective exchange rate (henceforth NEER and REER), i.e. a weighted average against the six most important currencies for South Africa's foreign trade and other transactions (Kantor 1995: 2-3); and (ii) the nominal and real bilateral exchange rate with the US dollar (henceforth indicated as NERUSD and RERUSD, respectively)[1]. Multilateral and bilateral RER often move in different directions, and the use of the former indicator is preferable as a measure to assess the changes in a country's international competitiveness (Edwards 1989: 90-100). However, given the measurement unit for GPUSD, these bilateral exchange rates can also prove useful.

Besides the gold price and the exchange rate, other variables considered by the analysis include an inflation index (CPI), a narrowly defined money supply (M1), foreign reserves[2], the discount of the commercial *versus* the financial rand (DIS), and ISIC (International Standard Industrial Classification) quantity indices of (i) exports in mining and quarrying (excluding gold) (QMIN), and (ii) manufacturing exports (QIND). Furthermore, a variable for gold exports in volume terms (QXG) has been used, which was obtained by dividing the monthly value of gold exports in thousands rand, as registered by the Central Statistical Service (henceforth CSS) monthly bulletins of statistics, by the corresponding gold price figures in rand (GPZAR), provided by SARB quarterly bulletins.

The analysis starts by examining linear relationships between the variables in terms of simple correlation coefficients, for the whole 13-year period and for sub-periods (sub-section 2.1). With regard to three variables, namely the gold price in US dollars, real effective exchange rate, and NER with the US dollar, tests for non-stationarity in the series are subsequently applied (sub-section 2.2). This exploratory analysis is carried out as a preliminary step to the econometric applications in the following sections. These applications include: in section 3, (i) a co-integration analysis of the exchange rate variables vis-à-vis the gold price, following alternative techniques and examining the scope for a second explanatory variable; in section 4, (ii) ARIMA models for each of the main variables[3], and (iii) the Kalman filter technique on the structural models used in (i), with a view to examining the plausibility and scope for estimating time-varying parameters; in section 5, (iv) a less detailed econometric analysis based on the same variables in the broader framework of possible implications for other aspects of the real and monetary economy, as outlined above. Conclusions are drawn in section 6.

4.2 Exploratory time series analysis

4.2.1 Correlation analysis

A comparison of simple correlation coefficients between the variables offers a useful preliminary insight. For the period 1980-1992 (monthly data) these coefficients are positive in the case of the relationship between the gold price and both the effective nominal and real exchange rates, while the latter two variables are highly positively correlated between themselves. Similarly, negative correlations are found between the gold price and the NERUSD and RERUSD, although in this case no significant correlation is present between the two exchange rate variables[4]. In absolute values the correlation coefficients between the gold price and exchange rate measures lie between 0.46 and 0.56. If variables are transformed in percentage growth terms, such a link between gold price and exchange rates is still present, although to a more limited extent. These preliminary results are consistent with the possibility of small occurrences of Dutch disease in South Africa during the 1980s and early 1990s determined by gold price surges, and exchange rate depreciations in periods of declining gold price. In order to better understand this topic and select the variables for the regression analysis, relationships between different exchange rate measures and possible breakdowns of the time series into sub-periods are here focused on.

A result worth noticing concerns the correlations between the two nominal and the two real exchange rate measures, separately. Whereas a negative coefficient close to unity seems to suggests no substantial difference in the use of either of the two NER variables in regression analysis, the choice between effective RER and the RERUSD appears to be more likely to produce different results, since the simple correlation coefficient between the latter variables barely amounts to -0.67 (refer to note 1 as an explanation for the negative sign). However, the two indices seem to move closer during the last four years (December 1988-1992), corresponding to a negative correlation coefficient close to unity. Moreover, if one cleans the variables from their possible pattern of autocorrelation by taking the first differences of the logarithms of the original values, all four indices appear to be highly intercorrelated, with simple correlation coefficients exceeding 0.9 in absolute terms.

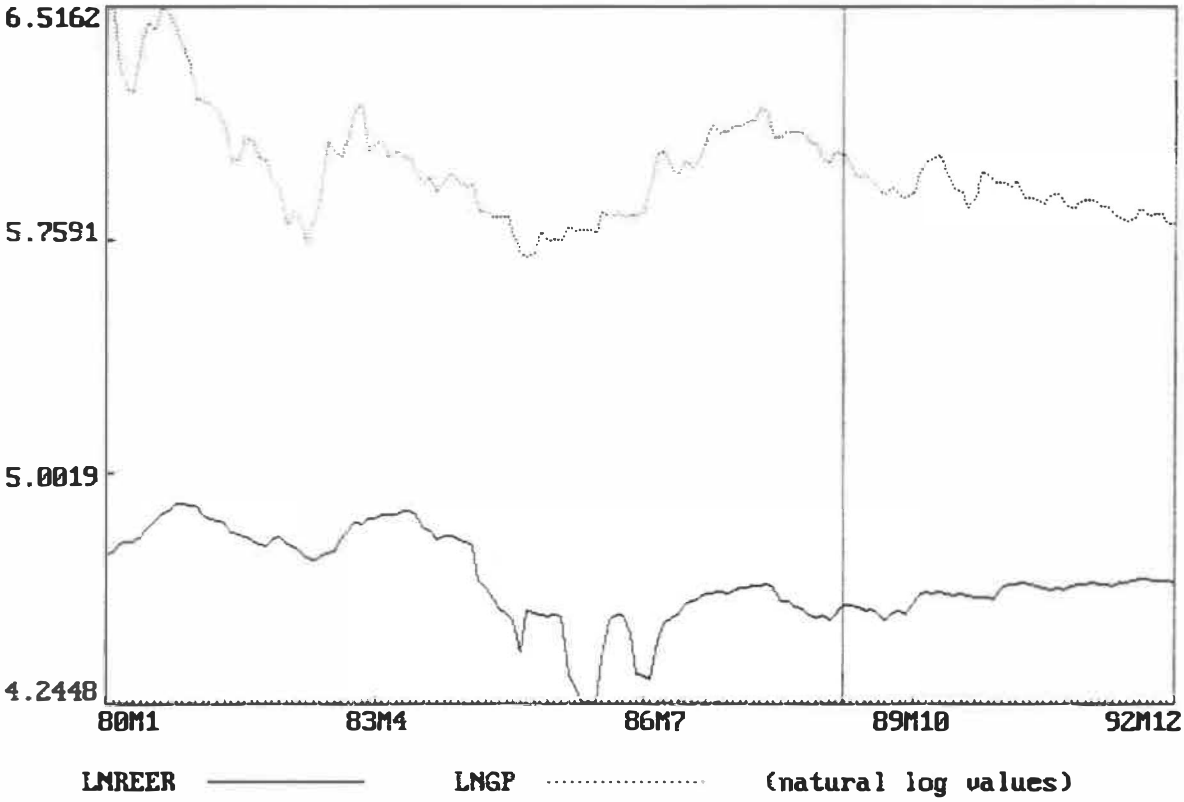
A concern for possible spurious results deriving from patterns of autocorrelation suggests to consider variables such as the CPI, the money supply and foreign exchange reserves only in terms of the log-transformations mentioned above. While no relevant links are identified for foreign reserves and money supply, inflation tends to be modestly related to real and nominal appreciations. In the period 1986-1993 the respective correlation coefficients are found to be relatively higher, between 0.4 and 0.5 in absolute terms. This result could suggest that possible Dutch disease-related inflationary pressures may have happened during the second half of the decade. However, from a simple observation of the scattergram of the gold price *versus* the REER, the result seems to be contradicted by an apparently weaker relationship in the late 1980s and early 1990s (Figure 4.1). This is later confirmed by the econometric analysis.

In this regard, for a possible indication of a change in exchange rate policy in the late 1980s, towards a REER less connected with gold price variations (as commented in chapter 3), an inspection of the data suggests to try December 1988 as a break month. Correlation coefficients for the sub-period before that month reveal a substantial consistency with previous results for the overall period. However, in the 1989-1993 interval the correlation coefficient between the gold price in US dollars and the REER turns into negative (-0.49), in contrast with an increasing positive correlation between the gold price and the NEER over the two sub-periods (0.48 and 0.85, for the first and second interval, respectively). An inspection of the plot of REER and NEER for the last few years of the series reveals a divergent pattern, with a tendentially depreciating NEER faced by an, although only slightly, appreciating REER. Coupled with the declining trend of the gold price over this second period, these results seem to provide some support to the above hypothesis of an exchange rate policy more independent from gold price trends[5]. If these variables are measured in terms of annual growth rates, rather than levels, during the two sub-periods, simple correlation coefficients substantially lose statistical significance. This issue is reconsidered in greater detail in sub-section 3.2.

As for the remaining indicators, the performances of the industrial, non-gold mining and gold export sectors do not appear to be significantly inter-correlated, nor do they show a clear link with the behaviour of the REER. While the value of gold exports, expressed in rand millions, appears to be significantly correlated with foreign exchange reserves in rand and the gold price in rands (GPZAR), the latter variable is slightly negatively related to the gold export supply in volume terms. This result, which may not appear to suit the Dutch disease pattern of an expansion of the *booming* primary export sector in times of price surges, is not surprising for South African gold mining in view of its specific institutional and structural features. Gold supply is found to be inversely related to real rand gold price in the long term, due to the particular taxation system established since the 1920s (Moll 1992: 188-190). This system allows for a threshold of profit share in mine revenues, below which mines are exempted from taxation or are even subsidised. In the presence of gold price increases companies can find financially more convenient to mine at lower ore purity levels. Domestic taxation issues are examined in chapters 5 and 6.

As a preliminary conclusion, the analysis of correlation seems to provide only partial and contradictory evidence in favour of a Dutch disease interpretation of South African gold exports. RER appreciations tend to be connected with gold price increases,

Figure 4.1 - Real effective exchange rate and US$ gold price (Jan 80-Dec 92)



but possibly RER-related inflationary pressures emerge only in the late 1980s, when gold price and RER trends seem to diverge. Also, in relation with these appreciations, no indication of (short- and medium-term) contractionary effects on non-gold sectors emerges.

4.2.2 Analysis of stationarity

Before examining the relationship between the gold price in US dollars and the effective RER, both variables were tested for unit roots, by applying an augmented Dickey-Fuller regression. The test was also applied to the NER of the rand with the US dollar, in view of the inclusion of this variable in the analysis of co-integration. Tests for non-stationarity, although still in the process of further developments, can be useful in order to avoid the acceptance of *spurious* relationships in regression analysis. These spurious relationships can often be detected by the coexistence of satisfactory indicators of goodness of fit accompanied by low DW statistics. The latter problem can be avoided by applying methods to remove serial correlation, thus leading to a quick acceptance of a false initial hypothesis of a long-run equilibrium relationship.

A stochastic process is defined as strictly stationary if the joint distribution function of its values is unchanged over time. In practice, one prefers to deal with less stringent conditions, i.e. *weak* or second-order stationarity, which implies constant means and variances over time and covariance values depending only on the lag length between two periods, and not on the actual time to which this covariance corresponds (Charemza-Deadman 1992: 118; Banerjee *et al*. 1993: 11). An *integrated*, or *homogeneous* non-stationary, process is a non-stationary process that can be made stationary by differencing. For instance, a process integrated of order *d* must be differenced d times to reach stationarity and can analytically be indicated as I(d). It has been demonstrated that other methods of de-trending a non-stationary series, that is inserting a time trend into the regression equation or removing the fitted values from a regression on time from the series, do not solve the problem of a possibly spurious relationship (Banerjee *et al.* 1993: 82-83).

Unlike the original Dickey-Fuller (DF) test, the augmented Dickey-Fuller (ADF) regression avoids problems of serial correlation in the errors, and can equally be extended to test simultaneously for the presence of a drift and a linear deterministic trend (Harris 1995: 30). Results of unit root tests based on alternative ADF regressions on the variables here considered are presented in Table 4.1. The tests cover the period from January 1981 to December 1992[6]. Following standard practice in this kind of analysis (Banerjee *et al.* 1993: 28-29), data were first transformed into natural logarithms. The regressions assume the following form, including a deterministic trend and an autoregressive process (*d* indicates here a differenced series):

$$d\ln(y)_t = \alpha_0 + \alpha_1 T + \alpha_2 \ln(y)_{t1} + \sum_{i=1}^{m} \beta_i d\ln(y)_{t-i} + \epsilon$$

In order to take into account possible seasonal patterns as has been done in other studies (Deaton 1992), lags of 12 to 14 months were included besides the short-term lags, where 12-month lags proved to be significant to some extent. The Breusch-Godfrey Lagrange multiplier test for serial correlation of order 12 does not allow the hypothesis of no serial correlation to be rejected at a 95% confidence in all cases except in the regression of the REER. Also in the latter case, however, the value of the χ^2 statistic is very close to the 1% critical value for a χ^2 distribution with 12 degrees of freedom. Results for this test are reported in the last column of Table 4.1.

The τ statistic suggested by Dickey and Fuller tests the hypothesis that $\alpha_2 = 0$ and is provided by the t-ratio of the corresponding estimated coefficient. However, the null hypothesis would imply regressing an I(0) variable on an I(1) variable, and in such cases the t-ratio does not converge asymptotically to a normal distribution: its distribution is not known with precision, but is found to be negatively skewed and critical values have been generated through simulations (Charemza-Deadman 1992: 132). The distribution of this statistic is model-dependent, varying according to whether or not a trend variable is introduced in the regression.

For sample sizes of 100 and 250 observations, the appropriate DF critical values at a 5% significance level are -3.45 and -3.43, respectively (Fuller 1976: 373). Simulations on a larger set of replications, allowing for more than just a few finite sample sizes, would suggest -3.442 for 143 observations, as an estimated critical value corresponding to the 5% significance level (MacKinnon 1991: 275). All τ statistics reported in Table 4.1 lie below the above values in absolute terms: the unit root hypothesis cannot therefore be rejected for the three variables in level form. If instead of the DF critical values, an alternative set of critical values is used, with upper and lower bounds (Charemza-Deadman 1992), the computed τ statistics are smaller than the lower critical value (higher in absolute terms) for a sample of 150 observations at a 1% level of significance (-2.79) for the estimate of gold price, and at a 5% level of significance (-1.91) for the other two variables. In contradiction to the comparison with DF critical values, the latter approach indirectly supports the hypothesis that the three variables are I(0) at a 95% confidence interval, although results are inconclusive at a 99% confidence interval for the exchange rate variables. However, this outcome should be interpreted with caution, in view of the authors' remarks on the test reliability (Charemza-Deadman 1992: 134, 317).

In order to further examine the time series properties of the three variables, results of DF tests on the joint zero null hypothesis on the estimated parameters α_0, α_1 and α_2 ($\Phi 2$), and α_1 and α_2 (Φ_3), are presented in Table 4.1. These tests are analogous to F-statistics on testing the significance of restricted as compared to unrestricted models. However, consistently with what was noticed for the τ statistics, their critical values differ and are reported in Dickey and Fuller (1981: 1063, Table V and VI). The critical values for the 95% confidence interval lie all above the estimated statistics, so that the null hypotheses cannot be rejected. These results are consistent with the indication of non-stationarity suggested by the ADF test. Moreover, they suggest that the use of a deterministic trend is not particularly helpful in the three ADF regressions. This may also be the case of the nominal exchange rate with the US dollar: the t-statistic associated with α_1 is significant at a 90% confidence level, but the corresponding τ statistic lies below the respective critical value (Dickey-Fuller 1981: 1062). As for the presence of drifts, the t-statistics associated with the constant terms are significant, in spite of a failed rejection of the null hypothesis of joint zero coefficients for the parameters α_0, α_1 and α_2 (Table 4.1).

Repeating the ADF regression on the variables differenced twice, and the lagged level term differenced once, allows for testing the hypothesis of non-stationarity with integration of order 2, instead of order 1. The results of ADF tests point to stationarity in the series differenced once. Summarizing, the estimated regressions lead to a preliminary cautious conclusion that log-transformations of gold price, effective RER and NERUSD may behave as I(1). The three variables can be modelled as random walks with or without positive drifts. However, while the direction of non-stationarity, if any, is not clear for gold price and effective RER, in the case of NERUSD it appears to follow to a limited extent an upward trend.

In view of the nature of the time series, a statistical test for seasonal integration was carried out on the three variables over the same period. A possible reason for seasonality in the exchange rate variables may be attributed to the end of the financial year for gold producing companies, coinciding with the month of June: if these companies were affected by reduced gold proceeds, as according to the prevailing trend in certain years, the connected shortage of dollars may have exercised pressures towards rand depreciations (Austin 1984: 325-326). The opposite might have occurred in the case of a dollar surplus in the local market.

The augmented Dickey-Fuller seasonal integration (ADFSI) test differs from the ADF test only in the order of differencing of the endogenous variable and the lag in the *level* variable in the regression equation presented above. In order to remove possible seasonal non-stationarity in monthly data, the variable is first transformed into 12-differences ($d_{12}ln(y)_t = ln(y)_t - ln(y)_{t-12}$). The transformed variable then enters the ADF regression as a dependent and lagged endogenous variable (e.g. with lags up to the second order), along with a constant term, a trend variable and the original (*level*) variable with a 12-month lag. As in the standard ADF regression equation, the parameter α_2 corresponds to the level variable, and the corresponding τ statistic tests the zero null hypothesis on this parameter[7].

The critical values for the ADFSI test are the same as those for an alternative seasonal integration test proposed by Dickey, Hasza and Fuller (1984: Table 7). τ statistics obtained for the variables $lngp_{-12}$, $lnreer_{-12}$ and $lnnerusd_{-12}$ are lower than the critical values at a 95% confidence interval for a sample of nearly the same size, thus not allowing the rejection of the null hypothesis of a seasonal unit root. However, unlike the case of the simple unit root tests, the Φ_2 and Φ_3 statistics are in all cases higher than the respective critical values even at a 99% confidence level.

There seems to be therefore only weak evidence of seasonal non-stationarity in the series. Moreover, checking for the need for further differencing of the series to achieve stationarity does not lead to conclusive results (after differencing the deseasonalised series, which for the variable lnrer was tried up to the third order). Coupled with the above mentioned relatively limited statistical significance found for the estimated parameter of the original ADF regressions for the 12-lagged endogenous variable (around 80% confidence interval), it appears reasonable to discard seasonal differencing of the series as a necessary tool to obtain stationarity in the three series.

4.3 Co-integration analysis

4.3.1 Gold price and real effective exchange rate

Two integrated time series[8] are said to be co-integrated if they form a stable equilibrium relationship in the long run, beyond possible short-run divergent behaviours. In analytical terms, two time series variables x_t and y_t are co-integrated of order (d,b) (with d≥b≥0), i.e. x_t, y_t ~ CI(d,b), if (i) both series are integrated of order d, and (ii) there exists a linear combination of these variables, such as $\alpha_1 x_t + \alpha_2 y_t$, which is integrated of order d-b. The vector $[\alpha_1, \alpha_2]$ is defined as a co-integrating vector. A particular case of specific concern for econometric testing is whenever d = b and the co-integrating coefficients can be identified in parameters of a long run (stationary) relationship between the two variables (Charemza-Deadman 1992; Banerjee *et al.* 1993).

In order to analyse the relationship between the gold price and the South African REER, firstly the Engle-Granger two-step procedure, based on the ADF test, was applied (Engle-Granger 1987; Stewart 1991: 204). Both variables have been found to be I(1), so that it is possible to run first a static co-integrating regression of the logarithm of REER on the logarithm of GPUSD. In the presence of two non-stationary variables I(1), the residuals from this regression will tend to be serially correlated. However, they must be I(0), not I(1), thus allowing the use of the results of the first regression to estimate a second regression equation, concerning the same variables in differenced form[9]. The latter equation would include an error correction term obtained from the former equation, so as to account for short run and long run effects. In order to check for the null hypothesis of no co-integration, an ADF test is therefore applied to the residuals from the first regression. Critical values are different from the standard ADF test, since residuals are estimated values (Engle-Granger 1987: 270).

The static regression and the unit root tests on residuals were carried out for the period July 1980-December 1992 and provided the following results (the variables are in natural logarithms):

$$\text{lnreer} = \underset{(4.54)}{1.69} + \underset{(7.91)}{0.49}\ \text{lngp} \qquad R^2 = 0.30 \qquad DW = 0.10 \qquad [1]$$

DF = -1.93 [-3.38]
ADF(1) = -2.24 [-3.88]
ADF(4) = -1.75 [-3.38]

T-statistics are given in parentheses under the estimated parameters. The presence of spurious elements and misspecification in the model is revealed by the existence of significant t-statistics coupled with low R^2 and DW values (Stewart 1991: 203)[10]. Neither according to Sargan and Bhargava's test based on the DW statistic (Banerjee *et al*. 1993: 206-207), nor following Engle and Granger's procedure can the null hypothesis of no co-integration be discarded. For the latter procedure, 95% critical values for the DF and ADF tests on residuals are reported in square brackets, with ADF tests having been carried out up to the fourth lag. These results highlight the need to revise the model, towards a more complete specification form[11]. Alternatively, the gold price may be attributed a limited relevance as an explanatory factor for REER movements in South Africa, and the nature of the REER's supposed non-stationary random walk could be analysed with time series modelling techniques.

As an alternative to the Engle-Granger method, another two-step co-integrating analysis starts from the estimation of a long run relationship through the use of an autoregressive distributed lag (ADL) model (Phillips-Loretan 1991; Charemza-Deadman 1992: 157-158). While the second step is identical to the Engle-Granger procedure, in the ADL method the long run coefficient $\beta*$ is not obtained directly from the OLS-estimated slope parameter, but is derived from the parameters of the ADL model as follows:

$$\beta* = \sum_{j=0}^{n} \beta_j / (1 - \sum_{i=1}^{n} \alpha_i)$$

with the ADL model being: $y_t = \sum_{i=1}^{n} \alpha_i y_{t-i} + \sum_{j=0}^{n} \beta_j x_{t-j} + \epsilon_t$.

In case of a loglinear equation form, this coefficient can be interpreted as the long run elasticity of y_t to x_t. The first step regression is thus not static any more. The first step co-integration regression, especially if carried out in the static form proposed by Engle and Granger, can be expected to yield a low DW. However, a very low DW statistic is generally associated with I(1) residuals (Hendry 1991: 55): if no further investigation is pursued, this may lead to a too unconditional rejection of co-integration between two variables.

The application of a first-order ADL model to the same period as above (July 1980-December 1992) provides the following results:

$$\underset{(-0.78)}{\text{lnreer} = -0.09} + \underset{(39.9)}{0.94}\ \text{lnreer}_{-1} + \underset{(2.75)}{0.18}\ \text{lngp} - \underset{(-1.73)}{0.11}\ \text{lngp}_{-1}$$

$R^2(adj) = 0.94$ $F(3,146) = 824.5$
Dh = 2.90 [2]

DF = -9.66 [-4.17]
ADF(1) = -6.76 [-4.17]
ADF(6) = -5.05 [-4.18]

The estimated equation is substantially more significant than equation [1], with unit root tests allowing the rejection of the hypothesis of non-stationarity of residuals, up to the sixth lag. One should also notice that a t-test on the estimated parameter for the lagged endogenous variable leads to a rejection at a 99% confidence level of the hypothesis that its value is equal to 1, and t-tests on zero null hypotheses on the other slope parameters are significant as well[12]. The second step has therefore been the estimation of a short run model with an error correction, embodying the long run coefficient $\beta*$ as expressed above. The model yields the following results:

$$dlnreer = -0.089 + 0.176\ dlngp - 0.062\ (lnreer_{-1} - 1.016\ lngp_{-1})$$
$$(-3.28) \quad (2.84) \qquad (-3.28)$$

$R^2(adj) = 0.10$ $\quad F(2,147) = 9.17$

$DW = 1.55$ $\quad$ [3]

DF = -9.66 [-3.80]
ADF(1) = -6,78 [-3.80]
ADF(6) = -5.05 [-3.30]

All the variables in equation [3], including the error correction, are I(0), and unit root tests on the residuals point to a correct specification of the model, with residuals also being I(0). Results are statistically significant, except for the positive serial correlation indicated by the Durbin-Watson test (this result is close to the inconclusive area according to DW critical values at a 1% significance level). The low R^2 is a normal reflection of the differenced form of the equation (Pindyck-Rubinfeld 1986: 551-552). Hence, one can conclude that, following a first order ADL specification, the South African REER and the gold price in US dollars appear to be co-integrated of order (1,1), i.e. CI(1,1), with a long run elasticity of the former variable to the latter close to unity.

4.3.2 Structural stability

In order to check for the stability of parameter estimates over the entire period, different statistical exploratory and testing methods have been applied to the series. The main aim here is to check for the supposed change in exchange rate policy occurring in South Africa since the late 1980s, which was less favourable to gold and mining (chapter 3, sub-section 2.1*c*). To this end, regression equation [1] has first been estimated recursively and attention has been paid to changes in the estimated parameter over time when additional observations are used. Similarly, a rolling regression has been run on the same equation, with time widths of 12 and 36 months. Finally, a CUSUM test has been applied to the regression model.

Both recursive and rolling procedures seem to indicate a possible break around mid-1986 (July 1986), while another possible structural change is identified in May 1989. After removing serial correlation, the Chow test on the stability of estimated parameters over the period examined leads to (i) reject to some extent the null hypothesis of no structural change in the two sub-periods July 1980-1986 and August 1986-May 1989 (in favour of a reduction of the slope parameter value in the second sub-period), and (ii) accept the null hypothesis of no structural change between the sub-periods July 1980-May 1989 and June 1989-December 1992. The latter result is unexpected, because the CUSUM test indicates a clearer break towards the end of the decade[13]. Moreover, the 12-month rolling regression shows parameter values close to zero in the early 1990s, thus favouring a model embodying a structural change towards the end of the last decade.

In order to further check for the hypothesis of a policy change in the late 1980s, a piecewise linear regression has been attempted, by inserting the appropriate structural break or *spline* variable for the logarithm of the gold price in May 1989 into equation [2][14]. While not negatively affecting the statistical significance of the other estimated parameters and the overall fit, the slope of the spline variable is -0.07, with a t-statistic of -1.67 being significant at the 90% confidence level. By adding this value of the slope parameter to the newly estimated parameter for the logarithm of GPUSD (+0.19), one can obtain the slope of the function after the break month.

4.3.3 Gold price and nominal exchange rate

In order to analyse the response of exchange rate policy, in terms of NER movements, to changes in gold price, the above procedure was applied to the relationship between NERUSD and the gold price, over the same period as above. The use of NERUSD instead of NEER is not likely to entail substantial differences in results, in view of the high correlation between the two variables. Unlike the case of the real exchange rate, the former variable was preferred because of its direct comparability with the gold price in terms of measurement units. As in the previous case, the first step of the Engle-Granger regression does not hold significant results. An alternative ADL model of the same form as equation [2] shows a significant fit:

$$\underset{}{lnnerusd} = \underset{(3.25)}{0.52} + \underset{(120.6)}{0.98}\ lnnerusd_{-1} - \underset{(-4.54)}{0.30}\ lngp + \underset{(3.52)}{0.24}\ lngp_{-1}$$

$R^2(adj) = 0.99$ $F(3,146) = 7255.7$

$Dh = 2.82$ [4]

DF = -9.64 [-4.17]

ADF(1) = -6.88 [-4.17]

ADF(6) = -5.50 [-4.18]

As in equation [2], the hypothesis of non-stationarity of residuals is rejected by unit root tests and, in spite of its closeness to unity, a t-test on the estimated parameter of the lagged endogenous variable allows rejection of the unit null hypothesis at a 99% confidence level (see note 12 though). Besides, the other parameter estimates are also significantly different from 0. Both the short and long run response of the NERUSD to the gold price in US dollars is negative, as expected: in the long run, on average, a 10% decrease in the gold price can bring about nearly 30% nominal devaluation of the rand with respect to the US dollar. The different sign of the lagged exogenous variable in equation [4], similarly to what observable in equation [2], could be explained by short term adjustments to initial shocks, once the influence of the lagged endogenous variable is accounted for. If the lagged endogenous variable is removed, parameter estimates of the exogenous and lagged exogenous variables assume the same sign, in both equation [2] and [4].

The short run model with error correction appears as follows:

$$dlnnerusd = 0.37 - 0.254\ dlngp - 0.015\ (lnnerusd_{-1} + 3.24\ lngp_{-1})$$
$$\quad (2.27)\quad (-3.76) \qquad\qquad (-2.22)$$

$R^2(adj) = 0.12$ $\quad$ $F(2,147) = 11.59$

DW = 1.54 $\quad$ [5]

DF = -9.65 [-3.80]

ADF(1) = -6,89 [-3.80]

ADF(6) = -5.63 [-3.30]

As in equation [3], unit root tests on the residuals allow the non-stationarity hypothesis to be discarded. Also in this case, the two variables appear to be CI(1,1), with a long run elasticity close to -3. Compared with equation [3], the estimated parameter associated with the error correction term shows a slower speed of adjustment of temporary deviations from a long-run equilibrium path.

4.3.4 Possible extensions of the model and application of the Johansen procedure

Co-integration analysis becomes substantially more complicated and controversial if an attempt is made towards a more realistic multivariate model. For instance, in the presence of more than one explanatory variable some authors consider inappropriate the use of an explanatory variable of a lower order of integration than the dependent variable (Charemza-Deadman 1992: 147-149), while others tend to accept this procedure (Stewart

1991: 208). Moreover, with a multivariate model, the existence of a unique co-integrating vector is not guaranteed (Harris 1995: 21, 62). In the present analysis further difficulties are caused by the lack of suitable data at a monthly basis for possible determinants of exchange rates (such as capital account data). While general aspects of the literature debate on these factors have been considered in chapter 3, here a few specific remarks are added.

The distinction between exchange rate determinants has been questioned in some cases. According to Mussa (1978: 55), a developing economy with a high dependence of its export earnings on an individual primary commodity tends to experience cycles of balance of payments surpluses and deficits, following world price fluctuations in this commodity. Real and monetary causes would then partly be intertwined, with fiscal and monetary policies keeping the level of domestic absorption more stable than what would be implied by the commodity price fluctuations, but contributing to exchange rate instability. The influence of institutional and other possible factors on mineral supply behaviour in producer LDCs with serious balance of payments problems is examined in chapter 6.

For the determination of the South Africa RER in the period 1976-1986, with an analysis based on quarterly data, Gerson and Kahn (1988) show the relevance of terms of trade fluctuations and net flows of foreign capital, possibly originating from recurrent political shocks, while monetary shocks are not found to be a significant explanatory factor. In view of the availability at a monthly basis of a terms of trade index which excludes gold (SARB, v.y.), this variable was considered here as a possible second regressor. While being moderately correlated to GPUSD, no significant correlation is found in both level and percentage growth form with the exchange rate variables. Besides the connected problems of multicollinearity, the use of this variable as a second regressor is questioned by its behaviour as an I(0) according to unit root tests. The introduction of a dummy variable for the period February 1983-August 1985, to account for exchange rate unification and capital account liberalisations (as suggested by Gerson and Kahn), does not modify or improve the results of the static regressions [2] and [4][15].

Finally, as an alternative co-integration procedure, geared to check the validity of the regression results above reported, the Johansen procedure was applied. This procedure is based on vector autoregression (VAR) modelling and as such substantially differs from the structural approach, requiring no *ex ante* endo-exogenous division of variables. Although this feature may hinder a clear interpretation of results, this method is considered to be statistically more precise and powerful than the Engle-Granger procedure and its variants (Johansen-Juselius 1990; Hall 1989; Charemza-Deadman 1992: 195-202). While a description of this method is presented in the Appendix, results are commented upon.

The VAR model was first applied to GPUSD and REER in logarithm form, allowing for different specifications in terms of both trends (with/without deterministic and stochastic trends) and lag length (from 2 to 8). The same procedure was then also applied to the log-transformed values of GPUSD and NERUSD. For a correct interpretation and avoidance of dynamic misspecification, the value of the lag length should be neither too large, nor too small. On the whole results appear to be sensitive to model specification: the Johansen likelihood ratio (LR) test alternatively points to all three possible solutions, with the number of cointegrating vectors being 0, 1 or 2.

If the trended case of VAR(6) is chosen, the Johansen procedure indicates the existence of two co-integrating relationships in both cases, which is against theory[16]. However, once the co-integrating matrix is normalised, i.e. after setting the first elements of the β vectors of this matrix equal to 1, the estimates of one of the two co-integrating vectors, chosen on the basis of an inspection of the associated vector of residuals, appear to be robust to changes in lag length and sample size and provide similar results to those previously obtained as far as the short run model with an error correction is concerned (equations [3] and [5]). The first element of the corresponding normalised adjustment vector (in matrix α: see Appendix) has a negative sign in both cases, which complies with the hypothesis of an error correction mechanism, interpretable in terms of deviations from a long run equilibrium path.

Using the results of the VAR(6) model for a dynamic model with an error correction, the estimated parameters for the differenced exogenous variable and the error correction term in equations [3] and [5] would become 0.145 and -0.051, and -0.284 and -0.017, for the two equations respectively. Unit root tests on the residuals similarly discard the non-stationarity hypothesis. A major difference is represented by the estimates of long run responses of exchange rates to gold price variations. Both elasticities are substantially lower as compared to previous results, ranging between 0.3 and 0.4 for the REER and close to -0.5 for the NERUSD. On the other hand, these elasticity estimates are higher than those which would be obtained by applying a procedure for removal of serial correlation, such as the Cochrane-Orcutt iterative method, on the static equations (0.2 and -0.3, for REER and NERUSD respectively), and are similar to the 2-month cumulated elasticity values obtainable from removing the lagged endogenous variable from equations [2] and [4] (0.28 and -0.4, respectively).

4.4 Alternative specification forms: time series models and state-space models

4.4.1 Stochastic time series models

As an alternative procedure to structural co-integrating models, stochastic time series models have been applied to the three variables examined in the preceding section. As far as REER estimates are concerned, a comparison of the predictive power of the two alternative procedures has subsequently been made, with regard to the last six months of the series. The main aim of models of stochastic processes lies in studying the systematic (trend, cyclical-seasonal) and non-systematic behaviour of a variable for which a sufficiently long time series is available. This variable may not accurately be *predicted* by a structural model, because of unclear theoretical underpinnings and hypotheses. In the specific case of the gold price, REER and NERUSD, the insufficient knowledge of explanatory factors, possibly including *unobservable* factors, and the supposed presence of non-systematic elements may render the use of these models particularly appropriate.

Among stochastic time series models, ARIMA (integrated autoregressive-moving average) models combine the characteristics of AR and MA models, applied to homogeneous non-stationary series. Given a stationary variable w_t, obtained from differencing d times the original variable y_t behaving as I(d), the objective of an ARIMA model is to find a vector of AR parameters Ω and a vector of MA parameters Θ such as to minimise the sum of squared errors, with an error term ϵ_t defined as:

$$\epsilon_t = \theta^{-1}(B)\omega(B)w_t$$

with B being a backward shift operator (Pindyck-Rubinfeld 1986: ch. 17). The observation of the correlogram (graph of the autocorrelation function) of the variable w_t provides hints to the specification of the orders of the AR and MA parts of the model, which can be indicated as p and q respectively. Hence, an ARIMA(p,d,q) can be estimated.

The sample autocorrelation functions for the three untransformed variables and their log-transformations fall only slowly to values close to zero. While for the gold price this happens after the 15th lag, for the REER one has to wait up to the 40th lag, and for the NERUSD up to the 50th lag. Coupled with statistically insignificant Box-Pierce Q statistics, these results point to the presence of non-stationarity, especially evident for the variable NERUSD. Differencing once the logarithm of the gold price appears to render this variable stationary, with a Box-Pierce $\chi^2(5) = 6.47$ failing to reject the zero null hypothesis at a 5% level of significance. In the case of the other two variables, an analysis of the correlogram of the differenced log-series seems to indicate stationarity, although the Q statistic is not satisfactory. Differencing twice still would not lead to indirect acceptance of stationarity according to the Box-Pierce test: rather than allowing for a possible non-homogeneity of the series, an observation of the respective correlograms reveals the risk of overdifferencing in the series. Seasonality in the series is also discarded by the absence of 12-lag peaks in the autocorrelation functions. The three variables were therefore modelled as I(1), exactly as applied in the co-integration analysis.

The periodicity of oscillations in the autocorrelation functions of the differenced variables suggests a second or fourth order autoregressive specification. As for the moving average properties, an examination of the initial spikes leads one to choose a first order for the gold price, a first order (and second order at the utmost) for REER and a second order for NERUSD. The correlogram associated with the REER in log-differenced form is presented in Figure 4.2. Empirical results of the ARIMA estimates with diagnostic tests are presented in Table 4.2. The error term had to be initialised with an arbitrary decimal number adjacent to 0 only in the estimation of the gold price in log-differenced form with ARIMA(4,1,1). The Box-Pierce Q statistic on the estimated residuals, aimed at checking for white noise, is distributed as a chi-square with K-p-q degrees of freedom, with *K* representing the number of first residual autocorrelations included in the Q statistic. For low-order models, K equal to 15 or 20 is considered to be a sufficient limit. Except for ARIMA(2,1,1) applied to the REER, for which the Q statistic is too large, the non-*white noise* hypothesis can be rejected in all other cases at a 95% confidence level.

The standard measures of goodness of fit, such as R^2 and t-statistics, are a suitable indicator only for inherently linear specifications, such as ARIMA(p,0,0). Moreover, as in the second step of co-integration analysis, the low R^2 merely reflects, in this case, the presence of differenced variables. Besides a satisfactory Box-Pierce test, the accuracy of an ARIMA model can be assessed on the base of the root mean sum of squares of prediction errors, or *root-mean-square (rms) simulation (ex post forecast) error*, for the last six months of the series (July-December 1992), chosen as a simulation period. According to this criterion, the preferable specifications should be ARIMA(4,1,1) for gold price, ARIMA(2,1,2) for REER, and ARIMA(4,1,2) for NERUSD (the latter, i.e. fourth order AR-second order MA, specification was not attempted for the REER) (Table 4.2).

In terms of the estimated residual plot, slightly heteroscedastic behaviours seem to be present, with a higher residual variance in the period up to mid-1983 for gold price (in differenced form), and a relatively larger residual variance in a 3-year middle period (nearly 1984-1986) for the exchange rate variables (Figure 4.3). An interesting aspect is that this pattern is similar to the behaviour of the residuals of the co-integrating equation [3] for REER, re-estimated over the same period used for ARIMA regressions (January 1980-June 1992) (Figure 4.4)[17]. A closer analysis of estimated residual values for the two regressions, indicated in the Figure as etha1 and etha2, allows the identification of four troughs (July 1984, January and August 1985, and June 1986) and three peaks (February 1985, January-February 1986, and September 1986). If the same diagnostic checking is applied to the co-integrating regression [3], for comparative purposes, the Box-Pierce Q statistic on estimated residuals is not significant ($\chi^2(15) = 72.6$) and the rms simulation error for the last 6 months is higher than in the ARIMA models (rmsse = 0.011), thus showing weaker predictive power.

Figure 4.2 - Correlogram of differenced log-values of REER
(first 51 autocorrelations)

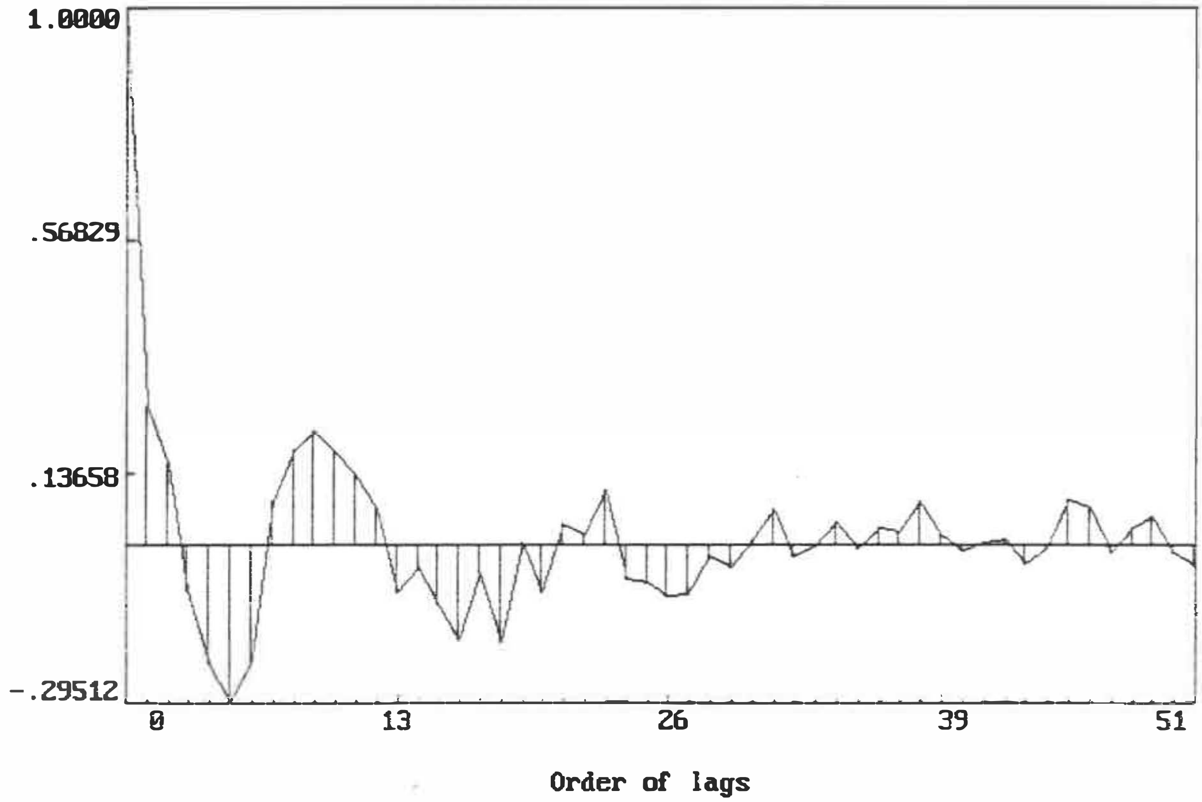


Figure 4.3 - Estimated residuals of ARIMA(2,1,2) for REER (Jan 80-Jun 92)
(with standard error bands)

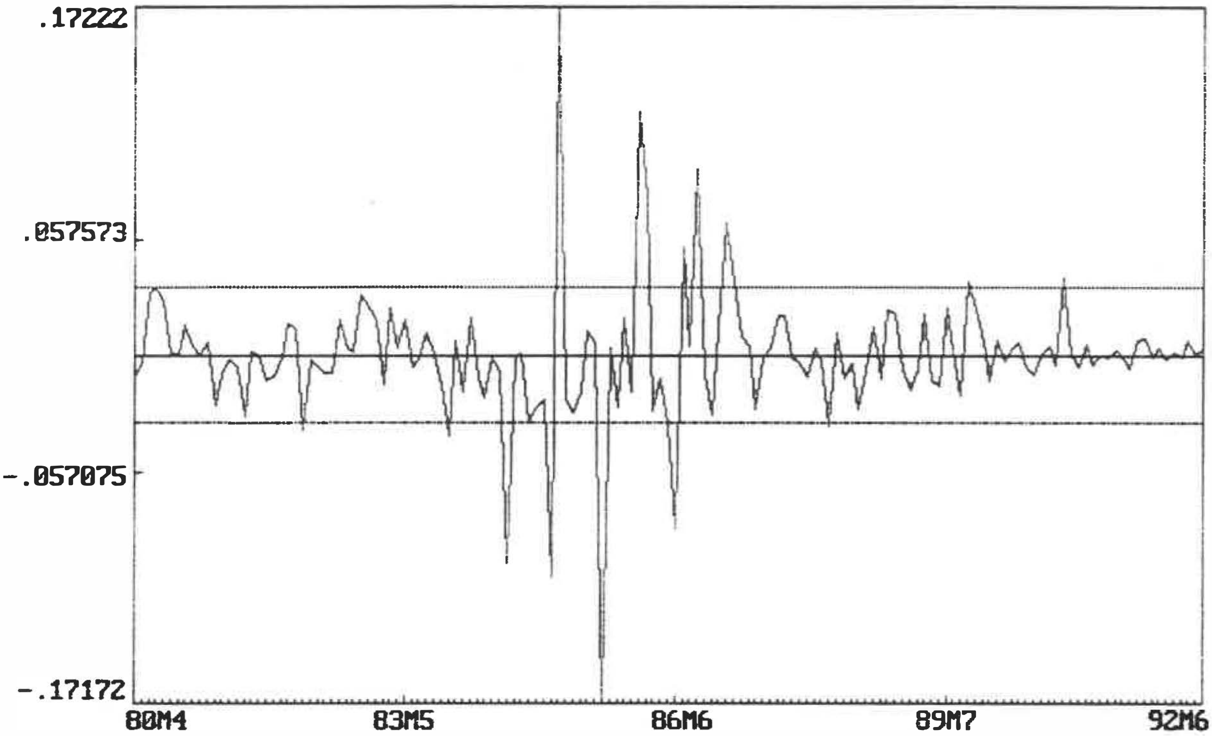
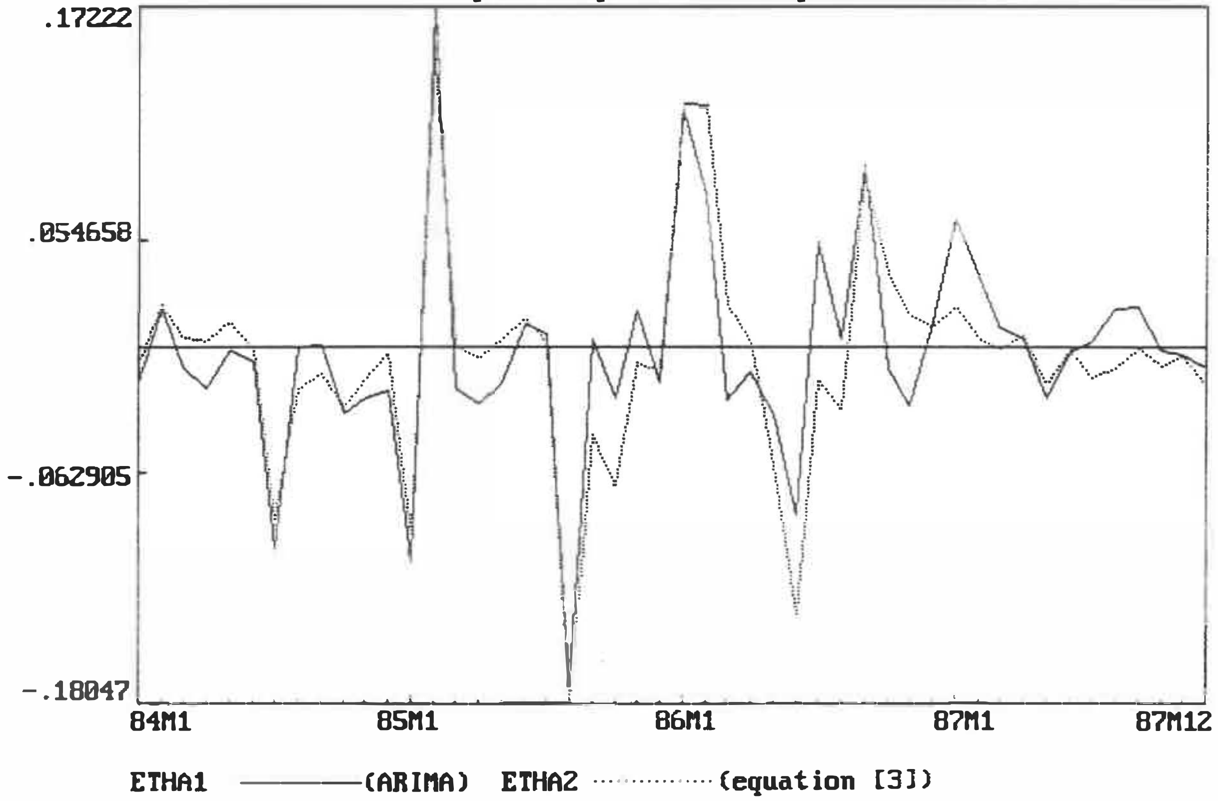


Figure 4.4 - Estimated residuals of ARIMA(2,1,2) and dynamic error correction model for REER: partial plot for mid-period (1984-1987)



4.4.2 Time-varying parameter models

The ADL models [2] and [4] and their respective dynamic error corrections, expressed in equations [3] and [5], assume a time-invariant adjustment process of the exchange rate variables to the gold price. An alternative approach to exchange rate modelling includes the role of expectations, based on prior information and an updating process with an optimal use of *new* information: this approach does not question the possibility of identifying structural relationships, but it allows for the parameters to be subject to a stochastic process (Cuthbertson *et al.* 1992: 218-219). A pattern of heteroscedastic residuals, as found for the REER by the co-integration analysis and ARIMA in the mid-1980s, can also suggest the possible presence of time-varying coefficients (Stewart-Wallis 1987: 257-258). The estimation of time-varying parameter models is not feasible with standard least squares techniques, and needs the resolution of a maximum likelihood problem through the Kalman filter procedure. While a detailed description of this procedure would overshadow the scope pursued by this analysis, some basic features are outlined here (Harvey 1981: ch. 4; Kendall-Ord 1990: ch. 9).

The Kalman filter is based on a three-step method: (i) firstly, prior guesses for the parameters and their covariance matrices are provided, eventually based on an OLS estimate over an initial period sub-sample; (ii) secondly, the variables are modelled in *state-space form*; (iii) thirdly, the maximum likelihood technique is applied to estimate recursively the unknown time-varying parameters. State-space models are defined in terms of a *measurement* or observation equation, and a *transition* or state equation. The former equation relates the observed dependent variable(s) to the explanatory variable(s) through a (set of) *state* variable(s), which can be thought of as partly not directly observable signals. The signals embody a stochastic process, which reflects for instance the influence of adaptive expectations with the possibility of "changes in gear" all over the period, that is time-varying adjustment coefficients. This stochastic process is modelled in the transition equation.

Similar to the distinction made for variables in co-integration analysis, time-varying parameters can be modelled according to different hypotheses on their stochastic process (Harvey 1981: 200-207): possible models range from those implying stationarity, with fully haphazard or partly systematic variations around the mean, to the more flexible random walk model, not constrained by a fixed mean and allowing for fundamental structural changes. In a random walk model applied to a bivariate regression, which is the most common formula used for the Kalman filter, the measurement and the transition equations appear as follows:

$Y_t = X_t\alpha_t + \delta_t$, and

$\alpha_t = \alpha_{t-1} + \eta_t.$

with the time-varying parameter α_t forming a state vector. The disturbances are assumed to be serially uncorrelated both within and across the equations, and with the initial state vector. The elements of the state vector are updated sequentially each period, as more information becomes available, through a recursive procedure. In this regard, one should add here that the recursive OLS technique is not a varying parameter model, since it does not try to model the variability of the estimated parameter according to a pre-defined algorithm and does not relax the classical assumption that the true underlying model (population) has a constant parameter (Cuthbertson *et al.* 1992: 208).

The Kalman filter in random walk form was applied to equations [2] and [4], for the real effective and the nominal bilateral (US dollar) exchange rate respectively. OLS estimates based on the first 24 observations (1980-1981) were used to initialize the filter, for the remaining observations (1982-1992). Results of these regressions show similarity with those in section

3. However, the long run elasticity to the gold price drops in both cases in absolute values as compared to previous results, to 0.64 for the REER and to -0.88 for the NERUSD. The *white noise* hypothesis on the δ_t residuals is moreover not respected in the case of the initialisation regression for the NERUSD. These new elasticity estimates, along with those suggested by the Johansen procedure, compel to exercise caution in assessing the long run responsiveness of the South African real and nominal exchange rates to the gold price, although all results point to the same direction in terms of estimated signs.

Graphical representations of the Kalman coefficients for the two equations are presented below (Figures 4.5 and 5.5). While the intercept parameter estimates are not included, the coefficients in the graphs correspond to the estimated parameter of the lagged endogenous variable (cokalman(2)), the logarithm of the gold price (cokalman(3)), and lagged values for the latter variable (cokalman(4)). All Kalman coefficients show a tendency to converge to stable values, with a high level of smoothness overall except for cokalman(2) in the first equation. In this regard, one can observe how equation [2] becomes highly driven by the lagged endogenous variable towards the end of 1984 and the beginning and the end of 1985, when clear jumps are detected by the graph for cokalman(2), with estimated values close to unity. A similar, even if less accentuated, pattern can be seen for equation [4]. Meanwhile, from mid-1984 onwards cokalman(3) assumes values which are generally higher in absolute terms and relatively more stable in both equations, and cokalman(4) more clearly appears to work as a short term adjustment factor, with stable negative values in equation [2] and stable positive values in equation [4].

Compared with the estimates obtained from the initialisation of the filter, the sample means of the Kalman coefficients are closer to the estimation results for the whole period presented in section 3. Even greater similarity can be found in the last updating estimates, corresponding to December 1992. The mean values are 0.91, 0.13 and -0.06 for the REER equation, and 0.95,

Figure 4.5 Kalman coefficients of REER on GPUSD (1982-1992)

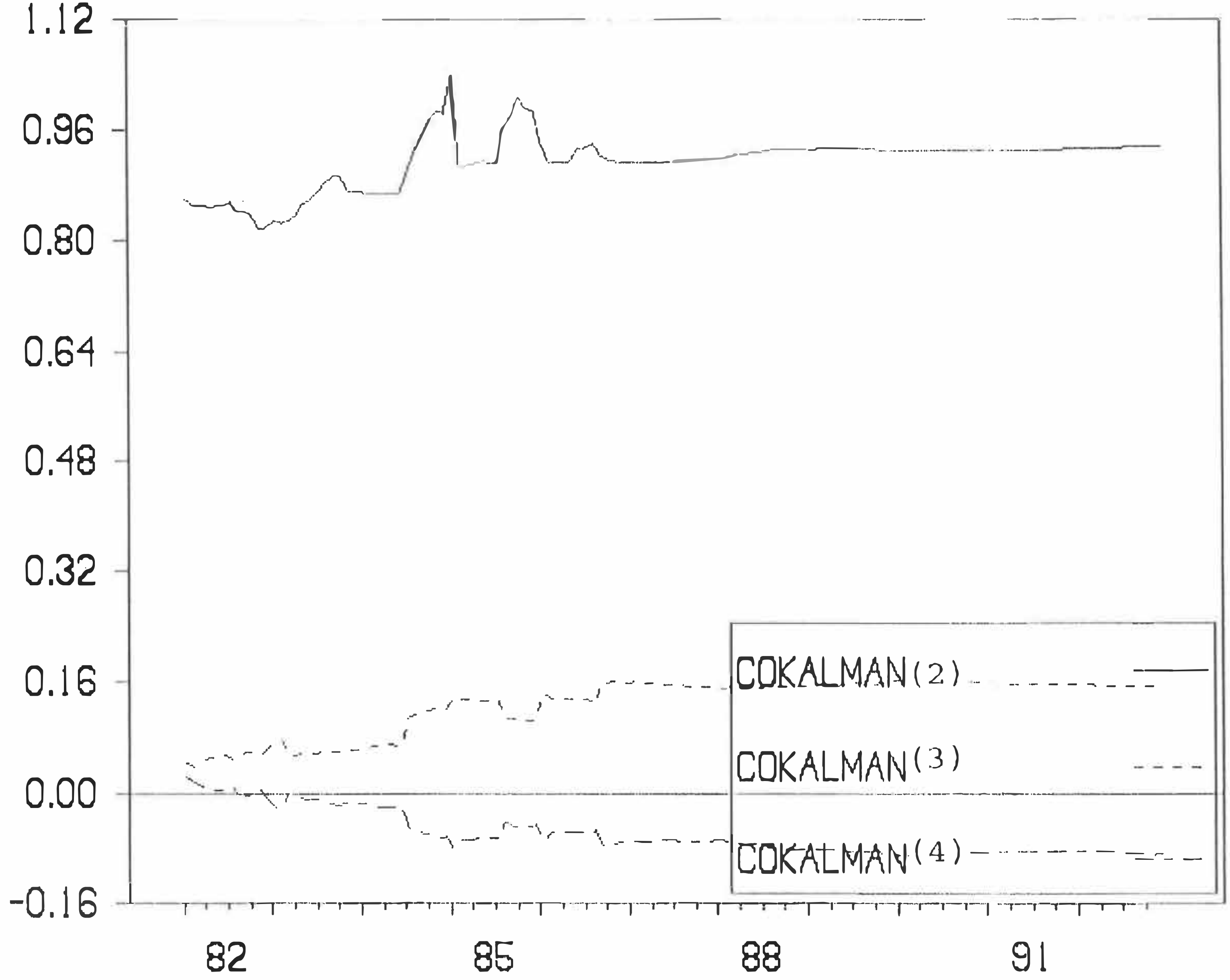
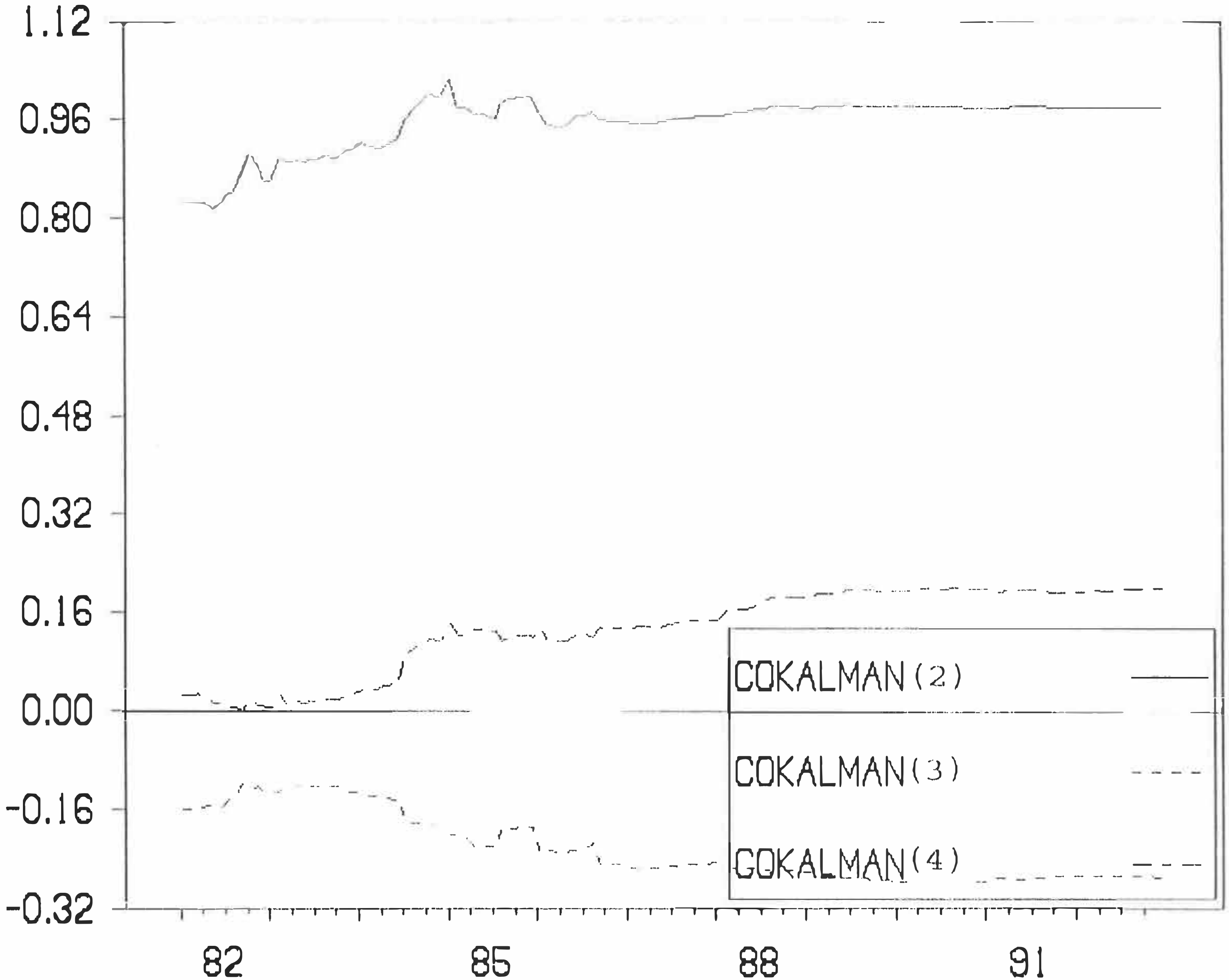


Figure 4.6 Kalman coefficients of NERUSD on GPUSD (1982-1992)



-0.22 and 0.13 for the NERUSD equation, with t-statistics rejecting at a 1% significance level the zero null hypothesis. The respective end-of-sample Kalman estimates are 0.93, 0.15 and -0.09, for equation [2], and 0.98, -0.27 and 0.20 for equation [4]. Similar results are obtained if the log variables of GPUSD are lagged once, thus removing the contemporaneous effect. The overall impression is a confirmation of the results in section 3, with no need for a time-varying random walk modelling of the two regression coefficients, except to a limited extent for the mid-1980s.

4.5 Broadening the focus to other aspects: rand discount, inflation and sectoral composition of export volume

In the short run, the maintenance of a relatively large discount can to a certain extent replace the need for a real devaluation and can also help the Central Bank avoid losing control over foreign exchange reserves, by reducing the need for sterilization as a countermeasure to downward pressures on the commercial rate (Collins 1988). A high discount can therefore be a rough proxy for RER misalignment, and can be associated with later losses of international reserves and/or RER depreciation (Edwards 1989: 66-67). A situation of serious and increasing overvaluation of the RER is often accompanied by trade restrictions and foreign exchange rationing (Dornbusch-Kuenzler 1993): these imbalances will stimulate demand for foreign exchange in the *parallel* market and hence raise the premium between the two rates (Edwards 1988: 46). Besides further cautionary remarks (Appendix to chapter 5), this pattern may suit the South African case only to a limited extent, since the financial rand was only used for capital account transactions by non-residents. However, the foreign exchange discount can be expected to have reflected to some extent the above features, connected with a real misalignment of the commercial rand.

In order to check whether gold price movements have indirectly affected the size of the discount rate, as a consequence of their effects on the RER level, a double-log regression was applied to the variable concerned (DIS), using a lagged endogenous variable and the effective RER as regressors. The regression was run on two separate time periods, respectively corresponding to the period before and after the 31-month interruption in the use of the financial rand in South Africa. In order to account for the endogeneity of the REER, two alternative methods of estimation were preferred to OLS. These were (i) instrumental variables (IV), with both first-lagged (predetermined) variables and the logarithm of the gold price as instruments[18]; and (ii) 2SLS, relying on estimates of the log-transformed REER based on a regression on its lagged endogenous values and the log-transformed gold price. The latter method incurs into autocorrelation in the first step regression, so that only IV regression results are shown in Table 4.3.

For the first three-year period, until January 1983, the discount *reacts* positively to changes in the REER, as also reflected in Figure 4.7. The short-term elasticity appears to be higher than unity, but a t-test on the unit null hypothesis is not rejected, thus suggesting an elasticity value close to unity. For the second period, from September 1985 to December 1992, the regression results change significantly, as can also be expected by comparing the scattergrams in Figures 4.7 and 4.8[19]. The possibly weaker responsiveness of the REER to changes in the gold price, suggested by the analysis in sub-section 3.2, is accompanied by a sign reversal of the short-term elasticity of the discount to the REER. This elasticity is estimated at nearly -0.5. Similar results, with the expected opposite sign in the estimated coefficients, are obtained for both periods if the RERUSD is used instead of the REER.

These results imply that, while real appreciations (depreciations) in the South African effective exchange rate tended to be accompanied by wider (narrower) spreads between commercial and financial rand in the early 1980s, this

Figure 4.7 - Scatter plot of the exchange rate discount on the REER (Jan 1980-Jan 1983)

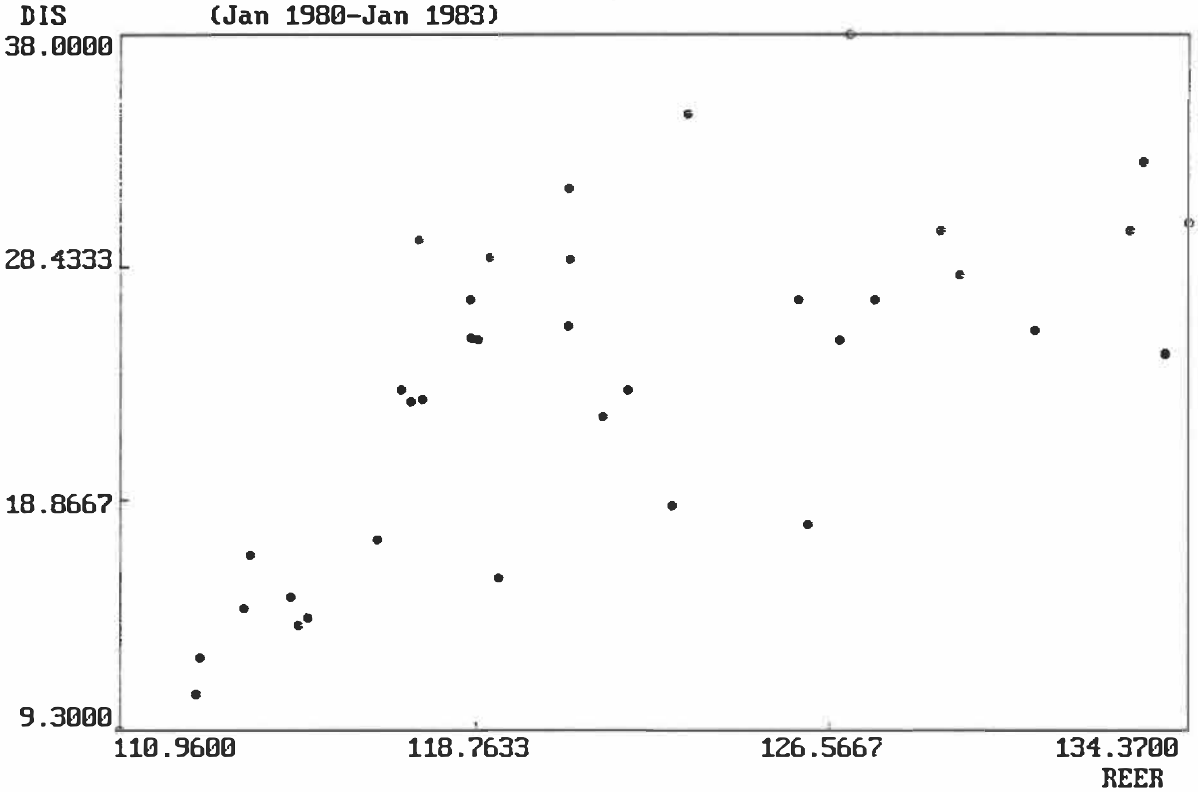
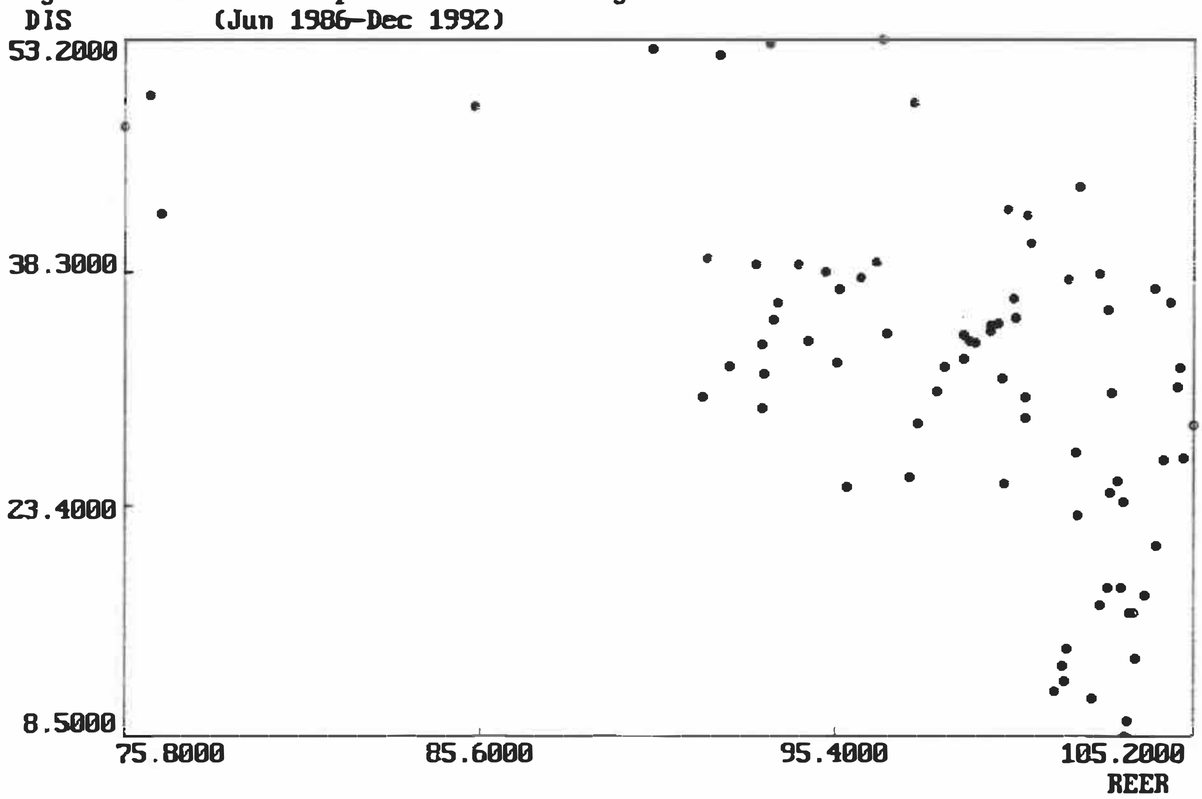


Figure 4.8 - Scatter plot of the exchange rate discount on the REER (Jun 1986-Dec 1992)



relationship does not hold in the second half of the decade, since it is even reversed. An explanation for this new tendency may lie in the restrictive macroeconomic policies, coupled with an enduring maintenance of a current account surplus, pursued by policy authorities since the mid-1980s. This allowed increases in foreign reserves (or, in some years, less severe reserve losses than would have otherwise occurred), in spite of a slightly increasing, or at least no substantial reductions, in the level of the REER and a declining trend in the discount. Moreover, the role of the discount may have been downgraded in the years immediately following the capital account shock of 1984-1985, due to the unavoidable drying up of capital inflows caused by sanctions. The latter interpretation loses relevance in the early 1990s, when a closer relationship seems to reappear between the two variables, with a slight upward tendency in both cases, particularly since the end of 1991.

Another topic worth investigating concerns the inflationary effects arising from sudden increases in export revenues due to gold price surges. As discussed in chapter 3 (sub-section 2.1c), inflationary pressures can be (i) demand-driven, as a consequence of a major export commodity price-related RER appreciation, and/or (ii) related to *inertial* government spending programmes in periods of export commodity price slumps. Particularly in the latter case inflation is likely to be spurred also by monetary expansion. However, econometric analyses on inflation in other African countries point to an endogenous or *accommodating* nature of money supply, to a great extent propelled by the inflation process (Maningi-Wuyts 1984; Mainardi 1991).

In order to examine the role of money supply expansion in South Africa, a single equation model for the analysis of causality was applied, following the Sims procedure. The differenced variable of the logarithm of the CPI was regressed on first and second order lead and lag values of the differenced log-transformation of money supply (M1). Results are statistically insignificant, with low t-statistics and even negative parameter estimates. Similar results are obtained by applying the Granger test, over both the whole period and two sub-periods (before and after the mid-1980s), and even after restricting the model to one lag variable in order to avoid problems of multicollinearity. This shows the largely spurious nature of the high simple correlation coefficient between the two variables in level form.

The Sims equation model was then reapplied on REER, by replacing the M1 lead and lag terms with the corresponding terms for the REER variable: results are reported in Table 4.3. As noticed for the co-integration and stochastic time series analyses, low R^2 are likely to be obtained as a consequence of using variables in differenced form and are not presented in the table. Results for the period July 1980-December 1992 seem to suggest a bi-directional pattern: in the very short term, REER appreciations appear to curb inflationary pressures, and inflation to increase the REER, or at least not to be sufficiently *corrected* by exchange rate adjustments. However, in view of the correlation results reported above, it seemed more appropriate to separate the whole period into two sub-periods, before and after December 1985. Results are similar, but reveal a higher sensitivity of the REER to inflation in the second half (besides an inconclusive DW test for the latter period). F-tests for causality are based on a comparison of two equation estimations, one with an unrestricted form with lead and lag terms, and another with zero restrictions on either lead of lag terms. Results, presented in Table 4.3 under the standard F statistic for the two sub-periods, highlight a two-way causality during the first half of the decade, followed by a clearer appearance of a direction of causality in the second half, from price movements to the REER[20].

As an approximate analysis of short-term implications of REER movements for the composition of exports in volume terms, three variables were considered: quantity indices for mining and quarrying exports (QMIN) and manufacturing (QIND), and gold export volume expressed in thousands of fine oz. (QXG) (1 troy ounce is equal to 0.031 kg). Each of these variables was regressed on its lagged values and the lagged effective RER, with all variables in natural logarithm form. The estimation period was again split into two sub-periods, due to a break in the ISIC classification in December 1989, as revealed by the comparison of data for QMIN and QIND over the monthly series registered by the CSS bulletins. This break happens to be close to the structural break month identified by the piecewise regression in sub-section 3.2 (May 1989), thus coincidentally allowing an assessment of the presumed change in exchange rate policy in the late 1980s also in terms of export volumes.

On the whole, results of these regressions reveal a large percentage of unexplained variation. No significant results are obtained for gold exports. This lack of results may be explained in view of the characteristics of South African gold mining mentioned earlier, further investigated in chapters 5 and 6. The remaining mining sector seems to have reacted to some extent negatively to REER appreciations, and positively to REER depreciations, in the first sub-period only. In terms of overall significance of fit, however, only the regressions on the manufacturing sector show acceptable results, which are reported in Table 4.3. For this sector, statistical evidence of a contractionary effect of real appreciations in the 1980s, and vice versa for real depreciations, is stronger than for the case of mining, with an estimated elasticity of -0.21 being significant at a 95% confidence level. However, the elasticity changes sign in the second sub-period, along with a lower reliability of this parameter estimate and worse results in terms of the overall goodness of fit. The latter result reflects the upward trend of industrial exports in the early 1990s, occurring in spite of a substantial constancy (or slight upward movement) in the REER.

4.6 Conclusions

The economy of a country with a high dependence of export revenues on a mineral commodity is vulnerable to short- and medium-term fluctuations in the international price of this commodity. Although the consequences for adjustment of domestic production are believed to be more severe in the case of long-term changes, these fluctuations can still cause, along with positive implications in boom times, disrupting effects on certain aspects of the economy. These effects can be particularly acute if sudden price fluctuations are not foreseen and adequately dealt with by the economic policies of the country concerned. With regard to these policies, attention has been paid here to the short- and medium-term implications of gold price movements for the nominal and real exchange rates in South Africa over a 13-year period of monthly series (1980-1992). In view of the possible connection of RER changes with other aspects of the economy, according to a sort of Dutch disease pattern, the relationships with some other aspects of the economy have also been focused on.

Given the length of the time series, tests for non-stationarity were applied to the effective RER, the nominal exchange rate with the US dollar, and the gold price in US dollar terms. Although not conclusive according to alternative procedures, the results seem to suggest that the three variables, in logarithmic form, can be made stationary by differencing once and do not need seasonal adjustments. Even if it intuitively appears to be unlikely, some seasonality can not be discarded *a priori* for the variables examined. The above result is however supported by the absence of 12-lag peaks in the autocorrelation functions of the three variables in both original and differenced form. An analysis of correlograms of the variables in differenced form seems also to suggest a first order non-stationarity, although results are unequivocally clear only for the gold price.

Co-integrating regressions using the three variables examined in the analysis of stationarity suggest that, if a first order ADL model is adopted, both the effective RER and the bilateral NER with the US dollar depend on the US dollar gold price, with a co-integration of order (1,1), i.e. CI(1,1). Both first step regressions ([2] and [4]) satisfy the stability condition, with an estimated parameter of the lagged endogenous variable lower than 1 in absolute figures (although the t statistics are less reliable in this case). This feature causes a negative feedback in the error correction models [3] and [5]. The hypothesis of a unique co-integrating relationship seems to be questioned by the Johansen procedure, although results for the error correction models are similar. The major difference appears to lie in the estimation of the long run elasticities according to the two methods: they vary from 0.3 to 1 for the REER, and from -0.5 to -3 for the NERUSD. Apart from the uncertain size of long-term responses, which is also highlighted by estimates of Kalman filter coefficients, real and nominal appreciations (depreciations) of the rand appear to be determined by US dollar gold price increases (decreases).

Since the late 1980s the responsiveness of the effective RER to changes in the gold price seems to have weakened. This element could not be identified in a clearcut way by tests of stability of parameter estimates, but it was evidenced by other procedures, such as the application of a piecewise regression to the first-order ADL equation [2]. This result can still be compared and reconciled with the above outlined result of the co-integrating regression: while a Dutch disease interpretation of the role of the gold price for movements in the REER seems to be suited to the South African economy over the last decade and, possibly, in the long run, the exchange rate policy appears to have restrained from, or been unable to implement, real depreciations following the slackening gold price trend of the last few years (apart from the recent more favourable performance, in 1993 and 1994, of the international gold price).

As an alternative model specification, ARIMA models were applied to the three variables. Results point to AR processes with memories of 2 or 4 months, and MA processes with a memory of one month (gold price) or two months (nominal and real exchange rates). The ARIMA model for the REER shows a stronger short-term predictive power than the respective co-integrating regression, but it similarly presents a relatively larger dispersion of estimated residuals around the fit in the middle period 1984-1986. As a further respecification of the structural models for the exchange rate variables, the use of the Kalman filter algorithm over the period 1982-1992 reveals a substantial stability in the time-varying parameters, especially since the mid-1980s, with no indication of a fundamental change in the data generating process.

The interpretation of a wider exchange rate discount as a consequence of upward pressures underlying the commercial rand (towards real appreciation) is substantiated only for the first few years of the series. In the second half of the 1980s, on the contrary, the elasticity of the discount to the REER becomes unexpectedly negative: this result may be explained by a change in macroeconomic and trade policies in that period, or by a decreasing importance of the discount as a tool for capital account re-equilibrium in the years immediately following the sanctions. The last observations of the series, concerning the period from mid-1991 to end 1992, let however suppose a possible return to the pattern of the early 1980s, with a mild tendency to real appreciation accompanied by a widening discount. Since December 1992, outside the sample period here examined, there has been a tendency for both variables to decline, except for the last few months before the March 1995 abolition of the financial rand, when an enduring reduction of the discount was accompanied by increased capital inflows and slight REER appreciations.

With regard to inflation, a causality analysis does not support a pattern of short-term money supply-induced inflation, while controversial results are obtained in terms of the supposed causal linkage between inflation and REER, with a unidirectional link from inflation to REER appearing only in the second part of the period. In terms of changes in sectoral composition of export volumes, results point to the lack of gold export booms driven by sudden increases in the international gold price, while only limited evidence is found for a possibly connected contraction in size of, or constrained growth in, non-gold export sectors. Manufacturing exports do appear to have suffered from real appreciations of the rand in the 1980s, but this result does not hold in the early 1990s. This specific issue should deserve further investigation, e.g. by extending the analysis to possible indirect negative effects of mineral commodity booms for agricultural tradables (Benjamin *et al.* 1989).

As a matter of fact, among the three sectors considered by this analysis (gold, non-gold mining and industry), only manufacturing exports in volume terms show a significant positive correlation with the rand gold price. This result may reflect a combination of factors. The South African nominal and real exchange rates have largely depended on the performance of the international gold price, at least until the late 1980s (and possibly in the "long run", according to co-integration results). Until the second half of the 1980s, the mining sector indirectly supported the manufacturing industries, through the use of export proceeds from mining, and especially gold, to finance government subsidies for certain industrial exports and to overcome the constraints to international competitiveness inherited by the previous inward-orientation. Complementary to the these aspects, over the last years South African production and exports have been able to diversify away from its mining specialisation, towards a greater share of manufacturing. This has been achieved despite rather unfavourable movements in the REER[21], but also thanks to greater stability in the REER, stronger public support, such as under the GEIS, and a more open trading environment.

Table 4.1 - Unit root ADF tests on gold price, effective RER and nominal bilateral exchange rate (with US dollar) (January 1981-December 1992)

dependent variable	drift	deterministic trend	lags in dln(y)	τ [ln(y)$_{-1}$]	Φ_2	Φ_3	$\chi^2(12)$*
dlngp	0.56 (3.11)	-0.000026 (-0.29)	1,2,3,12	-3.16			19.64
dlngp	0.55 (3.07)	-0.000018 (-0.20)	1,2,12	-3.12	3.66	5.11	16.99
dlnnerusd	0.23 (2.55)	0.00034 (1.70)	1,2,3,12	-2.39			20.81
dlnnerusd	0.23 (2.68)	0.00035 (1.84)	1,12	-2.52	3.89	3.91	20.85
dlnreer	0.28 (2.34)	-0.000030 (-0.37)	1,2,3,12	-2.40	2.26	3.29	27.00

(t-statistic in parentheses under the drift and trend parameter; * Breusch-Godfrey test for serial correlation; for other symbols, see text)

Source: SARB (v.y.): Quarterly Bulletin

Table 4.2 - ARIMA models for gold price, effective RER and nominal bilateral exchange rate (with US dollar): estimation results and diagnostic checking (January 1980-June 1992)

ARIMA specification and estimation results	Box-Pierce statistic	rms simulation error (July 1992-December 1992)
ARIMA(2,1,1) $(1 + .32B - .14B^2)dlngp = -.002 + (1 - .14B)\epsilon$	$\chi^2(3.15) = 13.23$	0.020
ARIMA(4,1,1) $(1 - .60B - .02B^2 - .07B^3 - .13B^4)dlngp = -.005 + (1 + .80B)\epsilon$	$\chi^2(5,15) = 13.64$	0.017
ARIMA(2,1,1) $(1 - .07B + .19B^2)dlnreer = -.0007 + (1 + 30B)\epsilon$	$\chi^2(3,15) = 32.50$	0.0035
ARIMA(4,1,1) $(1 + .59B + .06B^2 - .15B^3 - .17B^4)dlnreer = -.0006 + (1 - .40B)\epsilon$	$\chi^2(5,15) = 15.01$	0.0036
ARIMA(2,1,2) $(1 + 1.22B - .80B^2)dlnreer = -.0004 + (1 - .99B + .73B^2)\epsilon$	$\chi^2(4,15) = 12.60$	0.0033
ARIMA(2,1,2) $(1 + 1.18B - .74B^2)dlnerusd = .004 + (1 - .91B + .67B^2)\epsilon$	$\chi^2(4,15) = 12.40$	0.014
ARIMA(4,1,2) $(1 + .96B - .62B^2 + .11B^3 - .16B^4)dlnerusd =$ $.006 + (1 - .70B + .55B^2)\epsilon$	$\chi^2(6,15) = 8.79$	0.012

Source: SARB (v.y.): Quarterly Bulletin

Table 4.3 - Effective RER, exchange rate discount, inflation and manufacturing export volumes: estimation results

period and estimation method	estimation results	R^2adj*** F-stat	DW
Jan 1980-Jan 1983 IV*	lndis = -5.2 + .69 $lndis_{-1}$ + 1.3 lnreer (-1.4) (5.5) (1.55)^	0.71 45.1	1.66 @
Sep 1985-Dec 1992 IV*	lndis = 2.9 + .82 $lndis_{-1}$ - .50 lnreer (2.3) (15.4) (-1.92)	0.75 129.4	2.44 @
Jul 1980-Dec 1992 OLS**	dlncpi = .01 + .014 $dlnreer_{-2}$ - .028 $dlnreer_{-1}$ + .039 $dlnreer_{+1}$ + (32.0) (1.33)' (-2.73) (3.74) + .010 $dlnreer_{+2}$ (0.93)'	5.55	1.85
Jan 1980-Dec 1985 OLS**	dlncpi = .01 + .018 $dlnreer_{-2}$ - .026 $dlnreer_{-1}$ + .027 $dlnreer_{+1}$ + (20.7) (1.29)' (-1.84)^^ (2.05) + .009 $dlnreer_{+2}$ (0.71)'	2.25^^ 2.37^^ 2.77^^	1.57
Jan 1986-Dec 1992 OLS**	dlncpi = .01 + .018 $dlnreer_{-2}$ - .029 $dlnreer_{-1}$ + .060 $dlnreer_{+1}$ + (23.3) (0.97)' (-1.75)^^ (3.34) + .016 $dlnreer_{+2}$ (0.68)'	4.11 1.61' 7.00	2.07
Jan 1980-Dec 1989 OLS	lnqind = 2.18 + .72 $lnqind_{-1}$ - .21 $lnreer_{-1}$ (3.23) (10.73) (-2.01)	0.60 90.9	2.66 @
Jan 1990-Dec 1992 OLS	lnqind = -3.24 + .51 $lnqind_{-1}$ + 1.21 $lnreer_{-1}$ (-0.77) (3.59) (1.24)'	0.40 12.5	2.21 @

(t-statistic in parentheses under the estimated parameter; for symbols, see text)

* IV (instrumental variables): $lndis_{-1}$, $lnreer_{-1}$, lngp

** for Granger-Sims causality test: instead of R^2adj and F-statistic, three F statistics are presented: standard F-stat, F-stat for zero restrictions on lag variables, F-stat for zero restrictions on lead variables (the latter two only for the two sub-periods)

@ invalid Dh test (negative number under square root)

' less than 85% confidence interval

^ 85% confidence interval

^^ 90% confidence interval (in all other cases: 95% confidence level or more; confidence levels for intercept estimates are not indicated)

Source: SARB (v.y.): Quarterly Bulletin
CSS (v.y.): Monthly Bulletin of Statistics

Notes

(1) In contrast to the most common definition, value increases in the effective RER index reported by the SARB imply real appreciations of the rand, and vice versa for decreases. For the bilateral NER with the US dollar the most common definition is adopted, with higher NER implying nominal depreciation. The RER of the rand with the US dollar was calculated by using monthly data of the wholesale price index of the United States, for the period here analysed. These data were obviously standardised to the same base month (July 1990) of the South African consumption price index, in order to transform the NERUSD into RERUSD. In view of the presence of more than one base month over individual time series, data of other variables were also made consistent.

(2) Similar to the level of the REER and the dual exchange rate discount, foreign exchange reserves are considered as an indicator guiding exchange rate policy. As a consequence of net current and capital account outflows, declining reserves can entail the need for a devaluation. However, this situation can be overcome through increased foreign borrowing, thus maintaining foreign exchange reserves (Fischer 1988: 116-117). The use of this variable has therefore been limited to the initial analysis of correlation.

(3) If properly specified, ARIMA models can have a high predictive power. Although sometimes criticised for being "devoid of any explanatory power" (Darnell-Evans 1990: 89), a comparison of results with structural econometric models can be useful whenever scarce theoretical knowledge, along with supposed non-systematic elements and possible non-stationarity, is present, such as in the cases considered here.

(4) If the sub-period 1980-1988 is examined, the two bilateral exchange rate variables appear significantly correlated, with a coefficient of 0.67.

(5) The use of different break periods for the analysis of supposedly interconnected issues (December 1985 and December 1988 in sub-section 2.1 and May 1989 in section 3) depends on the variables examined and the methods used for the identification of these break points (simple inspection of time plots, *a priori* assumption, *ad hoc* statistical tests). As far as the relationship REER-inflation is concerned, for instance, shifting the break month from December 1985 to one of the later breaks would slightly reduce the absolute value of the correlation coefficient in the first period, and increase it in the second period. Although the evidence for clearcut breaks is not overwhelming, the first three or four years following the capital account shock of the mid-1980s seem to be characterised by some structural changes affecting the relationships between the variables in the subsequent years.

(6) The first year monthly observations were excluded because of limitations in the statistical package processing capacity. This is also the reason for not including the first six month observations in the co-integration analysis.

(7) In general terms, a non-stationary variable is defined as seasonally integrated of order (d,D), i.e. $SI_s(d,D)$, if it can be rendered stationary by first applying s-differences D times and then differencing the resulting series d times using first differences.

(8) Time series is here meant as a single realization of a stochastic process.

(9) A possible criticism to the Engle-Granger method concerns its *a priori* assumption of consistent OLS estimates in the first step of the procedure, which leads to accept the estimated slope parameter as an approximate indicator of a long run relationship, although the variables involved are non-stationary (Charemza-Deadman 1992: 157).

(10) As mentioned in sub-section 2.2, the application of the Cochrane-Orcutt method would remove the positive serial correlation in equation [1] and would provide significant results in terms of goodness of fit (the R^2 would become 0.94), but this procedure is not acceptable within a co-integration analysis and is likely to lead either to the acceptance of a wrong assumption on the existence of a long run relationship, or to an incorrect estimation of the true long run parameter value. Nonetheless, the Cochrane-Orcutt method has been used here as a preliminary step for the Chow test of stability of parameter estimates, in order to remove serial correlation, thus assuming that the possible bias introduced by this corrective procedure would not affect the stability of estimates in different periods. As can be seen from regression results in equations [2], [3], [4] and [5], in a co-integration analysis the use of an ADL model may not be sufficient to guarantee a complete absence of an autocorrelation pattern in the residuals. If feasible, it may be useful in this case to look for a second explanatory variable.

(11) In the case of co-integrated variables, the *superconsistency* property of the OLS estimator renders estimates of a static regression asymptotically valid. However, in finite samples these estimates are biased, with this bias found to be inversely related to the value of the R^2 in the static regression, and being "captured" by the estimated residuals (Harris 1995: ch. 4). A bivariate model of the same form as equation [1] may therefore imply an increased risk of incorrectly accepting the null hypothesis of no co-integration.

(12) Due caution is needed in the interpretation of the t statistics because of the non-stationarity of the series. These statistics, as well as the R^2 of the co-integrating regression, are often ignored in this type of analysis (Charemza-Deadman 1992: 116-171).

(13) One should notice, however, that the formal power of CUSUM and CUSUMSQ tests is considered to be low (Cuthbertson *et al.* 1992: 117).

(14) A brief treatment of piecewise linear regression is provided by Pindyck and Rubinfeld (1986: 126-127). The same technique is used in chapter 2 in order to model breaks in commodity price trends.

(15) The number of major trading partner countries of South Africa on which the REER used by Gerson and Kahn (1988: 126) is based, as a weighted average, is eleven instead of six. The latter is the REER provided by the SARB (v.y.) and adopted by this analysis.

(16) The presence of two co-integrating vectors casts some doubts on the endo-exogenous distinction of the variables as suggested by the theory. Rather than contradicting the basic hypothesis, this

result seems to point to the need to broaden the modelling framework for exchange rates determination beyond single equation estimation (Charemza-Deadman 1992: 201-202). Moreover, this result for VAR(6) also questions the non-stationarity of the variables, since if the rank of the co-integrating matrix, as detected by the Johansen LR test, is equal to the number of variables in the VAR model, these variables should be stationary and an unrestricted VAR model in level form is sufficient (Johansen-Juselius 1990: 170-171; Campbell-Perron 1991: 170; Cuthbertson *et al.* 1992; 143-145). This issue is further discussed in the Appendix.

(17) Heteroscedasticity is found not to affect the asymptotic distribution of unit root test statistics (MacKinnon 1991: 270).

(18) In the absence of serial correlation, the lagged endogenous variable is uncorrelated to the disturbances, so that this variable can be used as its own IV without affecting the consistency of IV estimates (Stewart 1991: 190-192).

(19) Figure 4.6 does not include the first nine months of the second period, which seem to stray out of the main underlying fit.

(20) The option of joint zero restrictions on lead regression coefficients is rejected at a 99% confidence, while the alternative model with joint zero restrictions on lag coefficients does not substantially alter the explanatory power of the initial unrestricted model.

(21) A trade-weighted average RER, such as the REER, can however conceal substantially different geographical distributions of trade flows by individual manufacturing sectors (Kahn 1993: 139). This diminishes the adequacy of the REER as an indicator of competitiveness.

Appendix

The Johansen method for co-integration analysis

The Johansen procedure for co-integration analysis is based on a VAR model. This model can be seen as an unrestricted reduced form of a structural simultaneous equation model with no exogenous variables (Charemza-Deadman 1992: 183). VAR modelling was developed in the 1980s as an alternative econometric approach to structural models, with a view to avoiding two major drawbacks of traditional econometric modelling. These are the *ex ante* endo-exogenous subdivision of variables (which can actually most often be interrelated by feed-backs), and the imposition of zero restrictions in certain equations of the system, or vice versa the sometimes forced search for and introduction of new variables, as a way to achieve exact parameter identification.

In VAR models each current variable is regressed on all variables of the model, lagged a number of times. Apart from sample limitations, the *k* number of lags used for the right-hand variables should be chosen so as to allow to comply with the VAR assumption of no serial correlation in the residuals. If the equations are to be used separately for policy analysis, an orthogonalization procedure is recommended to remove possible contemporaneous correlation (Charemza-Deadman 1992: 187).

Given a Z_t vector of *n* variables which have been found to be integrated of the same order (as a standard case they should be I(1)), a VAR(2) model (with k=2) has the following matrix form:

$$Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + \epsilon_t,$$

which can be transformed into a specification suited for co-integration by adding to both sides of the equation Z_{t-1}, Z_{t-2} and $A_1 Z_{t-2}$. Rearranging one obtains:

$$Z_t - Z_{t-1} = \Delta Z_t =$$

$$= - Z_{t-1} - Z_{t-2} - A_1 Z_{t-2} + A_1 Z_{t-1} + A_2 Z_{t-2} + Z_{t-2} + A_1 Z_{t-2} + \epsilon_t$$

$$\Delta Z_t = Z_{t-2} [- I + A_1 + A_2] + \Delta Z_{t-1} [- I + A_1] + \epsilon_t =$$
$$= Z_{t-2} \Pi + \Delta Z_{t-1} \Gamma + \epsilon_t \qquad [1]$$

Given the co-integrating transformation [1], the Johansen procedure can schematically be represented as in Figure 4.9. In the presence of n variables, there may be up to n-1 co-integrating vectors, embodied in the matrix Π (Cuthbertson *et al.* 1992: 144). The Johansen method aims at identifying the number of co-integrating relationships and estimating the corresponding long run equilibrium parameters. The co-integrating vectors of matrix β (ϵ Π), once estimated, are standardised by imposing a unitary coefficient on one variable in each equation. This allows to estimate the error correction term for the short run dynamic model(s). The analysis in sub-section 3.4 highlights a sensitivity of the results to the VAR specification adopted, in terms of both number of co-integrating vectors and estimates of long run parameters. Due to this reason, the r=2 case in VAR(6) was also investigated, even if this implicitly conflicts with the non-stationarity assumption on the variables.

Compared to the two-step co-integration methods based on OLS, this procedure offers the following advantages (Hall 1989: 213; Banerjee *et al.* 1993: 162-163):
(i) avoidance of small sample bias in the parameter estimates of the static first-step regression;
(ii) invariance in the distribution of the test statistic to the VAR specification (as opposed to the sensitivity of DF tests);
(iii) (for three or more variables) estimation of unique co-integrating vector(s), while OLS estimates do not guarantee this result and may lead to linear combinations of these vectors.

On the other hand, among possible criticisms, the Johansen procedure basically leaves to the researcher's intuition which co-integrating vector should be interpreted as the long-term equilibrium relationship for the problem under study (Thomas 1993:

170).

Secondly, the equation system [1] does not include time as a regressor, so as to be only suited to test for deterministic co-integration (Campbell-Perron 1991: 181), which is a more restrictive form of co-integration as opposed to stochastic co-integration (*ibidem*: 164-165). Deterministic co-integration implies that the co-integrating vectors remove both the unit roots and any possible deterministic trends from the data. Critical value tables produced by Osterwald and Lenum (Charemza-Deadman 1992: 215-216) try to redress this deficiency. Osterwald-Lenum critical values are considered to be more accurate than Johansen original critical values, and are included in the econometric computer package used for this analysis.

Thirdly, the choice of the lag length is subject to a trade-off: on the one hand, the need for avoiding autocorrelation in the residuals would suggest a sufficiently large number of lags; on the other hand, "in order to interpret the adjustment matrix α sensibly, the value of k cannot be large" (Charemza-Deadman 1992: 200-201). In view of their substantially different approaches, the Engle-Granger and the Johansen methods are regarded as complementary tools for co-integration analysis, rather than alternatives.

Figure 4.9 - Schematic representation of the Johansen co-integration procedure and model selection

example of a VAR(2), with 2 = number of lags; n = number of variables; T = sample size

$\Delta Z_t = Z_{t-2}\, \Pi + \Delta Z_{t-1}\, \Gamma + \epsilon_t$ [1]

rank of matrix Π = n ⟶ all variables are I(0) (unrestricted VAR in levels)

< n ⟶ = 0 no co-integrating relationship (unrestricted VAR in first differences)

< n ⟶ = r (>0): r is then the number of co-integrating relationships (unrestricted VAR is inappropriate; need for ECM)

↓

Estimation of the co-integrating matrix β of order [n x r], which:
(i) renders Z_t stationary, i.e. Z_t is I(1), but $\beta' Z_t$ is I(0);
(ii) constitutes a multiplicative component of Π, such that $-\Pi = \alpha\beta'$ (α = adjustment matrix)

equation [1] can be rewritten in this case:

$\Delta Z_t + \alpha\beta' Z_{t-2} = \Delta Z_{t-1}\, \Gamma + \epsilon_t$ [2]

↓

($\alpha\beta'$) is unknown: estimation of *residual vectors* R_{0t} and R_{kt} (R_{2t} in this case), obtained from regressing ΔZ_t and Z_{t-2} on ΔZ_{t-1}, respectively. Equation [2] then becomes:

$R_{0t} + \alpha\beta' R_{kt} = \epsilon_t$ [3]

↓

Maximum likelihood estimation of the co-integrating vectors belonging to β:
a) computation of cross-products (S_{0k}, S_{k0}) and second moments (S_{00}, S_{kk}) of R_{0t} and R_{kt};
b) solution of the eigenvalue problem: $\det(\lambda S_{kk} - S_{k0} S_{00}^{-1} S_{0k}) = 0$ (with an eigenvector matrix *V* associated with the eigenvalue vector λ);
c) ordering of the n eigenvalues in descending order;

↓

Johansen LR or trace statistic (test of the null hypothesis that there are at most r co-integrating vectors; Osterwald-Lenum critical values):

$LR(n - r) = - T \cdot \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i)$ (~ 0 when $\hat{\lambda}_i \sim 0$)

↓

If the first r eigenvalues are non-zero, the associated eigenvectors $\hat{v}_i$ (ϵ *V*) are the maximum likelihood estimates of the co-integrating vectors ($\epsilon\ \beta$); after standardisation (text), these estimates can be used in a short run model with error correction (ECM), as in the second step of the Engle-Granger procedure

5. Economic growth and exchange rate misalignment: the role of gold in South Africa

5.1 Introduction

The impact of a large mining sector for South African economic growth is considered to have been ambivalent. On the one hand, in contrast with mineral economies with an *enclave*-type mining sector and a weaker infrastructural development, the dynamic export performance of minerals, particularly gold, stimulated domestic investment demand and spilled over into other sectors of the economy, such as construction and engineering industries, and provided also a substantial base for government revenues. In this respect, mineral exports, especially gold (and diamonds limitedly to the first half of the century), have been attributed a role of *engine of growth* for the South African industrialisation process (Houtman 1986). On the other hand, particularly in view of the dominance of gold, a *one-crop economy* pattern of erratic or misled domestic policies and severe fluctuations can be hypothesized, although this view has been questioned by part of the literature, as examined in chapter 3.

Independently from the controversial aspect of whether these fluctuations have had procyclical, rather than anticyclical effects in South Africa, a paradoxical argument concerning gold and other mineral exports has often been raised by the literature (Lombard-Stadler 1980: 60; Standish 1992). While these exports have actually provided a buffer against otherwise unfavourable trends in the terms of trade over the last two decades, they have also weakened the balance of payments position and the tax revenue base by exposing these aspects of the economy to the vagaries of a largely primary commodity-oriented form of export specialisation, thus also impinging upon short-term policy-making.

For an open developing economy, stability in export earnings can be considered a precondition for the maintenance of sustained growth. Besides the direct growth effects of mining, as a factor contributing to such aspects as domestic investment, employment and exports, adequate attention should be paid to its indirect implications. The latter include the influence of international mineral commodity prices on the local exchange rate. In several developing mineral economies, including South Africa, unstable and misaligned levels of the RER have been attributed negative effects on the tradables sector, to the extent of being found "the one single most important form of distortion affecting economic growth" in LDCs (Agarwala, quoted by Ghura-Grennes 1993: 158)[1]. RER volatility and misalignments tend to induce uncertainty in investment decisions and inefficiency in allocation of resources.

With reference to the South African experience in the 1980s, results in chapter 4 partly substantiate the above argument. The level of time disaggregation chosen in chapter 4 allows one to account for variations in the very short term and to check for possible spurious correlation over time between exchange rate variables and the gold price, by applying specific econometric techniques. However, due to data constraints, the statistical results do not distinguish between possible changes in the equilibrium RER[2] and actual RER misalignments. Since it covers a period of twelve-thirteen years, moreover, the framework adopted by the preceding chapter cannot provide a clear indication of long-term growth implications of the variables examined. This task is more feasible if annual data are used, for a larger set of variables.

The following analysis considers the role of gold for the growth of the South African economy over the period 1970-1994, and applies an *ex ante* simulation to the second half of the 1990s. The analysis links micro features of gold mining, such as tax rates and ore grade, to more general macroeconomic characteristics, partly considered in chapter 4. Among the latter, particular attention is paid to the estimation of exchange rate misalignment. The choice of gold is due to its dominant role and high sensitivity to changing international conditions. In South Africa other minerals, the analysis of which is left until chapter 6, are either less relevant as a source of government revenue, or determined to a relatively greater extent by changes in local demand, besides international markets.

Subsequent to a review of macroeconomic and gold sector-related issues (section 2), an econometric model encompassing the outlined framework is applied in section 3. The results of the model are then extended to an analysis of links between the gold price, real exchange rate equilibrium and growth. Based on projections of the exogenous variables, an *ex ante* simulation is subsequently performed on the model, with a view to estimating potential growth attainments in the 1990s. Conclusions are drawn in section 4.

5.2 Economic growth, exchange rates, and gold mining in South Africa

5.2.1 Performance of the economy

The primary objectives of macroeconomic policies are considered to have gradually shifted in South Africa from a mainly growth-oriented strategy, in the 1960s, to policy areas such as inflation control and balance of payments equilibrium, in the later decades. The latter policy goals have been given priority particularly since the mid-1980s (Abedian-Standish 1992a). The reasons for this change have been attributed to political events, constraints to a sustained growth inherent in earlier domestic policies, and/or peculiar features of the South African growth process. More precisely, possible explanations include mounting internal and external pressures for a political change in the 1970s, the limits of the import-substitution policy and the failure to effectively implement the export promotion strategy which had already been recommended since the early 1970s, the lack of effectiveness of monetary and exchange rate policy in containing inflationary expectations, and the tendency of the economy to excessively rely on imports whenever experiencing positive cycles (*ibidem*: ch. 1).

For the above reasons, in spite of particularly favourable external circumstances in terms of gold exports, the country has not been able to achieve its full growth potential. Windfalls in South African gold export earnings over most of the 1970s and early 1980s largely derived from the worldwide inflationary impact of oil crises, new legislation introduced in the US allowing for private ownership of gold in bullion form, renewed tensions in some Asian countries in the second half of the 1970s (Iran, Soviet intervention in Afghanistan), and the 1982 debt crisis (SARB 1990). However, between 1971 and 1984 South Africa's potential growth is estimated to have been nearly 5%, in line with the growth achievements in the 1960s, while actual real GDP growth was only 2.9% per year (Houtman 1986; Harvey-Jenkins 1992). During that period growth was largely financed by gold export revenues and foreign borrowing. The government tended to regard this gold bonanza as permanent and embarked on an extensive infrastructure development programme (Moll 1992).

The capital account shock of the mid-1980s, coinciding with the events in the Vaal triangle, led to a shortage of external finance and highlighted the need to pursue adjustment through restrictive fiscal and monetary measures, and exchange rate depreciation. These deflationary and expenditure-switching policies had relatively greater effects on import contraction, than on export promotion, possibly also due to the impact of international sanctions (Kahn 1992). On the domestic side, constraints to an efficient export-led growth derived from an inadequate process of market deregulation, which was not sufficiently accompanied by structural changes needed in areas such as income distribution, education, and allocation of production resources. Beyond short-term adjustment measures, the high dependency of domestic investment on imported capital and intermediate products in South Africa also highlighted a need for restructuring the economy in the medium and long run.

External factors affecting the international gold price had been changing in the meantime. In the late 1980s an oversupply of gold in the world market, partly caused by increased sales by the former USSR, coupled with the increased recourse to gold loans by some major gold producers, led to a slump in gold prices (SARB 1990). Moreover, the 1990 third oil price shock was accompanied by an only slight strengthening in the US dollar gold price (*ibidem*). Sanctions severely affected the gold mining sector, with South African Krugerrand exports in 1985 amounting to less than one fourth of the 1983 figure. The decreasing proportion of gold in total exports was however more than compensated by an increasing contribution of other minerals in South African foreign exchange earnings. This was especially due to the role of the platinum group metals, which have never been subject to embargoes, and coal (Harvey-Jenkins 1992: 23).

5.2.2 Exchange rate management and misalignments

The shift from fast to slow growth occurring in the mid-1970s in South Africa, followed by a further downward shift in the mid-1980s, can only partly be explained by factors affecting developing countries as a whole. In this respect, in terms of growth performance, South Africa might have performed relatively better than countries at similar levels of development, in view of its gold export windfalls. Since the early 1980s, the government had been trying to redress this slowdown by fostering exports, especially of labour-intensive sectors, and strengthening the formal sector (Harvey-Jenkins 1992). Other government objectives included the maintenance of a constant real gold price in rands, inflation control and import restraint.

To the above end, a progressive change in exchange rate regime was undertaken, from a fixed exchange rate, to a managed floating, and finally to an even more flexible arrangement. These changes were accompanied by real interest rate increases, thus serving the double aim of defending the rand from an excessive depreciation and raising the relative cost of capital as opposed to labour. While a fixed rate had previously been pursued with regard to the British pound, from October 1972 till June 1974 the South African currency remained substantially pegged to the US dollar (SARB 1974: 15, September). This was followed by a system of limited independent managed floating, characterised by smaller and more frequent adjustments of the NERUSD, in tune with changing conditions in the balance of payments and the domestic financial market and economic situation. A *variable dollar-pegging* was then introduced in May 1979, set on a daily basis by the Reserve Bank. Although still under the control of the Reserve Bank, since August 1983 the exchange rate has become more directly market-determined (Barr-Kahn 1995).

These exchange rate policy changes did not however bring about the desired improvements in export performance and allocation of production resources. Various explanations have been suggested (Harvey-Jenkins 1992). Firstly, greater stringency was felt from international sanctions in the second half of the 1980s, particularly with regard to South Africa's largest trade outlet markets. Secondly, during the 1970s and 1980s the South African RER tended to depreciate in relation to most industrial countries and, to a limited extent, with respect to some South East Asian NICs, but it remained unresponsive or even appreciated compared to currencies of neighbouring countries[3], other sub-Saharan countries, such as Zaire, and export markets in other developing regions (Israel, Brazil, Argentina). Thirdly, the export sector remained dominated by large capital and skilled labour-intensive firms, which could only marginally contribute to employment creation in the formal sector: this bias has been attributed to generally insufficient levels of real interest rates and possibly overvalued exchange rates first, while later, since 1990, it has even been attributed to the GEIS (*ibidem*: 26). Labour-intensive consumer goods industries remained internationally non-competitive, with exports mainly limited to other Southern African countries. As far as the effects of the GEIS are concerned, this view can be criticised in view of the support granted by this scheme to labour-intensive sectors.

Notwithstanding the changes in the exchange rate arrangement, in a small and open financial market the ability of the Central Bank to control the course of the domestic currency is limited. In South Africa the rand is considered to have been largely determined by market forces since 1979. Variations in the external value of the rand have been attributed to various factors, including the gold price, terms of trade excluding gold, capital flows, changes in domestic liquidity (relative to the corresponding performance in industrial countries), and political events and connected perceptions by investors. Among these factors, some authors give relevance mainly to real shocks (Barr-Kahn 1995). Others include monetary shocks as well (Addleson 1989), although, as noticed in chapter 4 (sub-section 3.4), the latter factors are not found to be statistically significant as a possible explanatory variable for the South African RER. As for possible RER misalignments of the rand out of its long-term equilibrium path (as defined in Appendix), countries with abundant mineral resources are considered to be on the whole in a better position to postpone needed exchange rate realignments (Michaely *et al.* 1991: 118). As such, and in view of the volatile trends in the international gold price, the presence of sanctions and a rationed foreign exchange market, the South African currency is likely to have undergone substantial misalignments.

5.2.3 Gold mining: main features and trends

In contrast with the general tendency of the 1950s and 1960s, when the increasing costs of mine operations, faced with a fixed gold price and exchange rate, could be offset by raising the average grade of the ore milled, the next two decades were characterised by a declining trend in gold ore grade, even if with tendentially increasing levels of ore output. Since the early 1970s the net effect on gold production of declining ore grades and increasing amounts in ore milled has been negative on the whole, with the former factor mostly overcoming the latter (Chamber of Mines 1995b). Gold production in volume terms, i.e. fine gold in kilograms, declined by nearly 8% between 1980 and 1993. A slight recovery did however occur in the early 1990s, apart from the poor performance in 1994 (Chamber of Mines 1995b and computerised EASy database).

The trend reversal in ore grades has been attributed to various factors: metal price changes, tax treatment, and geological and technological factors. Since these factors underlie some of the hypotheses and modelling of the econometric estimations in this and the following chapter, they are briefly discussed below, except for the specific features of South African gold mine taxation. This topic had been already mentioned in chapter 4, and is reconsidered in greater detail in chapter 6, in view of its direct treatment of the related hypothesis on gold supply behaviour, through the use of net (fine gold), instead of gross (ore) supply.

In terms of prices, lower-ore-grade seams could be mined in view of increases in the US dollar gold price first (in the 1970s), and accommodating exchange rate variations in the rand later (in the 1980s). According to this interpretation, this allowed mining in areas where the prevalence of lower grade ores had previously prevented it, especially in new mine operations (Müller 1992: 260). Studies which pay attention to other determinants similarly argue that, in spite of the general tendency of the ore grade to decline, the tendential devaluation of the rand vis-à-vis the US dollar has recently allowed several gold producers to offset substantial revenue losses (Posel 1989: 47).

According to an alternative interpretation, even in the presence of favourable international gold prices, average unit working costs increases exceeded the corresponding upturns in the gold price in rands in the 1970s, thus eroding the average profitability of South African gold mines. Furthermore, in contrast with the general trend of the 1970s when the inflation rate tended to be lower than annual percentage changes in working costs, since 1982 inflation has tended to exceed gold mining working costs per tonne of ore milled on average, with high positive gaps especially in 1991 and 1992, although a strong gap reversal has been registered in 1994. In terms of payability of the mines, however, this trend has been accompanied by a less positive performance in the US dollar gold price. In the latter view, therefore, it is rather geological and technological conditions that have mainly accounted for changes in ore grade.

With the progressive depletion of higher grade ore reefs, South African mines are considered to have become more dependent on localised deposits, characterised by a greater heterogeneity in the ore grade (Minerals Bureau 1990: 12). By contrast, on a global scale recent estimates point out how gold exploration has been ahead of mining, with discoveries of new reserves more than compensating for the depletion process. Despite these new discoveries, it is believed that, at the current levels of mineral exploitation and assuming no further discovery, most gold reserves will be depleted within the next two decades, except for South Africa, Canada and the United States. Moreover, South African gold mines are considered to have remained more sensitive to gold price changes than the prevailingly opencast deposits in other major producer countries, due to their higher average grades and a larger extension of potentially payable seams (Handley 1990: 8, 14).

This favourable assessment could be tempered in view of recent occurrences, such as frequent work stoppages, enduring high rate of mine accidents, and a new interest of South African mining houses for starting prospection and extraction activities in other parts of Africa. According to the Chamber of Mines (1995: 60), besides the slowdown of shaft development activities, higher discontinuity in mining has been responsible for the decline in the average ore grade in 1994. Finally, in terms of technological developments, since the early 1980s, the introduction of new chemical procedures has allowed increasing amounts of sand dumps and lower-grade surface material to be sent to mills for reclamation (Posel 1989: 18, 87-88; Minerals Bureau 1990a: 12).

5.3 An empirical analysis

5.3.1 Model and data sources

The recursive equation model applied in this analysis embodies variables related to South African gold mining, exchange rate policy and growth, with a view to testing some of the issues examined in section 2. Although not formally integrated into the model, separate results of an estimation of RER misalignments are compared with the growth performance of the economy and the gold price, thus reassessing the results of chapter 4 within a longer time horizon. Finally, based on hypothesized current and future trends of the exogenous variables, the model is used for simulation over the period 1995-1999.

The model includes seven behavioural equations and four identities (Table 5.1, part a). Four variables are assumed to be exogenous, i.e. the gold price in US dollars, the nominal exchange rate, domestic inflation, and the capital stock in the 'rest' of the economy (i.e. all sectors except mining and quarrying). With regard to other five variables, respective one-year lags are introduced as predetermined endogenous variables. A list of the variables is presented in Table 5.1.

The last year of the series is associated with the recent political changes and a likely anomalous performance in some of the variables. Moreover, when these estimations were first run, statistical information for 1994 was not available for all variables included in the model. The later availability of complete updated data for 1994 has allowed to check for parameter stability over that year and suggested the insertion of dummies accounting for aspects not captured by the quantitative variables.

Respecifications of the functional forms initially adopted for OLS regressions over the period 1970-1993 and dummies have been considered necessary whenever the Chow forecast test fails to reject the parameter stability hypothesis (equations [1], [4] and [8]). In equation [8] a dummy have been introduced to account for changes presumably occurred in the gold tax system. In equation [9], the dummy for 1980 would not be necessary according to the Chow test, but it appears to be justified in view of the widening gap occurring in that year between profits and investment decisions. These aspects are reconsidered below, with a brief treatment of individual variables and equations, separately.

During most of the 1980s, the NERUSD can be assumed to have largely depended on international gold price movements, so as to maintain minimum levels of profitability for gold exports in rand terms, as hypothesized by various studies and tested in chapter 4. With the exogeneity condition this assumption is relaxed here, since the model is not used for *ex post* simulations. For the sake of simplicity, moreover, unlike the analysis in chapter 4, the interaction of inflation with macroeconomic policy variables, e.g. money supply and exchange rates, is ignored[4].

The average working costs per tonne of ore milled are supposed to depend on inflation (Posel 1989: 46-47) and a lagged endogenous variable. This lagged variable can assume a near-unitary coefficient. In this case, the functional form of the regression equation ([1]) is equivalent to a lin-log function with both variables in level form (i.e *wcos* and *ln(CPI)*). Except for 1993 and, particularly, 1994, this function captures well the pattern between the two variables over the period analysed, commented in section 2. Compared to a regression specification with both variables in differenced form, equation [1] offers the advantage of directly estimating average working costs in levels. Moreover, unlike the lin-log function in this specific case, it avoids serial correlation. A dummy variable for the 1994 exceptional working cost increases has also been added.

In contrast with its treatment in chapter 6, the grade of the ore is considered endogenous. This variable can be considered as partly endogenous, since, independently from the changing geological environment (which can to some extent be traced by a lagged endogenous variable), South African mining companies tend to adjust production according to gold prices and tax purposes. The latter factors affect the payability of different grade seams once operating cost pressures are accounted for (chapter 6: sub-section 2*b* and note 3; Minerals Bureau 1990a; Handley 1990a). In the regression equation which models the ore grade (equation [3]), therefore, the gold price in rands is adjusted by a deflator based on the fitted values of the average cost variable.

Given certain ore grade attainments and previous year levels of production, gold supply in terms of ore milled can be modelled (equation [4]). The volume of ore extracted can be considered a better measure of real economic activity of the sector than net gold output, in view of the reasons discussed in sub-section 2.3 and in Moll (1992: 190-191). In connection with the jump in working costs, for 1994 a dummy is added, given the extremely high contraction in gold mining output (close to 7% in volume terms, according to provisional estimates) (Chamber of Mines 1995b: 21). This contraction leads to a lack of parameter stability if equation [4] (with no dummy) is estimated over the 1970-1993 period, as compared to regression estimates including 1994, with an overestimate of the supply figure for 1994 and, most likely, too optimistic simulated values for the following years.

Results of the first three behavioural equations can then be used to estimate average working revenue, and average and total working profits (identities [5], [6] and [7]) (Posel 1989: 44-45). Total profit, with a one year lag, is in turn entered as a regressor for estimating government taxes, thus testing the implications for tax revenues of varying levels of overall pre-tax profits in the sector (equation [8]). Even if a plot (not shown here) of the two variables over time clearly highlights this relationship, government revenues out of gold mining also depend on changing tax rules, in terms of direct or indirect imposts (e.g. gold tax formula, government land leases, and import surcharges) (Minerals Bureau 1992: 14-20). This justifies the introduction of dummies for certain years, which appear to stray away from an average pattern. Years with a relatively higher tax incidence, namely a tax income higher than 50% of previous year working profits, are identified in 1975, 1976 and 1981, while the opposite extreme cases are represented by 1993-1994, with a tax incidence lower than 15%. As in equation [4], the specification in [8] avoids an excessively optimistic picture in the *ex ante* simulation.

Capital expenditure in gold mines is believed to follow to some extent the trend of the sector's total working profits (Minerals Bureau 1990: 11). However, in periods of higher gold profitability and higher gold ore production, large spill-overs in new investment projects by the five controlling mine houses can be expected to have occurred for the mining sector as a whole, besides, to a more limited extent, for activities in other sectors of the economy where these holdings are involved. For this reason, although the distinction is necessarily arbitrary, in equation [9] investment in mining and quarrying has been regressed on lagged values of total working profits determined by identity [6], deflated, and converted into billions of rands for the sake of consistency (the absence of such a conversion would not alter regression results in [9]). Following a comparison of alternative functional forms and a graphical inspection, a Koyck-type log-lin equation starting from the second lag has been chosen.

In analogy with taxation, in the investment equation a dummy accounts for the 1980 peak in real working profits. Following a rise in the international demand for and prices of minerals, real mining investment underwent a substantial increase in 1980 (SARB 1981: 8, March). However, real working profits grew even more, reflecting record increases in South African gold sales revenues and in the real international gold price, which respectively exceeded 75% and 80%. These profits, which subsequently dropped by more than 40% in 1981, largely accrued to government revenues, in the form of taxation and lease payments (Chamber of Mines 1981 and 1982; Chamber of Mines 1995a: 7).

On a macro level, in view of the absence of sectoral indicators for the rate of depletion of the stock, capital formation in the mining sector can almost by definition be made dependent on gross investment in this sector and the corresponding level of fixed capital stock in the preceding year (equation [10]). Following an alternative approach, one has tried to estimate the rate of depreciation first, as the difference between values of $\{kmin_{-1} + imin\}$ and *kmin* (defined in the list of variables in Table 5.1), and subsequently projected these estimates to 1999 with a linear trend model, so as to obtain mining capital as an identity. The latter procedure does not provide realistic results in the simulation.

Finally, the productivity of capital in mining, as opposed to the rest of the economy, is approximately estimated with a simple *two-sector/one-factor of production* function (equation [11]). A more complete function with other factors of production, such as a trend for technical progress, is avoided since it further aggravates problems of multicollinearity. These problems are commonly found in estimations of production functions and sources of growth.

Chamber of Mines and Minerals Bureau statistics, partly computerised in the EASy database, were relied on for the estimations. Chamber of Mines (1994a; 1995a) statistical information on ore grade, revenue, costs and profits refer to Chamber gold producers, whereas the variables for government revenues from gold mines and gold output in volume of ore treated concern the whole sector, including non-members of the Chamber. Chamber producers, however, account for at least 90% of total gold supply, and relating the total ore milled with the respective supply of members of the Chamber over the period examined provides a correlation coefficient of almost 0.99. SARB data on such variables as exchange rates, gold price[5], the CPI, and gross domestic investment and expenditure on GDP in real terms, could also be mainly extracted from the EASy database, and otherwise compiled and elaborated from SARB (v.y.).

5.3.2 Econometric results of the model

Econometric results for the recursive equation model are reported in Table 5.1 (part b). Alternative specifications, in terms of both functional form and explanatory variables (such as a trend variable to account for technological and/or geological changes, or lead variables accounting for expectations), led to either analogous, or less significant results, partly due to problems of multicollinearity. Among results reported in Table 5.1, some extent of multicollinearity is likely to affect equation [11], but this specification is to be preferred to a regression based on compound growth values, expressed in terms of logarithms of the ratios of the variables to their lagged values. The latter alternative would redress the possible pattern of autocorrelation, but it definitely worsens multicollinearity problems, due to the strong covariance in the pace of change of the capital stock variables. Similarly, shaky estimates would be obtained if an adjustment procedure for removal of possible autocorrelation is applied in [11].

The use of instrumental variables techniques was not found to improve the significance of the estimates. In a recursive model such as the present one, OLS can be considered as an adequate estimation technique, since error terms can reasonably be assumed to be uncorrelated across equations[6]. The estimated parameters assume the expected sign and are mostly statistically significant at a 98% confidence interval[7].

The long-run negative elasticity of the ore grade to the rand gold price (discounted by the trend in working costs) is found to be nearly unitary, according to results based on equation [3] with no dummy and in loglinear form, over the period 1970-1993. Gold output in quantity of ore milled has been tendentially increasing over the 1970s and 1980s, while an apparent reversal of this trend is observable in the early 1990s. The average ore grade has nearly mirrored these changes, with inverse trends over the whole period analysed. The turning points can be identified in 1989 and 1990, for ore grade and production respectively. As observed earlier, 1994 may be seen as an unusual year relative to these recent trends, since it presents declines in both gross gold production and ore grade (Figures 5.1 and 5.2). Average nominal working profits, instead, undergo an unstable performance, with peaks in 1974, 1980, and 1986, and a late upturn occurring in 1993-1994. Total working profits of gold mines, once deflated by the CPI, appears to be to some extent a leading indicator for investment in mining, apart from the 1980 peak (Figure 5.3). The fitted logarithmic values of the latter variable, obtained from regression equation [9] and feeding into [10], appear to model sufficiently the turning points of actual mining investment over the period (Figure 5.4)[8].

As examined in chapter 3, controversial opinions have been expressed with regard to a supposed asymmetric responsiveness of components of aggregate demand, particularly domestic investment, to changes in main mineral export prices and related foreign exchange earnings. While some authors attribute a relatively more disrupting effect to price downswings and greater *waste* of resources to boom periods, others tend to believe in nearly the opposite occurrence (relatively higher responsiveness of domestic investment during price upturns). To this purpose, equation [9] was re-estimated without the lagged endogenous variable, by alternatively or simultaneously inserting intercept and slope dummies with a two-year lag, so as to identify possible differences in responsiveness of mining investment to gold mine working profits in years with a relative decline in these profits (eventually also removing the 1980 dummy).

Once the Cochrane-Orcutt method is applied to remove residual autocorrelation in the transformed equation, the estimated parameter of these dummies, if separately considered, is found to be significant at a 75-80% confidence interval, with small negative parameter estimates in both cases. When the slope parameter is used, the elasticity of investment to gold mining profits during years characterised by real profit increases is nearly 0.17 (95% confidence interval), and the slope parameter estimate seems to indicate a nearly 5% decrease in this elasticity in periods of profit losses. These results lend only a modest support to the second of the above hypotheses, namely a reduced responsiveness in South African mining investment during price and profit slumps, so that long-term investment programmes would not be severely affected by these slumps. However, apart from its limited statistical significance, the lack of results when both dummies are inserted, coupled with the similar result obtained for the intercept dummy alone, suggests that downswings may rather affect *autonomous* components of mining investment, without an elasticity change.

Following results for tax revenues obtained from a regression model excluding dummies, the marginal tax propensity is estimated to have been close to 0.3 on average over the whole period. If equation [8] is used, however, a clear difference in this propensity can be identified between the period 1970-1992 and the last two years of the series, with this estimate declining from 0.5 to 0.26. The latter equation has proved to yield apparently more plausible *ex ante* simulated values than an equation with no dummy. The introduction of an intercept dummy accounting for high-tax years does not improve the estimation or substantially alter simulated values.

In equation [11], the two elasticity estimates are not statistically significantly different, according to t-tests on null hypotheses for each other values, although some degree of multicollinearity impinges upon the possibility of isolating the effects of each of the two variables. The estimates actually seem to suggest that capital formation directly attributable to mining

Figure 5.1 - Gross gold output (Mt of ore milled) (1970-1994)

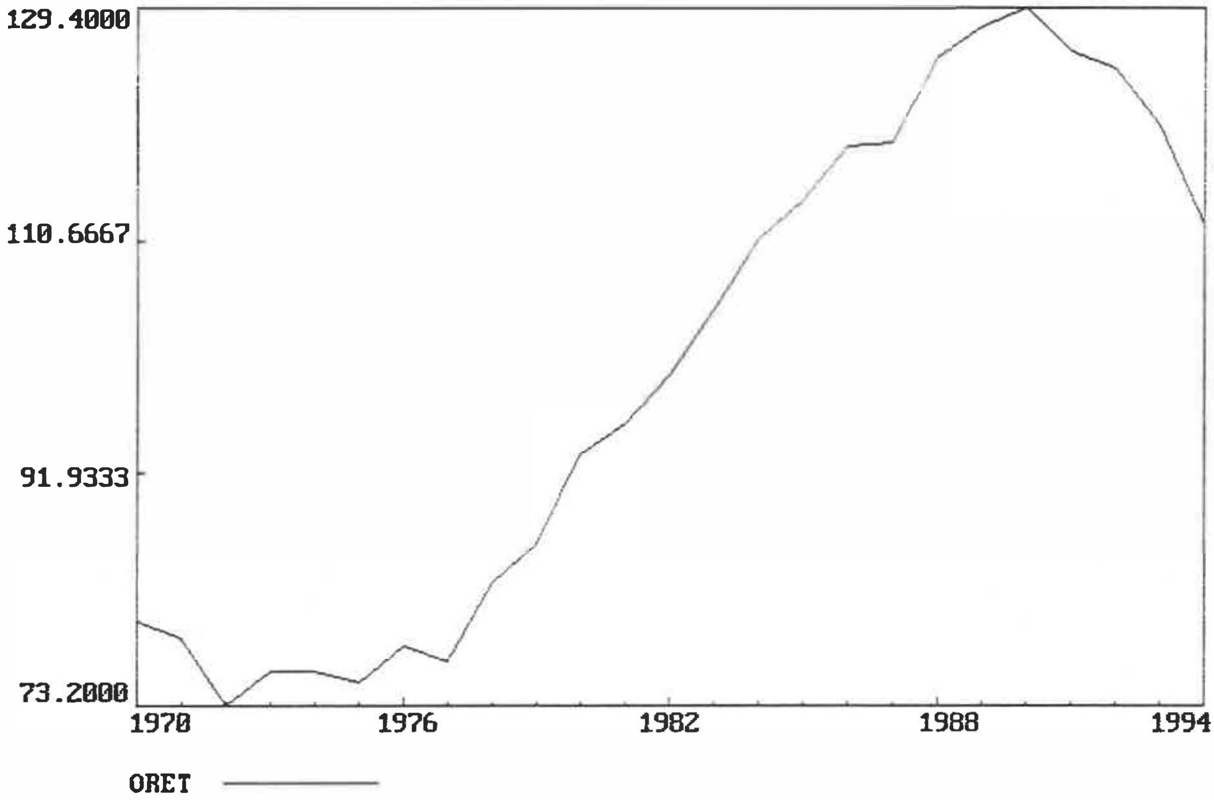


Figure 5.2 - Gold ore grade (g of fine gold/t of ore milled) (1970-1994)

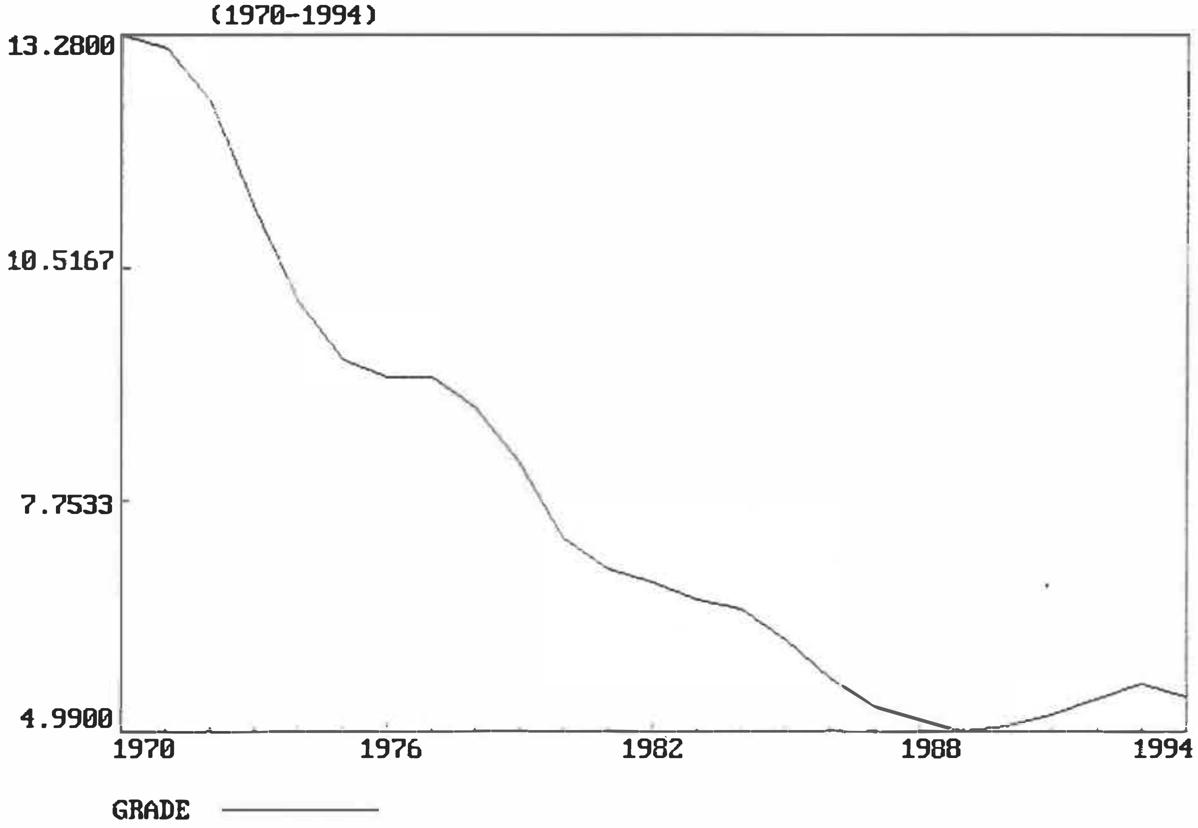


Figure 5.3 - Gold mining profits and mining investment (1990 R. bn.)
(1970-1994)

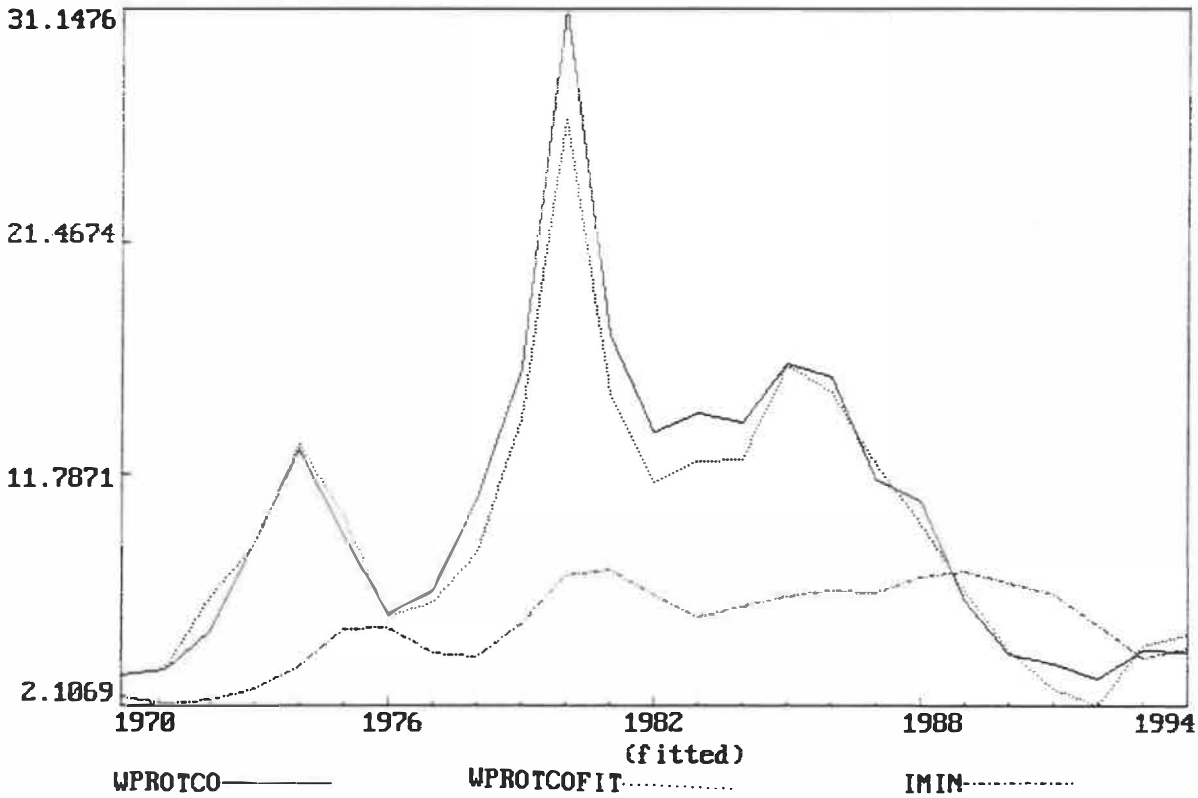


Figure 5.4 - Mining investment: actual vs. fitted values (1972-1994)
(with simulated values for 1995-1999)

may have had less influence on economic growth in South Africa than physical capital related to the rest of the economy as a whole. This obviously does not take into account inter-sectoral spill-over effects. Capital in both sectors has exhibited decreasing returns. In order to assess the influence of the capital account shock of the mid-1980s, a dummy assuming unit values from 1985 to 1992 (the last year of negative growth in the early 1990s) was introduced in both equations [10] and [11]. Statistically insignificant results are obtained for both regression equations.

5.3.3 Some extensions

a. *Exchange rate misalignments and growth*

The model used in this analysis treats growth as a function of a capital input in a two-sector economy, distinguishing between mining and non-mining. As expected, increases in the international gold price have tended to exercise positive effects on growth, particularly during peak years such as 1980 and 1987 (although apparently not in 1983). However, if not adequately dealt with by exchange rate policies, a constraint to growth may have been indirectly brought about, or accompanied, by sudden upswings and/or strong fluctuations in the gold price, through its impact on the RER. This aspect is difficult to assess correctly, in view of the interaction with several other variables, the presence of lagged effects, and possible bidirectional causal links. Moreover, modelling RER misalignments is subject to a certain degree of arbitrariness, following alternative estimation procedures and selections of variables (Appendix).

In this analysis, the equilibrium changes of the REER (as defined in chapter 4) in South Africa have been modelled by regressing this variable on a supposed permanent path of three major macroeconomic fundamentals. As considered in the Appendix, an ARIMA model could be useful to this purpose, although its use is not recommended on annual data over a relatively short sample period[9]. Preference has been given here to applying three-year centred moving averages to the regressors, assuming that 2 or 3 years would be sufficient to distinguish permanent from transitory sudden changes in the fundamentals. The use of 3 years appears justified by results of Koyck-type equations applied to model the impact of exogenous shocks on the RER, over the sample period. These shocks, represented by the three (untransformed) regressors separately considered, are estimated to exercise half of their impact, as measured by the mean lag (Pindyck-Rubinfeld 1986: 232), within periods of nearly 1.5 up to 3 years. Alternative procedures for equilibrium RER (henceforth ERER) determination are discussed in the Appendix.

Similar to other studies on ERER determination and in view of the specific empirical results for the South African RER commented in chapter 4 (sub-section 3.4) and in sub-section 2.2 (Gerson-Kahn 1988; Barr-Kahn 1995), the regressors, transformed in moving average (*ma*) form, included: the international gold price in US dollars (gpcma), the terms of trade excluding gold (totma), and net long-term capital movements in millions of rands (ltkcma). According to Edwards (1994: 84), external terms of trade and capital flows are generally the only RER fundamentals with reliable data. As in the preceding sub-section, the index variables refer to 1990 as a base year. The gold price and net capital flows are used in constant terms, i.e. deflated by a proxy for world inflation (US GNP implicit price deflator, as used by Roskill 1994 for all metal prices: this is indicated by a *c* after the respective symbols above). The introduction of a dummy accounting for the abolition of the financial rand in the period 1983-1984 does not improve the statistical significance of the regression.

In spite of the pegged exchange rate vis-à-vis the US dollar in the first part of the period, the South African REER shows variations before 1979 which cannot be only attributed to changes in relative inflation differentials with major trading partners.

Except for the period 1976-1978, the bilateral exchange rate with the US dollar fluctuated even before 1979. For this reason, a regression was run on the whole period, which turned to be 1971-1992 as a consequence of the moving average procedure. If the regression is applied to the period 1979-1992, the estimated parameters assume similar values as for the whole period, except for the statistically insignificant results for non-gold terms of trade. Dummies accounting for changes in the exchange rate arrangement, occurring in 1979 and 1983 (abstracting from the 1974 change), prove to be either insignificant, or to reflect elements already captured by the explanatory variables. Results are obtained by applying the Cochrane-Orcutt technique, since the DW test is inconclusive if an OLS estimation is applied. T-statistics are reported in parentheses, under the estimated parameters[10]:

$$\underset{}{reer} = \underset{(2.92)}{74.5} + \underset{(2.91)}{0.056}\ gpcma + \underset{(0.35)}{0.065}\ totma + \underset{(2.87)}{0.0046}\ ltkcma$$

$R^2(adj) = 0.58$ $\quad F(4,16) = 8.05$

$DW = 1.70$

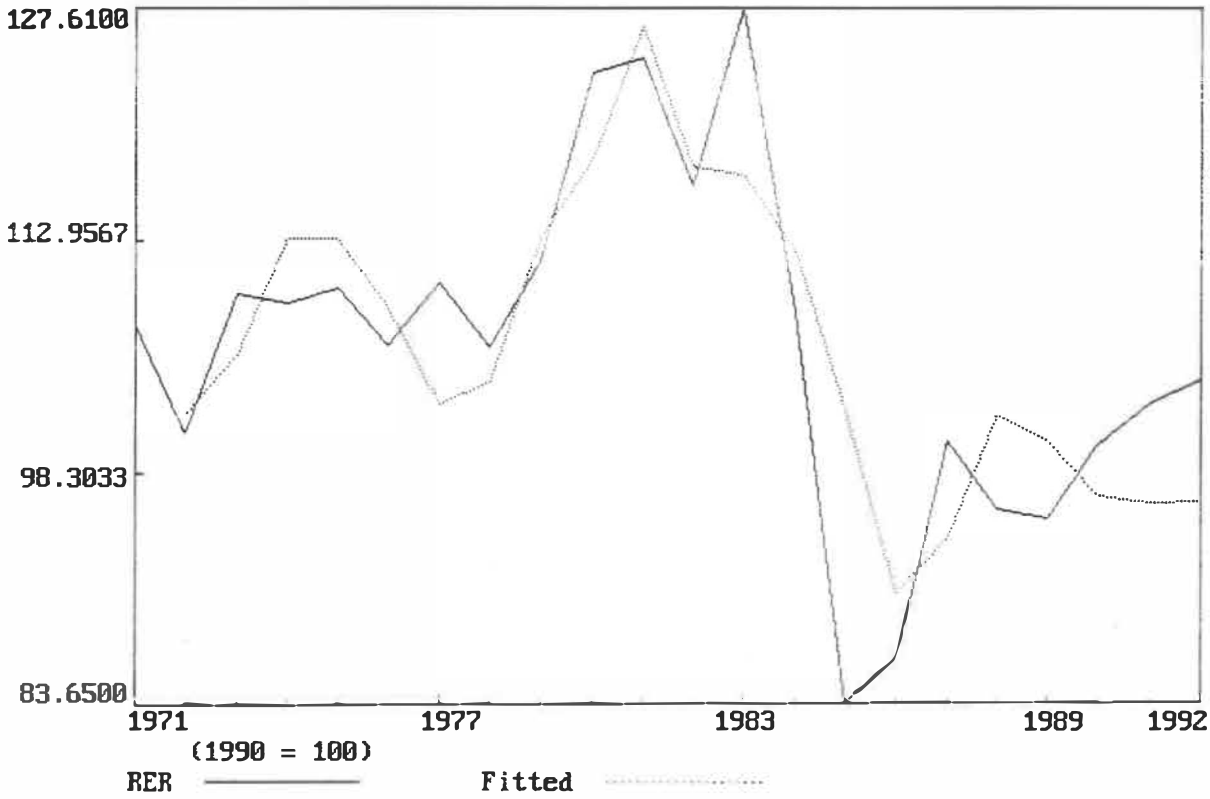
For the gold price and net capital flows the estimated parameters have the expected sign, and are significant at a 99% confidence interval. The terms of trade do not appear to influence the REER, in syntony with results in chapter 4. Although empirical evidence tends to associate terms of trade improvements with RER appreciations, no *a priori* assumption can be made on the parameter sign in this case, depending on the strength of the income *versus* substitution effects[11]. In the estimation, multicollinearity problems are associated with the terms of trade variable, which has a stronger linear relationship with variables other than the dependent one (with which it appears to have almost no relationship). The terms of trade excluding gold in South Africa show a tendential decline during the 1970s and early 1980s, followed by some recovery in the mid-1980s, and substantial stability in the late 1980s and early 1990s.

If the terms of trade variable is removed from the estimation, similar results are obtained, in terms of intercept and slope parameters, goodness of fit, and estimated residuals. In this case, however, the aim of the regression is not to study REER *determinants*, but to identify RER *misalignments*, defined in terms of gaps between the actual RER and the ERER. The ERER, similar to Edwards (1988) and Elbadawi (1994), is given by the fitted values of the regression (Figure 5.5). These values can be interpreted as an *unobservable* component of the RER which is determined by long-term variations in its macro fundamentals, which include the terms of trade. The theoretical underpinnings to the model have therefore been given priority, as compared to a strict compliance with standard econometric assumptions[12].

From the results, one can test whether gold price movements still account for exchange rate misalignments, once their likely effect on the ERER has been estimated. To this end, the simple correlation coefficient between the *transitory* component of the gold price variable (i.e. the difference between actual gold price in real terms and its moving average) and the residuals of the regression, considered as proxies for misalignments, can be indicative. Some degree of positive correlation is actually present (0.31). This may give credit to the argument that the intervention by the Reserve Bank to prevent the rand from appreciating during gold price booms has not been very effective (Barr-Kahn 1995).

The relevance of the exchange rate discount as a policy instrument allowing a postponement of RER realignments is confirmed only for the period preceding the interruption in the use of the finrand. While for this period, namely 1973-1982, the simple correlation coefficient between the discount and the ERER regression residuals is 0.40, for the period following the re-introduction of the finrand (1985-1994) this coefficient turns out to be negative and insignificant. This outcome supports the

Figure 5.5 - Real effective exchange rate: a proxy for misalignment (1971-1992)



corresponding results of chapter 4 on monthly data.

As for the relationship between growth and RER misalignments, pooled cross-country time-series data have been used in some studies to regress growth, and eventually other indicators of macroeconomic performance, on measures of RER misalignment and/or instability (Edwards 1988: 45-46; Ghura-Grennes 1993). This analysis has instead been limited to simple correlation coefficients, in view of the need for caution above noticed. Following correlation results, growth slowdowns appear to have been associated relatively more with the extent of fluctuations around the ERER, as represented by the residuals in absolute value (correlation coefficient equal to -0.44), rather than by RER overvaluations exclusively (-0.16). Of the three years characterised by the poorest growth performance in the period, two years are associated with overvaluations of the RER (1983 and 1992), while 1985 has been accompanied by a substantial undervaluation. The latter misalignment reflects the strong, possibly excessive devaluation which accompanied the debt crisis shock in 1985. This result would seem to support the argument that the extent, rather than the nature (overvaluations as opposed to undervaluations), of RER misalignments have been a more relevant disrupting factor accompanying years of lower growth of the South Africa economy. However, results are highly sensitive to the removal of the observations corresponding to the above three years: the correlation coefficient becomes slightly more significant for overvaluations (-0.24), while it turns insignificant for the residuals in absolute value.

b. Simulation (1995-1999)

In spite of the recent perception of over-exposure to gold by various Central Banks, the international gold price is envisaged by several analysts to follow a more favourable trend in the near future, compared to its performance in the late 1980s and early 1990s. Among other factors, this could be due to still modest levels of gold reserves by Asian countries (Roskill 1995: 104; and various press reports, such as Booyens 1995), and positive trends in the demand for jewellery (although particularly high price increases may in turn curtail this demand)[13]. The average price of gold in 1995 is expected to be nearly 390-392 US dollars per ounce (Roskill 1995: 145; Bureau of Economic Research: note 14). The Bureau of Economic Research (BER, Stellenbosch) forecasts a 2.3% average growth p.a. in this price in nominal terms between 1995 and 1999, in contrast with an almost continuous decline from the 1987 peak to 1992. According to the BER, this expected growth would however experience a gradual slowdown towards the end of the 1990s.

Besides the gold price, BER forecasts on other variables for the South African economy have been used as a baseline scenario in the simulations[14]. According to these forecasts, inflation is envisaged to return to 2-digit levels by 1996: while lying close to 10% in 1995, the inflation level is expected to rise to almost 14% in 1997, thereafter followed by a slowdown in 1998-1999. GDP growth is in turn prognosticated to gradually decline from an expected 4% in 1995 (see note 14) to 1.6% in 1998, followed by a recovery in 1999. A similar trend would be traced by domestic investment.

As for the remaining exogenous variables, the bilateral exchange rate with the US dollar has been projected over the simulation period through a linear autoregressive model of order 1. Estimates for 1995 and 1996 are very close to Nedcor forecasts (Nedcor 1995: 8), while the 1999 projected figure amounts to 4.96 rands per dollar, which implies a nearly 7% average annual devaluation over the period 1994-1999. Non-mining fixed capital stock has instead been endogenised following the same procedure as for the corresponding variable related to the mining sector: (i) once estimates for mining investment have been obtained for the simulation period, based on equation [9], domestic investment in other sectors of the economy can be derived by subtracting these estimates from BER forecasts of total investment; subsequently,

(ii) a behavioural equation identical to [10], replacing mining with non-mining sectors as a unit, can be applied to estimate conditional simulated figures for non-mining fixed capital stock.

The use of the whole sample period as a base for *ex ante* simulations can be questioned, in view of structural changes occurring in the South African economy. However, on the whole these changes do not appear to have substantially affected the parameter stability of the model, although this is not likely to hold in the future. If the regression equations are re-estimated over the period 1980-1994, the estimated coefficients look stable compared to previous results. An exception is represented by equation [4], which provides slightly higher *ex ante* simulated values than those presented here. In equation [11] the multicollinearity problem is further aggravated, and this in practice impedes the estimation of this equation over the sub-period. In this respect, however, although a realistic assessment has been pursued through subsequent model revisions, this simulation should not be regarded as a forecasting analysis. It is rather aimed at testing the growth potential of the economy, given certain structural relationships hitherto characterising gold mining, domestic investment and growth, and the consistency of this scenario with medium-term growth targets as forecasted by the BER.

Results for two years of the simulation period are presented in Table 5.2. Average working costs can be expected to increase at a slightly faster annual average compound rate compared to the early 1990s. With the annual growth of these costs remaining at around 7% over the simulation period, average working costs would not experience peaks such as registered in 1990 and 1994, and would remain below the inflation rate. The gold price in rands would in turn increase at higher rates than average working costs. From 1996, however, due to the levelling off in the changes of the rand gold price towards the end of the simulation period (following the expected performance of the gold price in US dollars), the margin between these growth rates would tend to shrink over the late 1990s[15].

The favourable evolution in the gold price would also allow a reversal of the trends which had characterised the grade of the ore and total gold production in terms of ore milled since the late 1980s and early 1990s, thus somehow re-catching the previous tendencies (Figures 5.1 and 5.2). This would entail a progressive return to lower grade treatment and increased supply, which would both be at levels close to the respective 1988 figures by the end of the simulation period. As a consequence, the supply of fine gold in kilograms would fluctuate within the approximate range of 620-635 tonnes p.a.. The lower ore grades would not prevent the nominal average working revenue from increasing over the last part of the decade. In the period 1996-1999 the annual average compound growth of unit working revenues, costs and profits is simulated to amount to 7.4, 6.8 and 8.6, respectively. In real terms, therefore, in view of the expected rates of inflation commented earlier on, average profitability would be eroded. The profit-to-revenue ratio would however recoup its levels of the late 1980s, increasing from nearly 20% in the period 1990-1992 to slightly over 30% towards the end of the 1990s.

Provided that the envisaged more than doubling of average nominal working profits between 1993 and 1999 is realised and if equation [8] with no dummy is relied on, in nominal terms tax collections from gold mining may rise, by the end of the 1990s, to levels comparable only with the best years of 1981 and 1986-1987. If only the period 1980-1993 is used as a base for the simulation, or, alternatively, a slope dummy as in equation [8] is introduced, more conservative estimates are obtained. The latter estimates still imply a recovery from the negative trend of the last few years in tax revenues from gold mining. This recovery would occur also in real terms, with an over 10% average increase p.a. between 1994 and 1999. Nevertheless, by 1999 gold tax revenues would still correspond to only 60% of their 1990 level in real terms.

The stagnation of gold mining profits in real terms, at levels slightly higher than their 1994 attainment, would determine a gradual slowdown in the recovery which is simulated to take place in mining investment from 1994 onwards (Figure 5.4). If BER forecasts are compared with these estimates, the mining sector would reduce its contribution to total fixed domestic investment, from a 9% share in 1994 (SARB 1995, March) to an expected 7.5% in 1999. Following a decline in the period 1992-1994, the capital stock in the mining sector would consequently level out in the second half of the decade, approximately maintaining its 1989-1990 achievements.

If results are finally applied to equation [11], the simulation model produces economic growth rates for the late 1990s which are substantially below the BER forecasts (Table 5.2) and the actual 1994 growth achievement of 2.3%, even if they reverse the negative performance of the early part of the decade. The growth performance simulated by the model appears to trace the lowest and most conservative of three scenarios envisaged by a World Bank econometric model for South Africa, based on estimations over the period 1960-1992 (Fallon-da Silva 1994: 128). This seems to imply that, if BER growth forecasts for the South African economy are to be accepted, various conditions ought to affect significantly the macroeconomic framework of the model in the late 1990s. No account has been taken here of the growth implications of a faster process of skill accumulation, higher fiscal revenues from mining, and external resources, in terms of technology and investment flows. Furthermore, the progressive opening of the economy, with increased trade links with both industrial countries and other African countries, as well as spill-over effects between different sectors, should also contribute to raise factor productivity and improve the prospects for economic recovery and growth.

5.4 Conclusions

This analysis has been aimed at complementing the results of chapter 4, by focusing on a longer time frequency, namely annual data, and a longer period. The aim of the analysis has been widened, to include aspects treated in chapters 2 and 3 and concerning the linkages between specific features of the mineral sector, commodity export prices, exchange rate misalignments, and growth. At a more disaggregate level, some of these aspects are further investigated in chapter 6.

Without diminishing its relevance as a source of foreign exchange, fiscal revenues and employment generation, gold mining has sometimes been blamed for its supposed destabilising macroeconomic and policy-related implications in South Africa. Moreover, as considered in chapter 2, the presence of a large mineral wealth, or, more plausibly, an inadequate use of this asset, may have retarded the implementation of needed policy adjustments, in areas such as foreign trade or education. This problem is believed to have concerned also the level of the RER, possibly characterised by extensive misalignments. Besides domestic policy constraints, further hindrances to a more effective use of the growth potential of the country have been determined by external factors, such as the long period of international isolation. The removal of these negative factors can hopefully contribute to narrow the gap between the growth rates achievable in the near future according to the simulation model on the one hand, and the current growth forecasts for the next few years on the other.

Although at an aggregate level, the recursive equation model adopted by the analysis has highlighted the high dependence of the South African economy on such factors as the performance of gold mining, the exchange rate policy and domestic price changes. The potential of gold mining in terms of government revenue is likely to be understated if only the most recent performance is considered. In spite of a declining role over the last few years, according to simulation results the gold mining sector appears to hold a potential for regaining some importance in terms of its contribution to fiscal revenues, even if these government earnings would definitely lag behind those of the 1980s in real terms. The government revenue from gold mines has generally been very unstable (Chamber of Mines 1995b), but it presents a sharp slowdown from the mid-1980s, decreasing from 10% in 1986 to less than 1% in 1993, while some recovery has been registered in 1994, and estimates for the new fiscal year 1994/1995 seem to confirm a recent upward tendency (Chamber of Mines 1995: 59). Similarly, mining and quarrying have progressively reduced their share in fixed domestic investment, passing from almost 15% in 1988 to close to 9% in 1993-1994. Simulation results point to a possible further decline of this share up to nearly 7% by the end of the 1990s.

The vulnerability of the economy to international gold market fluctuations does not seem to have had serious repercussions on investment: contrary to indications of studies on other mineral economies, no clear asymmetrical responsiveness by investors to international commodity price and market upswings and downswings is evident. However, this does not deny the presence of excessively optimistic perceptions on the duration of gold price booms, which are likely to have led to lax macroeconomic policies, prior to the capital account shock of the mid-1980s. Among other aspects, these misconceived perceptions, coupled with the objective of protecting producers from profitability losses due to sudden decreases in the international gold price, have led to prolonged periods of disequilibrium in the real effective exchange rate.

In this regard, the analysis has tried to build upon preceding results based on monthly data, which pointed to a link between the RER and the international gold price. No attempt has been made here at identifying *a priori* a benchmark year of exchange rate equilibrium, supposed to be characterised by a sustainable level of external and internal macroeconomic balance.

The relative equilibrium achieved in the external balance for South Africa since the mid-1980s appears to have largely been accompanied by a worsening internal balance, with restraints on imports affecting the level of domestic investment. Besides, the level of domestic production activity has chronically been far from full employment equilibrium.

Following the approach of other studies, RER misalignments have been proxied by the residuals of a regression equation which tries to identify changes in the equilibrium RER. These changes are supposed to be determined by a set of macroeconomic fundamentals, thus implying the existence of no unique equilibrium year. The results inevitably depend on the choice of the reference period and fundamentals, and on the technique for modelling the permanent path of these fundamentals. The analysis not only supports the conclusions of chapter 4, but it also indicates an influence of the international gold price on both equilibrium and actual RER. Finally, years of particularly negative growth performance appear to have overlapped with a relatively more volatile behaviour in RER misalignments, although results do not hold if these years are disregarded by the analysis.

Table 5.1 - Gold mining as a source of government revenue and growth

a. econometric model

(predetermined variables indicated in italic; expected signs of the coefficients under the variables)

$$\text{wcos} = \text{f}\,(\underset{+}{\mathit{infl}},\ \underset{+}{\mathit{wcos}_{-1}};\ \underset{+}{\text{dum94}}) \qquad [1]$$

$$\text{gprand} = \mathit{gpusd} \cdot \mathit{nerusd} \qquad [2]$$

$$\text{grade} = \text{f}\,(\underset{-}{\text{gprandco}},\ \underset{+}{\mathit{grade}_{-1}}) \qquad [3]$$

$$\text{oret} = \text{f}\,(\underset{-}{\text{grade}},\ \underset{+}{\mathit{oret}_{-1}};\ \underset{-}{\text{dum94}}) \qquad [4]$$

$$\text{wrev} = \text{grade} \cdot (\mathit{gpusd}/\text{convf}) \cdot \mathit{nerusd} \qquad [5]$$

$$\text{wpro} = \text{wrev} - \text{wcos} \qquad [6]$$

$$\text{wprot} = \text{wpro} \cdot \text{oret} \qquad [7]$$

$$\text{tax} = \text{f}\,(\underset{+}{\text{wprot}_{-1}};\ \underset{-}{\text{wprottaxl}_{-1}}) \qquad [8]$$

$$\text{imin} = \text{f}\,(\underset{+}{\text{wprotco}_{-2}},\ \underset{+}{\mathit{imin}_{-1}};\ \underset{+}{\text{dum80}}) \qquad [9]$$

$$\text{kmin} = \text{f}\,(\underset{+}{\text{imin}},\ \underset{+}{\mathit{kmin}_{-1}}) \qquad [10]$$

$$\text{gdp} = \text{f}\,(\underset{+}{\mathit{knm}},\ \underset{+}{\text{kmin}}) \qquad [11]$$

List of variables

convf	conversion factor (1 troy oz. = 31.1035 g)
dum80	dummy for 1980 (peak in real working profits, only partly reinvested: see text and Figure 5.3)
dum94	dummy for 1994 (political change, with exceptional performance of gold mining, e.g. in terms of working costs increases and gross output contraction)
gdp	(expenditure on) GDP, in constant 1990 prices (R. bn.)
gprand	gold price in rands (per troy oz.)
gprandco	gold price in rands, deflated by an index based on wcos (1990 base year)
gpusd	gold price in US dollars (per troy oz.)
grade	ore grade (grams/metric tonne milled)
imin	gross domestic fixed investment in mining and quarrying, in constant 1990 prices (R. bn.)
infl	inflation rate (based on the CPI, 1990 base year)
kmin	fixed capital stock (mining and quarrying), in constant 1990 prices (R. bn.)
knm	fixed capital stock (non-mining sectors), in constant 1990 prices (R. bn.)
nerusd	nominal exchange rate of the rand with the US dollar (rands per US$)
oret	total gold production in terms of ore milled (Mt treated, excluding mines doing only dump treatment)
tax	government revenue from gold mines (excluding taxes from non-mining) (31 March year end) (R. mn.)
wcos	average working costs (rands per metric tonne milled)
wpro	average working profit (rands per metric tonne milled)
wprot	total working profit (R. mn.)
wprotco	total working profit, deflated by the CPI deflator (1990 base year) (R. bn.)
wprottaxl	total working profit (slope) dummy for years with relatively lower tax incidence (1993-1994: tax $<$ 15% $wprot_{-1}$) and for simulation years (1 from 1993 onwards; 0 otherwise)
wrev	average working revenue (rands per metric tonne milled)

b. econometric results (1970-1994)

equation	constant	b_1	b_2	b_3	b_{dum}	DW Dh #	R^2 n
[1]	-3.20 (-1.34)''	0.53 (2.63)		1.05 (77.1)	10.25 (3.19)	1.08	0.99 24
[3] *	1.23 (8.96)		-0.14 (-8.41)	0.86 (59.0)		1.08	0.99 24
[4]	36.2 (3.95)		-1.86 (-3.82)	0.79 (13.6)	-9.0 (-3.0)	-0.04	0.98 24
[8] **	-1043.6 (-1.18)'"		0.50 (11.8)		-0.24 (-5.3)	1.61	0.94 23
[9] *	0.58 (3.60)		0.009 (1.32)''	0.62 (5.61)	0.31 (2.22)	0.92	0.75 22
[10] *	0.27 (6.45)		0.09 (4.78)	0.90 (69.1)		0.08	0.99 22
[11] *	2.65 (3.39)	0.34 (1.80)^^	0.16 (1.42)''			1.19***	0.96 22

in the presence of a lagged endogenous variable
* all variables in natural logarithms (except for $wprotco_{-2}$ in equation [9])
** Cochrane-Orcutt autoregressive iterative method
*** indeterminate region (DW test)

(t statistic in parentheses under the estimated parameters)

' less than 80% confidence interval (" 75%)
'' 80% confidence interval
^^ 90% confidence interval (in all other cases: 98% confidence interval or more)

b_1 estimated regression coefficient of the exogenous variable
b_2 estimated regression coefficient of the (lagged or simultaneous) explanatory variable determined within the model
b_3 estimated regression coefficient of the lagged endogenous variable
b_{dum} estimated regression coefficient of the (intercept/ slope) dummy variable (for equation [8], it is the coefficient associated with $wprottaxl_{-1}$)

R^2 R^2 adjusted for degrees of freedom in multivariate models
n number of observations

Sources: EASy computerised database; Chamber of Mines (1994a; 1995a); SARB (v.y.)

Table 5.2 - Simulation results on endogenous variables, based on forecasts and extrapolations of exogenous variables for the period 1995-1999

variable	1994 (actual)	1996	1999
wcos	172.9	196.6 (± 10.6)	239.8 (± 25.5)
gprand	1176.7	1665.5	2132.6
grade	5.40	5.34 (± 0.30)	5.17 (+ 0.43)
oret	112 (provisional)	117.5 (± 8.2)	122.9 (± 10.9)
tax	818.6	1301	2499
imin	4.49	4.84 (± 2.10)	5.06 (+ 2.56)
kmin	68.9	68.1 (± 4.0)	67.8 (+ 6.5)
GDP growth	2.3	0.6	0.7
GDP growth (BER forecast)	2.3	3.3	3.2

95% confidence bands in parentheses for OLS estimations

Sources: EASy computerised database; Chamber of Mines (1994a; 1995a); SARB (v.y.); estimates obtained from the model in Table 5.1, and elaborations therefrom

Notes

(1) Ghura and Grennes (1993) find a negative influence of RER overvaluations in Africa even on imports, as an indirect effect of increased import barriers, raised as a response to a decline in export earnings.

(2) The concept of equilibrium RER, briefly discussed in chapter 3, is examined in the Appendix in greater detail.

(3) In 1989 seven neighbouring countries were estimated to receive nearly one fifth of South African non-gold exports; this share rises to one third if only manufactured products are accounted for (Harvey-Jenkins 1992: 21-22). Moreover, official statistics are believed to have underreported actual trade transactions of South Africa with these countries, because of clandestine trade. In view of the contradictory trends in bilateral RERs experienced by the country over the last two decades, Harvey and Jenkins (1992: 7) argue against an excessive reliance on a multilateral trade-weighted RER index for South Africa.

(4) The inflationary effects of exchange rate devaluations for a small open and largely mineral-led economy as Botswana are studied by Atta *et al.* (1994).

(5) Among the four dominant trade markets where the gold price is fixed on a daily basis (London, New York, Zurich and Hong Kong), the Johannesburg Stock Exchange follows the London-based bullion price and is used in this analysis. The New York-based price, which has been used here for cross-country analyses (chapters 2 and 6), is nearly coinciding with the London bullion fixes, with the simple correlation coefficient for figures between 1970 and 1992 being almost unitary.

(6) This possible problem could be corrected through Zellner estimation, which involves burdensome computations and is supposed to be less effective for small samples (Pindyck-Rubinfeld 1986: 331-334).

(7) Table 5.1 reports the t-statistics for the constant term since the analysis is later extended to include a medium-term simulation. The presence of some degree of multicollinearity in equation [11] induces a higher probability of type II error, with t-statistics being lower than they would otherwise be. The forecasting power of an econometric model is assumed to be generally unaffected by multicollinearity (Stewart 1984: 135-136).

(8) The 1972 observation in the fitted values of mining investment is lost due to the Cochrane-Orcutt procedure, while the preceding years are lost because of the lagging procedure. The latter outcome is also noticeable in Figure 5.3 for total working profits in 1970.

(9) At least 50 to 100 observations are considered to be necessary in order to build reliable ARMA or ARIMA models (Gaynor-Kirkpatrick 1994: 406). This aspect is overlooked in Elbadawi's study.

(10) As in chapter 4, value increases in the REER index reported by the SARB imply real appreciations of the rand, and vice versa

for decreases. The use of deflated, as opposed to nominal, figures for variables deemed to model the RER, or the ERER, is controversial: Gerson and Kahn (1988: 126) use capital account figures in nominal terms, for quarterly data over 10 years; in Elbadawi (1994: 125-127) all explanatory variables, although in nominal terms, are expressed as ratios (besides a trend variable); for a pooled estimation on 12 countries and a 20-year period, Edwards (1988: 45) uses lagged capital inflows, among other regressors (such as lagged real growth), but no indication is provided as to whether these data have been deflated. The treatment of the gold price variable in chapters 4 and 5 is not accidental: chapter 4 aims at measuring short- and long-term effects of the international gold price on both nominal and real exchange rates, with a possible *domestic goods-spending* effect (on non-tradables) supposed to occur *already* as a result of nominal US dollar gold price changes in South Africa. The spending effect could also take place for tradables in the presence of money illusion. By contrast, an assessment, based on a longer period and low-frequency data, of the mechanism through which shocks in commodity prices or other *fundamentals* may affect the (E)RER should account for the world rate of inflation (Edwards 1986a: 245), as applied for the ERER estimation in this chapter.

(11) In the absence of offsetting fiscal and monetary policies and especially if not perceived as a temporary change, improved terms of trade, as well as increased net capital inflows, can stimulate aggregate demand for both tradables and non-tradables. While for the former the country can be assumed to be a *price-taker*, the latter goods and services are supposed to react relatively more *via* price adjustments, thus contributing to RER appreciation. Another channel of RER appreciation is represented by monetary inflation, fuelled by an accumulation of foreign reserves. As discussed also in chapter 3, these effects are generally believed and empirically found to outpace the substitution effect (Edwards 1986a; Elbadawi 1994: 98; ADB 1995: 201).

(12) This is symptomatic of the difficulty in modelling a *hidden* variable such as the ERER, with a trade-off between the necessity to comply with theoretical underpinnings and avoid excessively parsimonious models on the one hand, and the risk of incurring into multicollinearity problems on the other.

(13) A more pessimistic view points to the negative effects of the present benchmarking of the US monetary policy to movements in the US dollar gold price (Brickhill 1995). Increases in this price would be interpreted by monetary authorities as an indicator of inflationary pressures: interest rates would therefore tend to increase, and thus diminish gold investment demand. The opposite would occur with gold price slowdowns. The implications would be a reduced scope for speculative investment in gold. More in general, gold is seen to have become less reactive to events which previously tended to promote price upswings of the metal. By contrast, increasing costs of holding gold may stimulate sales by Central Banks, as actually occurred in Belgium and Holland in 1992, and happening again in Belgium in the beginning of 1995. Compounded by the anti-inflationary policies implemented by OECD countries, these tendencies may hinder a positive performance in the international gold price (*The Economist* 1993; Roskill 1995: 144; Chamber of Mines 1995: 59-60).

(14) Forecasts presented at the ESSA seminar at the University of Natal-Durban on 'Macroeconomic modelling and forecasting for the

South African economy', 2 September 1994 (by B. Smit). Later estimations on GDP growth have revised downward the 1995 expected growth figure (2.4%).

(15) In 1999 the simulated average cost increase attains 6.4%, compared to a 7.3% increase in the rand gold price.

Appendix

Exchange rate misalignment and growth: problems in empirical assessment (with references to South Africa)

An evaluation of the impact of mineral prices and exports and RER misalignment on the performance of the South African economy is liable to a certain degree of arbitrariness, depending on (i) which *proxy* is used for the RER, (ii) which concept of equilibrium RER is adopted, and (iii) which variables are regarded as determinants of changes in the RER, and eventually also in the ERER. Since some of these aspects have been examined in chapter 3, and briefly reconsidered in chapter 4, attention is here restricted to topics specifically related to the empirical analysis, not dealt with in detail in the preceding chapters.

According to Harvey and Jenkins (1990), for South Africa a multilateral exchange rate index, such as the REER compiled by the Reserve Bank, conceals substantial differences in the trends of the value of the rand in real terms vis-à-vis individual trading countries' currencies. Hence, bilateral rates should be preferred. As far as the REER of the SARB is concerned, however, the six most important trading partners accounted for slightly more than one third of South African exports in 1980 and 1990, while representing 53% and 58% of the respective imports in the two years (IMF v.y./a). Turning points for bilateral rates of the rand over the last two decades vis-à-vis most industrial countries' currencies have tended to be close or even overlap, with a few exceptions. By contrast, Africa as a whole, which is the region where the two authors find the most contradictory behaviour in the South African RER, has constituted a small proportion of trade, with ranges lying at 5.5-6% for exports and 2-2.5% for imports in 1980 and 1990, although trade flows are likely to be understated and less skewed towards gold in exports (IMF v.y./a).

Besides the controversy on whether bilateral or multilateral

RER should be used, further reasons for caution in statistical treatment of the RER lie in the choice of the base year and the price indexes, and the weights to be used for the REER (Edwards-Ahamed 1986: 420-421). Although normally readily available and recommended as a domestic price deflator in order to construct the RER, the CPI is subject to some flaws in LDCs, such as the lack of or insufficient coverage of rural areas, or the only indirect link with the primary commodity sector profitability. High instability in the share of major trading countries can moreover affect the reliability of the REER index, increasing its sensitivity to the base year. This problem is not found to be of great concern to the South Africa REER (Holden 1991).

With regard to methods of estimation of RER misalignment, distinctions can be drawn according to the time framework and the assumptions underlying the concepts of RER and ERER. The latter is usually defined as the RER which allows a simultaneous attainment of external and internal equilibrium conditions, given sustainable levels of other variables. The concepts of external and internal equilibrium tend to vary according to different authors. The PPP approach focuses exclusively on the external equilibrium, defined in terms of sustainable levels of the current account balance (Devarajan *et al.* 1993: 46). A more flexible approach prefers to consider the overall balance of payments, including capital flows, for external equilibrium, and a full potential activity level not accompanied by an overheating of the economy, for internal equilibrium (at or close to the natural rate of unemployment) (Williamson 1994: 205; Edwards 1988: 18).

If the analysis is limited to monthly or quarterly data over a sufficiently long period, misalignments can be approximately associated with tendencies of the RER to systematically stray away from a long-term equilibrium, as captured by stationarity and co-integration tests. In this respect, an analysis on quarterly data for South Africa subdivides the period 1979-1993 into three sub-periods, considered to be somehow characterised by different policy frameworks in the country (Barr-Kahn 1995). For each of these sub-periods, stationarity tests and co-integration techniques are applied to effective exchange rates, as defined by the SARB (NEER and REER in chapter 4), and to a ratio of foreign to domestic prices. Results point to divergences from PPP in the first two sub-periods, namely between mid-1979 and mid-1988, while the last few years are found to benefit from more stable and consistent monetary and exchange rate policies, and absence of real shocks. However, on the whole, for longer time series and other countries, most studies of this kind do not support a PPP interpretation (Williamson 1994: 3).

A second method, based on a narrow adoption of the PPP approach, consists in selecting a certain benchmark year in which the RER is supposed to be nearly in equilibrium, and in assuming a near-constant long-term ERER at that level of RER. In practice, for an LDC typically facing current account difficulties, the selected year is characterised by zero or near-zero resource balance (balance of trade in goods and non-factor services). Alternatively, in the presence of no zero trade balances and high annual fluctuations, a *normal* year with a supposedly sustainable deficit is chosen (Devarajan *et al.* 1993: 55, 58). For South Africa, over the period 1975-1994, Kantor (1995: 4) proposes 1990 as a benchmark year, on the grounds that, by that year, the impact of the 1985 capital account shock would be exhausted.

Once the benchmark year is selected, an estimate of the degree of misalignment can be obtained in terms of a ratio which defines the percentage deviation of the NER from the *simulated* RER (as a percentage of the NER for each time observation, i.e., in this case, year) (Vos 1989: 204-205):

$$r = (RER_0 - NER)/NER$$

The simulated RER (RER_0) is given by the product of the benchmark year NER times the ratio between domestic and trading partners' inflation. Setting r equal to 100 in the benchmark year, increases in the inflation differential which are insufficiently offset by nominal devaluations will imply a real overvaluation, and vice versa for an undervaluation. The latter approach, with similar variants, is followed by a number of studies (Krige 1978; Austin 1984). Among these variants, Cottani *et al.* (1990: 64) consider the years in which the RER was at its maximum, i.e. most depreciated, as a reference for correct alignment or a situation close to equilibrium. This is explained in view of the tendency for overvaluation to prevail in several LDCs. RER misalignment for an LDC is then proxied by the premium between the overall period average and the average of these RER values.

Another procedure replaces the above formula with a ratio of the relative price of non-tradables to tradables. For highly primary commodity-dependent developing economies (Vos 1989: 206), this ratio is thought to be approximated by the internal terms of trade of manufactured and service industries *versus* the agricultural sector. Given 1975 as a base year, in the period 1974-1985 for Ecuador the internal terms of trade appear to follow the trend of the above defined *r* ratio (Vos 1989: 205). Vos does not explain, however, why petroleum is left out of the estimation of tradable goods prices for Ecuador.

The authors of these studies mostly recognise the limits of this approach, which disregards the possibility of structural or policy-induced shocks affecting the ERER (Krige 1978: 44). As a *disturbance* of particular concern to South Africa, for instance, a country's ERER will adjust to price variations in the main export commodity, particularly if they are of a permanent nature. If decreases in the ERER are not offset by corresponding changes in the RER, or they are even coupled with RER appreciations, RER overvaluation can be underestimated (Demery 1994: 131-134; Devarajan *et al.* 1993). Actual and equilibrium RER are supposed to converge only slowly if no consistent and appropriate policy measures are implemented (Williamson 1994: 89). In this respect, RER misalignment has been proxied in some cases, for countries with illicit markets for foreign exchange, by the black market premium, although this procedure is likely to overstate the problem (Edwards 1988: 46; Dagnew 1992; Ghura-Grennes 1993).

For studies focusing on long-term effects and based on annual data, the econometric approach can try to estimate directly RER misalignments. As considered in chapter 3, according to a more flexible view of the PPP theory there is no unique equilibrium year, and macroeconomic fundamentals can affect both the RER and the ERER. This view offers the advantage of a more realistic analytical background, which is however overshadowed by the arbitrariness in deciding which variables to use for modelling the ERER. For instance, for some authors both real and monetary variables can affect the actual or observed RER, with short- and medium-run deviations from the ERER determined by temporary changes in these variables, while permanent *real* shocks tend to influence the position of the ERER (Edwards 1988: 5-6, 9; Devarajan *et al*. 1993; Ghura-Grennes 1993). By contrast, according to Cottani *et al*. (1990: 66), deviations from the ERER are usually associated with monetary shocks, thus somehow overlooking what Edwards defines as *structural* misalignment (chapter 3, sub-section 3.2*b*.2). Consensus is not even found on whether the fundamental determinants of ERER changes are trendless, thus implying that the ERER would itself fluctuate around a constant value in the long run (Williamson 1994: 4).

Edwards (1988: 44-46) constructs an index of RER misalignment from the residuals of a pooled regression explaining the RER of twelve countries in terms of a set of indicators. While possible fundamentals suggested by this author have been listed in chapter 3, in practice the explanatory variables used by this author include the terms of trade, lagged capital inflows, lagged real growth (as a proxy for technological progress), the rate of government consumption, a proxy for foreign exchange controls, and country-specific dummies. In a similar pooled econometric analysis, other fundamentals include the ratio of income to foreign trade flows (as an approximate indicator of trade policy restrictions) and a variable expressing the excessive domestic credit expansion, for given rates of devaluation, GDP growth and foreign inflation (Cottani *et al.* 1990). According to Devarajan *et al.* (1993), terms of trade shocks have been the most relevant determinant of ERER changes in LDCs since the 1970s. In Edwards's study, fitted values of the regression are considered to trace the ERER. National indexes of misalignment are then obtained as the average of regression residuals associated with each country, for the period 1965-1985.

An econometric estimation is also applied by Dollar (1992), for the construction of an outward-orientation index, which is used in chapter 2 as a proxy for RER distortion. In this case, however, the purpose is to assess not the extent of RER *misalignments*, given certain fundamentals such as the trade regime, but the distortion of the RER from its hypothetical free-trade level. A bilateral RER (domestic currencies vis-à-vis the US dollar) is regressed on per capita GDP (including a quadratic term to account for non-linearities) and dummies for Africa and Latin America, in a pooled analysis including 117 countries and ten years. Summers-Heston PPP per capita GDP is used as an indicator of relative per capita factor availability, in the absence of more suited indicators distinguishing between various kinds of human, natural and capital resources. Average values of country-related residuals are considered as proxies for RER distortions from the norm (note 15 in chapter 2). Although more densely populated countries are presumed to have relatively more expensive non-tradables, a second country-specific characteristic considered by Dollar, the population density, is not found to be relevant. Results are shown to be insensitive to the removal of regional dummies.

Beyond the advantage of parsimony, cross-country studies aimed at defining a norm for RER alignment are limited by the choice and statistical treatment of the explanatory variables. It would in fact be unrealistic to assume that the same exogenous and policy shocks influence the RER and ERER to the same extent for any country (Khan and Montiel 1987), especially if a country sample is characterised by substantially different exchange rate regimes. Unless correctly modelled with robust estimation techniques or dummy variables, the presence of a few outliers over the period analysed can also seriously bias regression results deemed to identify a fit which should trace the ERER. An approach which seems to avoid these drawbacks is followed by Elbadawi (1994), who estimates the ERER for three LDCs (Chile, Ghana and India) separately. This is accomplished by the author after applying, over the period 1965-1990, (i) a statistical procedure for decomposition of the macro fundamentals of the ERER in their permanent and transitory components (Cuddington-Winters 1987; Beveridge-Nelson 1981), or (ii), alternatively, moving averages of these fundamentals (five years, instead of three as adopted by this analysis: *ibidem*, 111).

In assessing the implications of misaligned RERs for growth, a problem of reverse causality may also arise. Theoretically, there should be a need to distinguish between RER appreciations brought about by productivity improvements in the tradables sector and by accompanying economic growth (with *changes* in ERER), and RER misalignments negatively affecting tradables, domestic investment and growth (Cottani *et al.* 1990). In practice, this is a subtle distinction, since these productivity improvements can derive from a temporary commodity boom bonanza, and as such they can induce a RER misalignment if no adequate policy response is implemented.

6. Supply determinants of mining companies: evidence across developing countries and minerals, with particular reference to South Africa and gold mining

6.1 Introduction

The use of aggregate data of mineral production and exports can help in assessing some of the problems and hypotheses reviewed in chapter 3, concerning the role of mining in a developing open economy framework, with emphasis on exchange rate issues. Some of the hypotheses raised by the mineral economics literature are however left necessarily unattended. Aggregate data do not permit the identification and explanation in a sufficiently clear way of different behaviours of mineral producers faced with changing market conditions. These conditions are influenced by factors such as international commodity price and exchange rate fluctuations, balance of payments crises, or transformations in the pattern of ownership and control.

Complementing the analysis of chapter 2 on long-term growth, a quantitative assessment based on more disaggregate data could consider the possible use of the mining sector as an instrument for balance of payments equilibrium and other policy objectives, given certain characteristics of the major mines and companies involved. This would have implications for long-term growth, in view of the possible connected problems of inefficient allocation of production resources. Furthermore, the analysis in the preceding chapters appears to point to an *accommodating* role of the South African exchange rate to variations in the US dollar gold price in the 1980s, thus to some extent suiting gold producers in periods of declining international prices. These results may be deepened by an empirical assessment based on enterprise-level data. This assessment would be aimed at testing (i) whether the supply responsiveness of gold producers has differed according to various features of the companies, such as the size of mine operation and the type of controlling holding, and (ii) whether the possible distinctions in performance, identified in (i), can also be traced back for other minerals relevant to South Africa. The latter point has been investigated only to a limited extent in this analysis, due to the paucity of reliable data disaggregated by company.

The following analysis builds upon the results of previous chapters by focusing on the issues introduced here. The objective is a study of supply determinants of mineral producers, particularly for gold, with a view to achieving a more disaggregate picture of the relationships between mineral commodity prices, exchange rates, and growth. The behaviour of mineral supply is investigated at the level of major mines, or groupings of mines, in order to test for alternative hypotheses.

Section 2 re-examines the literature which has been earlier broadly reviewed in chapter 3, in terms of impact assessment and econometric modelling, limiting the attention to supply-related aspects. In section 3, the methodological aspects related to the database utilised and the econometric estimation are analysed. This is followed by an assessment of statistical and econometric results, with regard to some of the hypotheses and empirical findings considered in section 2. The estimates first concern gold, and to a limited extent platinum, in a pooled cross-country time series application based on company-level data, while they subsequently refer to the same source of statistical information for major South African gold mines and for overall South African production figures for other minerals. Conclusions are drawn in section 4.

6.2 Supply responsiveness of mineral producers to market changes: some literature findings

The analyses on the supply behaviour of mineral producers can be distinguished in a number of partly overlapping, partly alternative explanations (Table 6.1). Some contributions stress the role of one basic institutional feature of the producing companies, namely whether these companies are state or private. Other contributions introduce more articulated distinctions, based on elements variously associated with this institutional framework, such as the nature and role of the state intervention, the local taxing system, or the presence and degree of control by foreign investors. While not disregarding the institutional framework, a third group of analyses is more concerned with macroeconomic features of the producing countries, as major determinants of different supply responsiveness. Finally, some studies distinguish according to the market characteristics of the mineral, for instance in terms of the extent of market concentration in few producers. Market assessments based on geological features of the deposits can be included in this category. In some cases the last approach has shifted the focus of comparison of supply responses from different companies or countries to different minerals.

a. State versus private control

If the worldwide tendencies of the last three decades in the mining sector are focused on, two periods can be distinguished. Between the mid-1960s and the early 1980s, an excess supply affected several minerals, such as bauxite, iron ore, nickel and copper. This was coupled with a scaling down or abandonment of large-scale operations, and an attempt by producing LDCs to strengthen their bargaining position by promoting producer associations and involving state enterprises in mining production. In legislation regulating mining, more emphasis was laid on efforts to tie mining development with national economic goals, such as employment creation, education and training, and inter-sectoral production linkages.

Over the last few years a partial reversal of this trend seems to have emerged in many LDCs, with the implementation of privatisation and vertical integration initiatives, aimed at facilitating the scope for technological improvements. Apart from this general evolution, LDCs have mostly maintained their relative position according to a scale of the degree of state control in mining, with no full privatisation programmes occurring in recent years in countries where mining was fully state-controlled in the early 1980s (Wälde 1985; UNCTAD 1994: 44-47)[1].

The rationale for or against strong control by the state of mining in LDCs has been debated extensively. On the one hand, as discussed in chapter 3, mineral economies with a weak private sector, such as Zaire or Togo, may favour state-controlled development as a strategy to foster the links of this sector with the rest of the economy. Moreover, these countries often have to undergo relatively more difficult negotiating processes for mining projects with foreign involvement, so as to justify the presence of more centralised decision-making. On the other hand, provided that adequate political, infrastructural and geological conditions are present, successful growth of the mining sector has in some cases been achieved through the granting of incentives to foreign private investors, such as in Chile and Indonesia. In practice, the mining activities of state-owned enterprises (SOEs) have also been more effective in the presence of relatively more solid technological, managerial and financial resources, e.g. in India (Wälde 1985).

When describing the supply behaviour of mineral producers, authors who adopt state *versus* private ownership as a distinguishing characteristic, have stressed the *social* objectives of state enterprises, especially in LDCs, as opposed to the profit maximisation target pursued by private companies. These social objectives would include the reduction of unemployment, poverty and dependence on foreign capital; the improvement of working conditions through training and infrastructural upgrading; and the removal of regional imbalances. Some of these objectives may conflict not only with private financial optimisation criteria, but also with some frequent policy distortions of a mineral developing economy, such as an overvalued exchange rate or heavily subsidised energy prices.

According to Gillis (1992), the SOEs' responsiveness to these *allocative* distortions does not differ substantially from the behaviour of private enterprises. However, SOEs do behave differently in terms of *X-efficiency*, namely efforts to minimise costs and maximise the effectiveness of utilisation of inputs: while X-inefficient private companies are bound to default, SOEs can persist thanks to political decisions. In this respect, Wolf (1982) hypothesizes a *trade-deficit ceiling* in state planners' decisions to allocate exports, whereby, as the actual deficit approaches this ceiling, SOEs become increasingly price-insensitive and are forced to increase their export supply to fill the potential foreign exchange gap. Similarly, according to Dobozi (1990), when world mineral prices fall short of the price required to achieve a minimal target revenue, the price elasticity of supply becomes negative. As argued in chapter 3, this is likely to lead to procyclical effects in the medium term, especially if all major producers of the mineral are contemporaneously affected by severe balance of payments problems. In view of the chronic foreign exchange shortages which characterise major producing countries for several minerals, the predominance of SOEs in mining production in some of these countries assures a lack of monopolistic behaviour against consumer countries (Wolf 1982).

The above interpretation is not shared by other studies, which prefer a *standard* market approach to mineral modelling, as also quoted in chapter 3 (Gocht *et al.* 1988; Vogely 1985). In contrast with Dobozi's pattern, according to Holtham (1988), prices of commodities, including minerals, tend to follow a *hog cycle*, with supply and investment responding negatively to lower price levels. This would allow a faster recovery of international prices once world demand is restored. An intermediate view seems to be proposed by authors who disregard supply responsiveness issues by assuming short- to medium-term rigidity in supply, and focus rather on the dampening role of fiscal and monetary policies geared to keep domestic absorption stable in LDCs highly dependent on a single commodity (Mussa 1978: 55).

b. *Further institutional aspects*

According to the World Bank (1989) the widespread presence of a state mining sector in many African mineral economies, coupled with their inadequate fiscal systems and high external indebtedness, has hindered an efficient performance of this sector and favoured excessive export supply in those countries, relative to prospecting activities. In Zambia, for instance, state mining has received the support of rent-seeking urban groups and, in view of the country's pressing need for foreign exchange earnings, has led to a rapid pace of depletion of mineral resources (Auty 1993: 47). In this regard, some authors have highlighted the relevance of the *kind* of state involvement. In some LDCs full state ownership is not regarded as a helpful means for effective control. By contrast, allowing private capital to share part of the investment risk, through joint ventures, can help in avoiding a potential loss of financial resources, while control over management can be exercised through an efficient institutional setting and policy guidelines. Even among countries with a very small degree of control, some governments have been successful at influencing production through mineral resource property rights and fiscal regulations (UNCTAD 1994a).

Within the state mining sector, in turn, some degree of competition can be stimulated by the government, as occurring in Indonesia (Wälde 1985: 18-19). Other producer countries have instead given priority to full control by the government, geared to preserve the centralised character of the political and economic decision-making process. This has sometimes been pursued even at the cost of an excessive rate of depletion of domestic mineral resources, high public subsidies and severe misallocation of other production resources. This group of mineral economies has been defined as *rent-earning* or *enclave-type* model, since it is characterised by an inefficient and *clientelistic* involvement of mineral SOEs in public services, with no clear distinction between roles of the state and the SOEs (UNCTAD 1994a)[2].

This issue is closely linked to the overall regulatory framework of producing countries. On the whole, African countries are considered to have been unable to cope with worldwide improvements in the regulatory framework offered to mining operations, thus losing market share for several minerals (World Bank 1992). The above distinction in supply responses would shift from the simple state-private ownership pattern to one of efficient *versus* inefficient and loss-making companies, with the latter companies being located especially in Africa and Eastern Europe, and the former in Asia and Latin America (UNCTAD 1994). In the African context, South Africa, along with few other cases, would stand out as an exception to the enclave-type pattern. However, gold supply is found to be negatively related to gold price changes: along with other studies, the correlation analysis reported in chapter 4 suggests a backward-sloping supply curve of gold mining in South Africa. This supply behaviour can not be attributed to Dobozi's hypothesis, but it has rather been explained by the local taxation system, which determines an inverse relationship between average purity level of the extracted ore and the real gold price (Lewis 1989; Moll 1992: 190).

More precisely, the tax formula used in South Africa since the 1920s, expressed as percentage share of gold mining profits paid to government, is the following:

$$t = a - b/x$$

where a and b are government-fixed parameters and x is the share of working or pre-tax profits (profit less capital redemption allowance, and deducting the State's share of profits) to gross revenue of a mine. Hence, during gold price increases, companies can be stimulated to mine at lower ore grades, even if this implies incurring a loss and decreasing gold output. This would in fact also allow to reduce the working profit ratio x and the tax rate t^3.

c. Macroeconomic conditions

Some contributions in the literature have focused to a greater extent on the macroeconomic features of the producer countries. The role of export specialisation is likely to be more relevant for smaller mineral economies, where changes in the composition of domestic production and foreign trade can be expected to occur more slowly than in mineral economies endowed with larger domestic markets (Lewis 1989: 1545-1546). This feature could imply that, faced with a sudden price decline in the main mineral export commodity, smaller producer countries may try to postpone disinvestment decisions in the commodity concerned more than larger producers do. In the presence of similar geological conditions, the responsiveness to mineral price upturns may instead be easier in the latter group of countries, because of economies of scale in mineral production.

A similar distinction between producer countries is drawn by Markowski and Radetzki (1987). Their study does not support the relevance of the state-private ownership criterion: in countries experiencing nationalisations in the mining sector in the late 1960s and 1970s there is no evidence of structural breaks and changes in mineral supply behaviour before and after the state takeovers. According to these authors, state ownership and low or negative supply elasticity are not linked by a causal relationship, but they are both typical of economies with a high dependence on mineral commodity exports, such as Zaire, Zambia and Chile for copper. These countries often happen to be relatively poorer economies. Independently from the prevailing ownership structure, governments of LDCs with a heavy dependence on copper exports as a source of foreign exchange earnings may have tried to force the copper industry to maintain output levels during years of price slump, for general social and economic reasons.

In an analysis by Stobart (1985) on the international markets for five base metals, the inelasticity, or even negative price elasticity, of supply for LDCs' mining companies has been attributed to (i) the objective of these companies to maintain a minimum cash flow to service debt obligations, and (ii) public support programmes implemented during recessions and demand slumps. This phenomenon is considered to have been particularly acute for some large mining operations heavily reliant on foreign and domestic borrowing. In this view, the *ownership and control* distinction would partly overlap with macroeconomic and market-specific elements, but it would not necessarily be a core argument.

Although the public sector is likely to have privileged access to financing, LDCs' governments may decide to subsidise private mining in order to sustain foreign exchange and employment, while also accounting for debt repayment needs of these companies. Examples of this policy include South Africa and the Philippines in the early 1980s for private gold producing companies. As far as South Africa is concerned, state assistance includes measures such as concessional loans and electricity rebates, and is considered to have had a relatively minor and declining importance for the mines (Minerals Bureau 1990: 17). In the absence of such state support, the medium-term effects in several LDCs would be a *squeezing out* of private producers (Stobart 1985).

d. Market-related characteristics

Besides the above outlined indirect determinant of rigid supply behaviour, related to local government policies, the study by Markowski and Radetzki identifies the supposed higher share of fixed costs in poorer producers' mining as a direct microeconomic cause of price insensitiveness in copper supply[4]. Beyond the related methodological problems which are later considered in section 3, the robustness of this empirical finding is questioned by the authors themselves, due to the limited reliability of the data used as *proxies* for variable costs and capacity utilisation (Markowski-Radetzki 1987: 24-27). This view is also contradicted by the nature of labour costs in several industrial countries, where these costs have a high near-fixed component, thus eventually supporting the same hypothesis for some relatively richer producers as well (Stobart 1985: 99). In the latter view, there would be rather a general tendency in modern mining towards a higher share of fixed costs, thus forcing the companies to keep mine operations at full production capacity.

Other studies have considered further market-related elements of differentiation, such as the availability and extent of high-grade ores, competitive labour costs and higher productivity: all these elements would allow for extra-rents by intra-marginal producers especially in periods of price bonanza. The overall supply response to negative market changes would to a large extent depend on the behaviour of marginal producers: if a mineral price decline is perceived as temporary, there may be a maintenance of minimum production capacity, instead of the alternative of a mine closure, with a view to avoiding the reopening costs and loss of customers. On the other hand, temporary booms have often been thought to last longer, thus causing overinvestment and oversupply for certain minerals (Stobart 1985). Purely geological factors are believed to count relatively more for fuel than non-fuel minerals (UNCTAD 1994a). For certain minerals, sudden price shocks of substitutes can have relevant implications on price and supply in the short-to-medium term, such as the case of uranium and coal following the oil shocks (SARB 1990: 15-16).

Geological and location factors can account for the higher and quicker responsiveness of certain mining complexes as compared to others (Handley 1990: 21). An area with a rich availability of ore and a long history of mineral exploitation, such as the Witwatersrand, can benefit from economies of scale deriving from established infrastructures. Moreover, such an area is more likely to be characterised by successive *cycles* of decline in capital expenditures: these cycles would coincide with later stages in a mine life, and possibly allow for evaluation and eventual opening of new conglomerates attached or close to an old (and declining) mine. On the other hand, climatic, topographical and geological conditions may slow the pace of mineral exploration and production in regions which are otherwise considered promising in terms of mineral reserves.

A typical case is Papua New Guinea, where gold mining has been facing some difficulties because of such constraints as heavy rainfall, location of the ore (volcanic formations, with geysers and *hot* rock), and location of the mines (e.g. Ok Tedi is close to a river used by locals) (Handley 1990a: 24-25). A number of high-grade deposits in Papua New Guinea have remained unexploited since their discovery in the 1960s (Roskill 1995: 85). Also in South Africa geological constraints often affect stoping and extraction operations of the mines: gold ore is extracted at up to 4 km of depths level, which is characterised by very high rock temperature and unstable ground conditions (Minerals Bureau 1989: 7).

An obvious feature accounting for mineral price formation and mineral supply behaviour in a private enterprise context is the market structure. For primary gold the very high concentration of production in a few large mining groups has favoured a nearly monopolistic structure, with Anglo-American Corporation (AAC) influencing almost half of world production. Other minerals, such as tin and bauxite, present an oligopolistic market structure (Gocht *et al.* 1988). The impact of AAC on world gold prices is limited in turn by the presence of large world stocks of gold.

Besides the main character of the market, a relevant market-related factor may lie in the organisation of producers: a mineral market characterised by scattered, unorganised producers, less integrated forward with semi-manufacturing industries, can be expected to be less responsive to demand changes and affected by higher price oscillations. Examples are provided by copper as opposed to aluminium (Stobart 1985), or gold as opposed to diamond

(Handley 1990a). Moreover, a particularly rapid increase in average unit working costs, as often experienced by South African gold mines involved in high-depth seams, may more than offset favourable factors such as economies of scale, technological advances and increasing links with the secondary industry. As a consequence, the payability and life of the mines is curtailed (Minerals Bureau 1990a).

In terms of its microeconomic impact, a devaluation in the exchange rate can have uncertain effects on mineral supply[5]. While it can protect local producers' revenues in local currency from international price slowdowns, it can negatively affect the cost side, with higher costs in foreign currency of shipping, repayments on foreign loans and imported capital goods. As examined in previous chapters, the net effect for gold producers in South Africa is generally considered to have been favourable, at least until the late 1980s. A reason for this may derive from the relatively lesser reliance of South African mining on imported capital and its possible greater ability to absorb the effects of labour cost increases, as compared to the rest of the economy and especially the industrial sector (Addleson 1989: 7-8). In this view, a positive mineral supply response would therefore be only indirectly related to slowdowns in international commodity prices: exchange rate devaluations resulting from adverse movements in these prices would directly affect supply. This can particularly occur in countries which are highly dependent on export receipts of the commodity concerned (Adams-Vial 1988: 92).

With possibly similar effects as devaluations, furthermore, different sales modalities can buffer against adverse international price movements. In South Africa there are three modalities of mineral sales: spot prices, producer prices, and term contracts. Producers of gold, silver and other seven minerals marketed at spot prices are partly protected by the use of futures markets from unexpected commodity price fluctuations[6] (at present, the SARB allows up to 30% of a mine's gold sales to be transacted in this form). Platinum group metals (PGMs), zinc and nickel have often been sold on main producer prices, although PGMs are now generally sold on long-term contracts (*Financial Mail* 1995). For PGMs producer prices offer the advantage of being much less volatile than spot prices, while in the case of zinc producer prices have tended to follow a damped and lagging pattern of spot prices. Finally, as a third sales procedure followed in South Africa, copper and other base metals are mostly sold on up to 12-month term contracts. These term contracts are often flexible, thus allowing the company to sell a proportion of the mine product at spot prices during price increases, and reducing this proportion whenever the opposite occurs (Austin 1984: 339-340). In practice, beyond this categorisation, in several cases different sales modalities are applied to the same minerals.

In the following sections some of the above hypotheses and empirical findings are tested on mineral enterprise-level international and South African data. Following some remarks on data and methodology, a first part of the analysis addresses institutional aspects related to points *a* and *b* in Table 6.1, along with partly alternative explanations based on the macro and microeconomic factors listed under *c* and *d*. In view of the relevance of gold and platinum for South African exports, the analysis is limited to these two metals. Some of the topics discussed in points *b* and *c* above, have already been considered in chapter 2, although in a long-term growth perspective. In addition to this long-term perspective, a short- to medium-term framework has then been adopted by chapters 4 and 5, with regard to exchange rates and, to a limited extent, tax- and market-related issues concerning South African gold mining, referred to under points *b* and *d* in the Table. South African enterprise-based production data for gold and other minerals allow further testing of these issues, at a more disaggregate level of analysis. This is pursued in the second part of analysis.

6.3 An empirical analysis

6.3.1 Methods and data sources

a. *Methodological issues*

In order to test different hypotheses on short- and medium-term supply determinants for mineral commodity producers, two approaches can be followed: (i) a cross-section study, focusing on different features of a number of producer countries, companies and/or minerals, and (ii) a time series analysis, geared to identify structural breaks in supply behaviour for a specific producer over time. Examples of the latter case would include the supply responsiveness to nationalisations, possible abrupt changes in the dependence of the economy on mineral export receipts, or specific shocks in a commodity market.

The difficulty in collecting suitable data may explain why most of the studies examined in section 2 do not attempt an econometric estimation, while limiting the analysis in some cases to descriptive statistics and graphical interpretation. Another factor hindering empirical testing in this area lies in the methodological complexities of mineral commodity modelling, as broadly discussed in chapter 3. Attention is paid here to problems of estimation with specific regard to two of these studies, which deal with copper supply.

Both Dobozi (1990), and Markowski and Radetzki (1987) assume that copper producers are *price-takers*, thus allowing for exogeneity in the mineral price variable and justifying the use of OLS or other techniques for single regression estimation. Another assumption adopted by both studies, which simplifies the econometric modelling, consists in discarding the possibility of substitution effects in the short run: this removes the need for introducing e.g. aluminium prices as an explanatory variable for copper supply. Moreover, as production statistics are more readily available than export data for mineral commodities, like in other similar studies, a high positive correlation is assumed between domestic production and export supply of the minerals. With regard to the South African mining sector, this assumption can be considered realistic, especially for precious minerals (gold, platinum-group metals, diamonds and silver).

With reference to mineral commodity prices, some doubts can be raised about the appropriateness of using international or domestic currency prices in regression equations representing mineral supply functions. For time series estimations on individual producer countries Markowski and Radetzki opt to use the refined copper price expressed in local currency. Dobozi prefers, instead, to model copper supply responses with the LME or the United States producer copper price in dollar terms. The latter choice could be more suitable because of the foreign exchange constraint and balance of payments objectives influencing SOEs' production decisions, coupled with the lack of currency convertibility and highly regulated domestic price systems typical of former centrally planned economies and LDCs (Dobozi 1990: 9). Besides these reasons, mineral supply could respond more to international than to domestic mineral price changes wherever the local market is dominated by *externally-located* multinational companies, or where local companies heavily rely on foreign inputs (Adams-Vial 1988: 89).

The adjustment of mine capacity utilisation to changes in prices and costs is supposed by Markowski and Radetzki not to exceed a calender year, in spite of the features of mine supply commented upon in chapter 3. In the actual estimations, however, a dynamic model embodying lagged responses leads to relatively more significant results. Similarly, Dobozi (besides a static equation) assumes that copper supply follows a partial adjustment process traced by Koyck and Almon-type equations. In spite of not being commented upon by the authors, results of both studies show that the gain in significance in estimation when passing from static to dynamic modelling is not so clearcut, except in a few cases. By contrast, a great deal of apparent improvement in statistical significance seems to be obtained by the use of dummy variables, accounting for one-time shocks such as strikes, severe recessions, or serious mine accidents[7].

Another methodological issue, apparently not sufficiently accounted for by Dobozi and Markowski-Radetzki, is the level of disaggregation of the statistical information. Markowski and Radetzki claim to have empirical evidence supporting an interpretation of supply response based on macroeconomic and market features, such as the level of dependence on mineral export receipts, as previously mentioned. Yet, this evidence relies on separate time series analyses of national copper supply over the period 1964-1983 for eight countries only.

Similarly, in order to test the state ownership hypothesis, Dobozi applies a time series analysis on 1970-1987 annual production data by major companies, aggregated according to the prevailing ownership pattern of country groups. For private companies, these groups include LDCs as a whole, United States, Canada, and the rest of the industrial countries; for SOEs, a distinction is made between former centrally planned economies and the rest of the world. The latter group is so heterogeneous as to include Chile, Finland, India and Turkey, among others. When the *balance of payments (BoP)* variable is used, along with the real copper price, in order to test for the supposed downward-sloping supply curve, the current account balances are merely aggregated for each country in each group. In this way the results can be biased due to (i) either production and balance of payments data offsetting each other across countries in certain years, or (ii) disproportionate weights of the producer countries in these two variables.

Furthermore, since Dobozi hypothesizes a strong covariance between the performance of SOEs' output, mineral commodity prices and BoP deficits, no reason is provided for the need to include both copper price and BoP deficit as explanatory variables in the regressions, with the possible associated problem of multicollinearity. Finally, the BoP variable is calculated by adding the actual balances of national current account BoPs, in *absolute* terms (Dobozi 1990: 25). This procedure does not account for the importance of trade deficits *relative* to an individual country's purchasing power of exports or the overall size of its economy. In this concern, Wolf (1982) suggests *normalising* the current account of the BoP by calculating its share in the value of exports. In this analysis the preferred indicator has been the percentage share of the current account before official transfers in GDP, instead of exports, calculated for each country and year[8].

b. Data sources

The following analysis has relied mainly on statistical information of a computerised database set up by RMG (Stockholm). This database includes detailed statistics on ownership and production by 34 major minerals and over 8000 companies. RMG has been collecting and systematising statistical information on world mining since the late 1970s. Production time series data for each company, as well as respective country totals, cover the period 1984-1993. While annual national production statistics for the formerly centrally planned economies (and China) are included in the database, coverage for their company-level production is only provided by the most recent update of the database, which was unavailable when this study was undertaken. Production statistics for these countries are moreover subject to greater uncertainty (Handley 1990: 18). The choice of 1984 as an initial year is likely to be particularly suited to the purposes of this analysis, being considered a break year from the previous tendencies towards state ownership control in several mineral economies (UNCTAD 1994: 5).

As far as gold and platinum are concerned, while the latter metal has an annual overall coverage ranging from nearly 70% to over 80% over the 10-year period in total world production, the total production of identified gold mines sum up to nearly 70-75% of annual world production. The generally lower coverage, especially for gold, compared with the corresponding figures of the RMG database for other minerals, are attributed to the relevant presence of small-scale, and in some cases illegal, mining operations. This can also explain the low coverage in the estimated total national production of the mining supply of companies selected by this analysis in certain countries, which are considered relatively more affected by unregistered operations (Brazil and Colombia for gold: Table 6.2). Other causes of mismatching could be due to incorrect production figures reported by companies or estimated at the national level, with these figures believed to be often understated for security reasons (Handley 1990).

For most years and minerals, RMG production statistics are obtained directly from company sources on an annual basis (annual reports). In a few cases of unavailability of this information, and whenever company production is known to be not negligible, estimates have been made by national mining institutions, such as the US Bureau of Mines, or by RMG itself. In some of these cases, however, no estimate has been possible. For the selection of production time series by company, enterprises with one or more missing or null values in certain years were excluded by this analysis, unless this deficiency concerned a mine/country of particular interest. Such an example is the Bougainville gold mining operation in Papua New Guinea, which stopped producing in 1989 due to sharp contrasts with the local population. The exclusion of this large mine would have left the estimations of gold supply responses in PNG possible only for another company (Ok Tedi), since other relevant gold mines became operative only in the 1990s.

Similarly, the availability of production data excessively relying on estimated figures, as opposed to company-reported statistics, for a certain number of years led to the exclusion of the companies for which the data were estimated. In these cases, preference would rather be given to reported national total production figures, provided that these figures do not substantially differ from the company's or eventually (if production for more than one major company is reported by RMG) from the sum of individual companies' estimates and the ownership pattern appears to be homogeneous across companies. In practice this occurs only for India in gold production and Colombia in platinum production. In view of the presence of financial years other than the calender year for a few companies (especially Indian and South African), the time consistency in the data across companies and countries has mostly been assured by RMG through collection of company statistics in quarterly reports.

Features and changes in the ownership pattern have been recorded by RMG for each company, and in several cases the physical mines and plants operated by a specific company are also indicated. With regard to ownership information by company, this information is used by RMG to construct hierarchically structured groups, from (subsidiary) mineral producers and exploration enterprises at the bottom, through holdings and other intermediary companies, up to controlling companies at the top. The RMG corporate control model is based on both the level of ownership and the structure of management, eventually supplemented by additional information such as board membership.

This procedure allows a more realistic assessment of actual control, by avoiding a complete reliance on either a pure *equity* approach, or a *management* approach. The equity-based method defines *controlled production* as the producer's output multiplied by the equity share of the holding company. This method tends to dilute the actual control out of the main shareholders. The opposite outcome tends to occur with the management method. According to the latter method, a holding company has full control on production of a mine if it holds more than 50% of the equity share, disregarding the possible presence of other major controlling companies. Furthermore, as mentioned in section 2, even if ownership is considered the most common way of exercising control and is expected to continue to be such in the 1990s, other strategies have been used over the 1980s to secure control, such as long-term production contracts, or administrative and technical management.

While the RMG corporate control method standardises to some extent the information on corporate control as variously defined by producer countries, it can substantially differ from the method used by specific countries and mineral industries. In South Africa, gold mining fully adopts the management principle as a criterion for control, thus overlooking the ownership structure. In practice, however, for the mines considered by this analysis, the two methods mainly identify the same mining houses as controlling companies (Appendix). A detailed description of the RMG method for measuring corporate control in mining, as compared to the two alternative methods outlined above, is presented in UNCTAD (1994: 51-53).

In the second part of the analysis, besides gold and platinum seven other minerals of particular interest in South African mining were included (Table 6.8). Tin and zinc, in spite of being suitable cases for a study on fluctuations in mineral supply and export earnings, were not considered since over the last few years they have tended to serve exclusively or almost exclusively the local market in South Africa. Diamonds were disregarded because of their highly monopolistic market and unavailability of export prices for South Africa after 1986, with local sales, exports and prices being *classified* information (Minerals Bureau 1993 and 1994a: 6-7). On the other hand, although covering a very low share in South African mine production and exports, silver was included in the analysis because this metal is almost entirely exported. As a non-metallic mineral, coal is not included in the RMG database, so that Chamber of Mines statistics on total exports in volume terms were relied on instead (Chamber of Mines 1994a: 52). In order to convert f.o.b. export unit prices into constant terms, the same deflator used by Roskill was used (US Dept. of Commerce GNP implicit price deflator: Roskill 1994). These figures were then expressed in both US dollar and SA rand terms.

Chamber of Mines annual statistics collected in a computerised database by EASy (Pretoria) were used to complement the RMG database in the pooled analysis on South African gold mines. While mine supply data coincided for both sources (apart from the more updated figures of RMG for four mines), EASy data provide statistical information on ore grade and working costs per tonne milled, by mine and year. It should be noticed that, in contrast with chapter 5, *gold supply* is not defined in gross terms (ore milled), but it refers to actual production figures of fine gold, in tonnes. Other supplementary statistical sources used for the analysis included Roskill (1994), for commodity prices in constant terms; World Bank (1994: Table 18), for current account BoP to GDP ratios (1983-1992); Summers-Heston (1988), for real per capita income (purchasing power parity) data; and World Bank (1993b: Table 24), for debt service ratios. The unavailability of complete time series for the last variable has limited its use to the initial correlation analysis.

6.3.2 Results of the econometric analysis

a. *Cross-country analysis for gold and platinum*

a.1 Gold supply: main characteristics of the sample

For the analysis of gold mining supply, the selection criteria outlined in the preceding sub-section led to the choice of 21 developing economies, of which eight were in sub-Saharan Africa (including South Africa), six in Latin America, and seven in Asia and the Pacific Ocean. In Table 6.2 a list of the selected SOEs operating in these countries is provided, while for the private sector only the countries concerned are indicated in view of the large number of companies for a few producer countries.

Colombia, Fiji, the Philippines and South Africa have essentially only private gold mining companies. For China, Ethiopia, India and Tanzania (besides the CIS) the complete coverage by respective state-controlled production data is due to the use of national production figures, replacing totally/ partly missing or estimated individual company-level annual data (e.g. note 9 for the case of Tanzania). At the opposite extreme, for Brazil and Colombia the annual share of the selected companies in national production figures is barely one-eighth or lower, but lack of complete data for other companies and further problems mentioned in the previous sub-section have constrained the scope for increasing this coverage. In only three out of nine cases where both private and state-controlled companies are present, the reported state gold supply exceeded private production in 1990, these cases being Ghana, Papua New Guinea and Peru (Table 6.2).

The aggregate national gold production of the selected economies represented nearly half of the world supply of gold in 1990. Besides these countries, for comparative purposes Table 6.2 reports figures for the CIS, in view of its relevance as a world supplier of gold. The CIS, which decreased its share in world production from over 20% in 1984 to less than 11% in 1993, was excluded from the sample used for the econometric analysis because of the lack of consistent time series for the BoP. Provided that a favourable investment climate is established, the CIS is estimated to have the potential to become the third largest world producer of gold, overtaking Australia, with the main reserves located in Russia, Kazakhstan and Uzbekistan (Roskill 1995: 109). In view of an average growth of national gold production of nearly 9% per year over the period 1984-1993, China may in turn displace Canada as the fifth largest producer. China is also the world's largest consumer of gold. Since 1992-1993 both the CIS republics and China have opened their markets to foreign investment in gold mining, although in China this liberalisation is limited to certain regions and lower grade deposits (Roskill 1995: 52).

Outside the developing regions, relevant gold producers include the United States, Canada and Australia: in 1990 these countries accounted for 13.8%, 7.8%, and 11.4% of world supply, respectively. Particularly dynamic has been the performance of Australian gold mining, with a fourfold increase of its share in world production between 1984 and 1993 (RMG database; Chamber of Mines 1994a: 47-49). However, given present known reserves, Australian supply is expected to fall rapidly before the end of the century (Handley 1990). Among LDCs, Venezuela held nearly 0.7% of world production in 1990, Bolivia 0.5%, Ecuador 0.4%, and Mali 0.14% (with a rapid increase up to 0.28% in 1993): the absence of sufficient information on the ownership and control structure of companies operating in these countries, coupled with the fact that only short time series were available for Mali, prevented their inclusion in the sample.

More than half of the gold production of the sample is concentrated in South Africa. Along with a few other producers, South Africa underwent a severe reduction in its world share of gold, from almost 46% in 1984 to 27% in 1993. However, the estimated gold reserves cover a much higher share in the world total, ranging between 40-43%, if gold as a by-product of copper and nickel is excluded, and 50% (Roskill 1995; Table 1.1). As for the other producing countries, those rapidly increasing supply and expanding their share in the world total can not be distinguished from the rest according to geographical location or relative size of supply: high and low performers stand out in Africa, as well as Asia and Latin America (Table 6.2).

In a few cases, the positive performance of certain countries of the sample can be partly explained by supply jumps due to the opening of new mines in the year before, such as 1988 in Brazil, 1991 in Ghana (new mines of Bogusu and Tererebie, besides the increase in production in Ashanti), 1992 in Indonesia and 1991 in Papua New Guinea (new large-scale mining operations of Kelian Gold for Indonesia, and Misima and Porgera, for PNG)[9]. Papua New Guinea had previously benefited from the launch of a large scale operation by Ok Tedi in 1984, with a more than sixfold increase in gold production by this state company in the following year. In spite of the underutilised resource base and the decline in exploration activities, this country might overtake Brazil and become the world's seventh largest gold producer by the end of the century (Handley 1990a: 26; Roskill 1995). Being at present the ninth largest world producer, Indonesia has experienced an extremely rapid increase in gold production. This has been largely due to the development, since the late 1980s, of one of the largest copper and gold mines in the world, Tembagapura (previously Ertsberg), located in the eastern province of Irian Jaya (RMG data; Roskill 1995: 77).

The above production jumps do not justify the introduction of corresponding dummy variables in the regressions: except for Ashanti, Bougainville and Ok Tedi, they concern companies not included in the sample. For the regression equation considering total (state and private) supply for the sub-sample of gold-dependent economies, a dummy was introduced for the years when both Bougainville and Ok Tedi were fully operative, but results do not substantially differ from those reported here (sub-sample A in Table 6.6).

With regard to the pattern of control, companies were subdivided into two groups, namely private and state-controlled. The latter group includes mining enterprises with at least 50% of control exercised by the state in November 1994 according to the RMG corporate control model. The database does not allow a careful backward tracking of changes in control structure over the period, but major controlling companies and institutions are reported by RMG whenever possible for each year. As pointed out in sub-section 3.1, privatisations over the period considered here tended not to be radical enough to affect the above subdivision[10].

Three companies were considered to be state-controlled although failing to comply with the above criterion: Mamut (Malaysia), where the state was presumably the major controlling agent in the mid-1980s and was holding 49% of control in 1994; Ashanti (Ghana), where the state has probably maintained a dominant position over the 10-year period despite not reaching the 50% cut-off, due to the dispersion of private holdings (in 1994 the state controlled 43%, as opposed to the 31% held by the second major controller, Lonrho); and Ok Tedi (Papua New Guinea), 30% of which controlled by the state in 1994 and for which similar conditions to those prevailing for Ashanti can be presumed.

a.2 Gold supply: statistical and econometric results

a.2.1 Simple correlation analysis by country

To provide a preliminary indication of the responsiveness of gold supply to changes in prices and BoP conditions, a simple correlation analysis was carried out on state and private-controlled production by each producer country separately and on pooled data of countries with both forms of production control, over the period 1984-1992. Supplemented by an inspection of scatter diagrams, this analysis can provide initial suggestions about (i) a possible dichotomous behaviour according to institutional or macroeconomic features of gold supply, as outlined in section 2; and, limited to the ownership and control issue, (ii) the necessity for or possibility of using both mineral price and BoP variables as determinants of mining supply in the state sector, rather than one or the other.

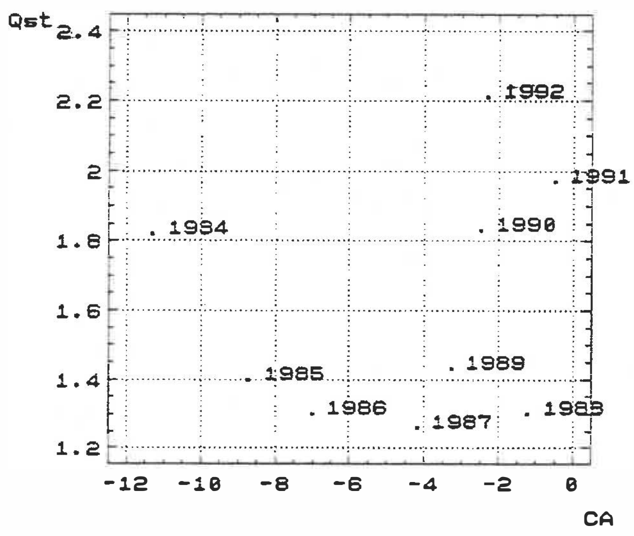
In line with similar studies on other minerals, one can first assume that gold producing countries with a predominantly state-controlled mining sector have been most affected by severe BoP problems over the period considered, and that the gold price performance has not on average relieved these countries from the foreign exchange constraint. If these conditions are true, SOEs' gold supply can be expected to be downward-sloping and negatively related to the BoP position (in syntony with Dobozi's study on copper mining). For the ten countries with state and private gold production[11], the correlation coefficient of state-controlled supply with the current account balance as a percentage of GDP has the expected sign and is statistically significant (Table 6.3, last row: LDCs). No significant correlation is however found for other relationships: the international price of gold does not appear to be related to the BoP position of the producer countries, nor is there any clear covariance between the former variable and state or private gold supply.

At the individual country level, a high heterogeneity in simple correlation results can be observed (Table 6.3). In order to better assess these results, in Table 6.5 the sample countries are subdivided according to (i) the relative position of the current account over the sample period, (ii) the level of external indebtedness, as proxied by the debt service ratios registered in 1980 and 1991, and (iii) the level of dependence of the economy on gold export receipts, as proxied by national production figures as a percentage of total merchandise exports. In general terms, one can expect that the *ownership and control* hypothesis holds especially true for countries with high and enduring current account deficits and/or high foreign debt exposure, particularly in the presence of a high dependence on gold mining, namely those countries listed in the shaded area in Table 6.5. On the other hand, should a purely macroeconomic interpretation based on the level of development and/or the degree of dependency on mineral export receipts be preferred, partly different groupings of countries would stand out as the most likely to be characterised by negative or zero supply elasticity.

If only the ten countries identified in the shaded area (excluding the Philippines: note 10) are accounted for, the high variability in supply responsiveness appears to persist (as preliminarily suggested by the simple correlation coefficients): among these countries, only five have an expected and significant sign for the relationship of state production *versus* gold price, and only three for state production *versus* the current account balance. The latter happen to be African LDCs: Ghana, Tanzania, and Zimbabwe. However, state gold supply behaves in a strikingly different way in a few other low-income economies, both within the shaded area (Burkina Faso, Zaire and Zambia) and outside it (China, Ethiopia, India). Furthermore, correlation results of supply vis-à-vis gold price and current account balances are not found, on average, to be stronger or more consistent with the *ownership and control* hypothesis in countries with 100% state control in gold producing SOEs (Tables 6.2 and 6.3).

The examination of separate scattergrams for each country, aimed at detecting possible non-linearities, reveals that only Chile appears to be characterised by a U-curve pattern in the relationship between state supply and the current account balance. During relatively more serious BoP imbalances, with current account deficits exceeding 4% of GDP as occurring before 1988, Codelco's gold supply appears to have behaved according to the *ownership and control* hypothesis, whereas the subsequent more contained current account deficits were accompanied by a *standard* supply 'response' (Figure 6.1).

Figure 6.1 - Scatter plot of SOE's gold supply vs. BoP: Chile



(Qst: SOE's gold supply; CA: current account balance/GDP %)

A surprising result is represented by correlation coefficients related to the private sector: four LDCs even show negative supply curves, contrary to expectations (apart from the statistically insignificant coefficient for Zimbabwe), while Fiji, Papua New Guinea and the Philippines, and to a lesser extent Brazil and South Africa, are the only countries with statistically significant positive correlation between the supply and price of gold. In the case of private supply vis-à-vis the current account position, the negative sign appears even more often than for the gold price.

On the whole, except in the case of a few countries, these preliminary results seem to call into question the relevance of an interpretation similar to Dobozi's analysis for the copper industry, and to point instead to a need for examining the *role* of the state or other factors possibly influencing gold mining supply, independently from the ownership and control pattern of the companies. However, the relevance of macroeconomic features, such as the level of development and the mineral export dependence of the economy, also seems doubtful, in view of the heterogeneous pattern arising from correlation results, according to some of these features as well (e.g. positive correlation between price and SOE-related supply in low-income countries such as Burkina Faso and Zambia).

a.2.2 Rank correlation analysis on cross-country simple correlation results and other macroeconomic variables (for country sub-samples with SOEs/private companies)

Simple correlation analysis and examination of scatter plots for individual producer LDCs do not seem to provide support for either an *ownership and control*-based, or a macroeconomic interpretation of different gold supply behaviours. A more thorough test should rely on further statistical and econometric tools, as pursued in this and the next sub-section. These two alternative views are also not supported by a rank correlation analysis applied to (i) the simple correlation coefficients obtained for each country and variable, and (ii) indicators of foreign indebtedness and average level of development (Table 6.4).

As mentioned in the preceding sub-section, according to Dobozi (1990: 7-9), copper producing countries with a dominant state mining sector are relatively more affected by BoP disequilibria and foreign debt exposure, with SOEs in some cases accounting for part of this debt. If this were true for gold mining as well, the cross-country Spearman rank correlation coefficients between debt service ratios and simple correlation coefficients of state-controlled supply vis-à-vis gold price and current account balance should assume significant negative values. Hence, LDCs with relatively more severe foreign indebtedness problems would exercise greater pressure on the mining sector in order to eventually offset international gold price downturns with increased gold supply. Whereas the respective Spearman correlation coefficients are negative, but not significant, an unexpectedly significant negative coefficient is obtained for the rankings of the correlation coefficient of *private* supply and gold price with the debt service ratio for 1991 (Table 6.4: third row).

No significant positive relationship is found for the rank correlation coefficients when testing for the hypothesis on the role of the level of development of the producer country, independently from the ownership pattern: results are reported in the sixth and seventh row in Table 6.4, with the *proxy* for the level of development referring to the last year of Summers-Heston per capita income data (RGDP2, except China, with only RGNP1 available: see note 11 in chapter 2) (Summers-Heston 1988). Besides these results, the debt service ratios based on two selected years with available information, 1980 and 1991, are highly inter-correlated according to the Spearman coefficient, at a 95% confidence interval for both country samples, and the 1980 level of foreign indebtedness is found to be highly associated with real per capita GDP in 1985 (94% confidence interval).

a.2.3 Regression analysis on selected countries and pooled data: testing three alternative hypotheses

The Koyck-type partial adjustment models adopted by this analysis for a gold supply function, which draws on Dobozi's model (except for the different specification of the BoP variable and the different data pooling, as outlined in sub-section 3.1a), assume the following general forms :

a) SOEs and/or highly gold-dependent economies:

$$Q_t = f(\underset{+}{Q_{t-1}},\ \underset{-}{GPUSD_t},\ \underset{-}{CA_t});$$

b) private:

$$Q_t = f(\underset{+}{Q_{t-1}},\ \underset{+}{GPUSD_t}).$$

Symbols, accompanied by expected signs of parameters, refer to the list of variables for Table 6.6. A positive and lower-than-unitary parameter value for the lagged endogenous variable allows for asymptotic convergency in the long run, according to a Koyck geometric lag model, while oscillatory convergency would be guaranteed by a parameter value comprised between -1 and 0. For specific OLS regressions, these models have been modified, so as to allow for limited sample size (separate estimations for individual countries), inconsistent cross-country patterns arising from pooled regressions (country dummies), or a further distinction in terms of ownership and control structure (degree of foreign control).

As reported earlier in terms of correlation coefficients, if the analysis is limited to highly gold-dependent economies with both a private and a state mining sector, Ghana and Zimbabwe seem to present a state supply responsiveness consistent with Dobozi's framework, with both countries having significant correlations with the expected sign (Table 6.3). Since similar results are, however, found for the respective national private sector supply responsiveness, state and private gold supplies were regressed on the current account variable and its one-year lagged values, with a view to testing this hypothesis for each of the two countries separately[12]. The results of the linear regressions provide strong evidence of state-controlled gold production as a BoP equilibrium instrument in these two countries, while a nearly null responsiveness is obtained for private gold supply. A loglinear model is applicable to Ghana, with the current account data taken with reverse sign, since these data are continuously negative over the period. This model shows positive elasticities (apparently close to unity in the short-to-medium run) of state mining production to BoP deficits as a share of GDP, as opposed to insignificant results for the private sector (Table 6.6).

The alternative hypothesis suggested by Markowski and Radetzki (1987), based on the role of mineral export dependency as a determinant of mineral supply rigidity, is not substantiated by the econometric estimations[13]. This is consistent with the preliminary indications provided by the simple correlation analysis. To this purpose, the country sample was subdivided between economies with a high export dependence on gold (six LDCs, indicated by an asterisk in Table 6.5[14]) and the other fifteen countries, with no distinction being made between state and private production. Within the former group, gold export dependency reaches very high values particularly for Ghana, Papua New Guinea and South Africa, with gold production corresponding to between 23% and 33% of merchandise export receipts in 1989. Over the last few years the foreign exchange dependency on gold has been particularly high for Ghana, where gold contributed more than 40% of export receipts in 1993 (Roskill 1995: 92).

For both country sub-samples defined here, the international gold price is not significantly related to total gold supply according to simple correlation coefficients, a finding similar to correlation results reported in the last row of Table 6.3 for gold producer LDCs as a whole. The simple correlation coefficient for gold supply vis-à-vis the current account variable for the first sub-sample (sub-sample A in Table 6.6) is highly influenced by South Africa: it is significantly positive and 'pulled' by the outlying observations for South Africa, but it turns negative if this country is excluded. This unstable pattern is reflected in the results of a linear regression, which moreover suffers from multicollinearity between the gold price and the current account variables. These results are shown for the sake of a comparison between alternative hypotheses (Table 6.6). Dummies are introduced to account for the South African case, with a *slope* dummy accounting for the price effects. For South Africa a problem may lie in an incorrect specification of the current account variable, since the latter is likely to represent a case of reverse causation. No significant results are obtained for the fifteen country sub-sample either.

As a third possible determinant of gold supply responsiveness, and in the absence of adequate proxies for other market-related characteristics, the average scale of mining operations was considered. Given a similar geological environment, larger scale mining operations may be expected to be able to react more quickly to price shocks, especially if coupled with excess capacity. As pointed out in chapter 3 (sub-section 3.2*a*), however, previous studies have found a relatively smaller long-run price responsiveness in large scale mining. To this end, the sample of LDCs with private companies was split between economies characterised by medium- to large-sized privately controlled gold mining operations (with the total production of the companies included in this analysis approximately ranging between 3 and 20 metric tonnes per annum) and other producer countries, with a smaller average size of gold mining operations and a total annual private supply by these companies of less than 3 tonnes of metal content[15]. An outlier case is constituted by South Africa, with a few private operations, such as Driefontein, Freegold and Vaal Reefs, alone running above 50 metric tonnes per year, and a total annual production for the included companies exceeding 500 tonnes.

Regression results for the two country sub-samples are presented in Table 6.6: since the BoP variable is not necessary in this set of regressions, the pooled data include 1993. As opposed to the supply rigidity of small scale producers (sub-sample C), countries with larger scale operations (sub-sample B) do show a higher short run supply responsiveness, even if this appears to be offset by an opposite behaviour in terms of lagged effects. Indonesia and South Africa stand out from this pattern because of more price-elastic short-run responses, with slope dummies for gold price being negative for the first country and positive for the second. The latter result is equivalent to the gold price parameter estimate obtained for South Africa in the equation on sub-sample A (Table 6.6): this may appear to contradict results in chapters 4 (section 5) and 5, and to be at odds with the role attributed to the fiscal regime for a supposed downward-sloping gold supply in South Africa (Moll 1992). This issue is further examined in sub-section 3.2*b*. At this stage one should notice that this result is not readily comparable with those of previous chapters. Moreover, the tax treatment hypothesis, strictly speaking, refers to the real *rand* gold price.

For a direct estimation of price elasticities, double-log equation models applied to the same sub-samples confirm the above results (last two rows in Table 6.6). Given the low statistical significance attached to the short-term elasticity parameter for small scale producers, and the lower parameter value associated with the lagged endogenous variable, the more rigid responsiveness of these producers is likely to be maintained in the long term as well. Finally, the use of an intercept or slope dummy to account for possible distinct supply behaviours of predominantly foreign-controlled enterprises proves to yield insignificant estimates and does not improve the overall fit of the linear regressions.

a.3 Platinum supply: sample characteristics and statistical results

In contrast with gold production, platinum supply is very concentrated in a few countries and mining operations, and recent trends seem to have strengthened this feature. Within the developing world, Colombia, South Africa and Zimbabwe constitute the only producer countries. Although, with the opening of new mining projects, Zimbabwe is believed to have the potential to supply about 3% of world demand for platinum by 1996, company-related production data for this country largely rely on estimates and are too small (ca. 0.02% of world supply in the early 1990s) to be taken into consideration at present. Colombia and South Africa represented nearly 70% of world supply in 1990 (Table 6.2). In spite of starting from an extremely low level, the Colombian share in world supply has increased rapidly from 0.33% in 1984 to 1.54% in 1993. In 1990 the CIS contributed another ca. 25% of world production, with a slight contractionary tendency over the period analysed, followed by a sharp reduction in 1992 (Table 6.2; Minerals Bureau 1993: 23). The other sources of platinum supply are Australia, Canada, and the United States.

Up to 1990, South Africa maintained a nearly constant share in world production, i.e. around 66-68%. In that year, AAC and Gencor controlled more than 62% of the world platinum supply. Partly reflecting the reduced Russian sales in the early 1990s, and partly determined by the widening or opening of platinum mines in the Bushveld Igneous Complex (BIC) in the northern Transvaal, South African supply substantially increased over the last three years of the series, almost reaching a 78% share in the world total by 1993. The BIC deposits are constituted by three reefs: Merensky, UG2 and Platreef. While the Merensky Reef has been so far relatively more exploited because of easier mineral treatment, the latter two reefs have been contributing an increasing amount of platinum and other PGMs[16], and are believed to contain large reserves in addition to those known. Besides PMGs, large reserves of chromium ore and nickel lie in the stratiform deposits of the BIC.

South Africa is estimated to hold between 70% and 88% of world PGMs reserves, as opposed to the 9% held by the second largest producer, the CIS. With domestic consumption corresponding to only 2% of total sales of PGMs in South Africa, these metals represent the second most important source of export earnings after gold. The corresponding percentage shares in 1992 total exports amounted to ca. 8.4% and 33.9%, for PGMs and gold respectively (Minerals Bureau 1993: 7; Minerals Bureau 1994: Appendices 1-2; Chamber of Mines 1994a: 2).

The platinum market concentration does not permit the testing of the hypotheses of the literature on mineral supply responsiveness to the same extent as for gold. Given the data constraints for Zimbabwe, recorded above, the analysis was limited to national figures for Colombia and South Africa. According to RMG information, platinum supply in both countries is fully private, which prevents an investigation of the *ownership and control* hypothesis. This investigation would also be limited by a small sample size. For the sake of comparison with gold supply, the degree of dependence of the economy on platinum mining in 1989 (as measured by the ratio of platinum production to total merchandise exports, and relying on the average platinum price for the period 1984-1993: note 14) amounted to only 0.23% for Colombia and almost 5% for South Africa.

The correlation coefficients of platinum supply vis-à-vis price are negative, contrary to expectations on a *standard* supply curve, particularly if the first three years of the sample period are excluded: over the periods 1984-1993 and 1987-1993, respectively, these coefficients are -0.39 and -0.73 for South Africa, and -0.54 and -0.94 for Colombia. A possible explanation for supply unresponsiveness to the international price may lie in the decisions of mines to continue operations, despite an unfavourable trend in real platinum price observable since 1986, in view of optimistic expectations of demand for jewellery, automobile and other industrial uses (Minerals Bureau 1993). Concern has recently been expressed for ongoing efforts at substitution of platinum by palladium in autocatalyst application, due to technological improvements and competitive Russian sales of palladium (*Financial Mail* 1995: 21). However, as mentioned earlier in sub-section 2*d*, the South African producer price has been remarkably more stable than the international price, thus protecting local platinum suppliers from world market instability (for a graph of this price in US dollars per troy oz.: Roskill

1994, 156). On the whole, therefore, among the factors reviewed above, market characteristics other than the international price appear as major determinants of platinum supply.

b. Cross-mineral analysis for South Africa

b.1 Gold supply: econometric results for South African mines

b.1.1 Sample characteristics and correlation analysis on pooled data

In the case of South Africa, an econometric analysis was applied on pooled 1984-1993 supply data for 28 major gold mines, with a view to examining in greater detail market-related determinants of mineral supply. A list of these mines is provided in the Appendix. Their total gold production over the period has been around 60% of the corresponding national total. With a few exceptions, such as Freegold and Vaal Reefs, all major producing companies and mines are included in the sample. Exclusions were due either to a lack of information, or to the fact that there had been no production for a substantial part of the period considered. Besides the gold supply and real prices in US dollar and rand terms, other variables, based on Chamber of Mines annual data, included an index of relative *cost-competitiveness* of the mine and the average grade of the ore.

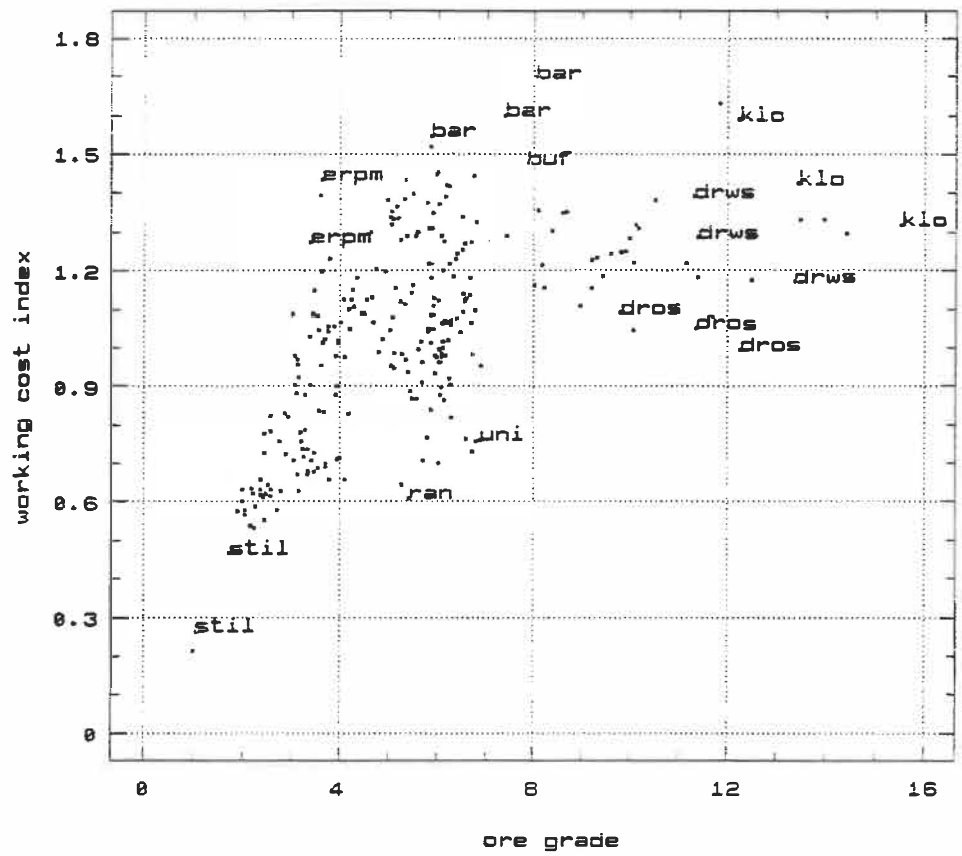
The cost-competitiveness index consists in the ratio of the average working costs of a mine to the corresponding average for South African gold mining as a whole, with the average costs expressed as rands per tonne milled. With regard to both working costs/ton and ore grade, a criticism is levelled at the common practice among mine managements of reporting average values of underground throughput and sand dumps treatment, instead of keeping separate values for high- and low-grade operations. The basis of this criticism is that this practice is equivalent to introducing a downward bias in both variables, since the waste treatment can be seen only as a supplementary operation to the main mine operations in the reef. This can, in fact, actually be a problem in the case of a few mines, such as ERPM, Hartebeestfontein and Western Deep Levels, where the dump reclamation process has recently tended to involve nearly one-third of the total ore milled by the mine. This deficiency in the data should be taken into account in making investment decisions on individual companies (Posel 1989: 87-94), but it is unlikely to affect the interpretation of estimation results for the purposes of this study.

The 1993 production figure for Marievale and the 1992-1993 figures for Bracken were excluded from the sample because of the anomalies associated with them. Both mines reduced production particularly heavily in the last year of the series, with gold supply in 1993 amounting to nearly one-tenth and one-fourth of the 1992 figure, for Marievale and Bracken respectively. This was accompanied by exceptional increases in ore grade and average working costs for Bracken. Once these figures are excluded, simple correlation coefficients for the pooled sample show a statistically significant positive correlation between gold supply (fine gold) and grade of the ore (0.66) and between the latter variable and the operating cost index (0.60). The latter result could be expected, since operating costs per tonne of ore milled tend to increase with the depth level of mining operations, besides depending on the method of haulage (Posel 1989: 13). With regard to gold prices vis-à-vis supply, while no significant linear correlation is found for the international price, the hypothesis of an inverse relationship between gold supply and price seems to be supported in the case of the rand gold price: the correlation coefficient is -0.13, which is significant at a 95% confidence for 265 observations.

A scatter plot of the working cost index with the ore grade (Figure 6.2), supplemented by an inspection of the actual data for the various mines, reveals how the above relationship is in reality not linear. The relative cost competitiveness tends to

Figure 6.2 - Scatter plot of the working cost index on the ore grade

(pooled 1984-1993 data for 28 South African gold mines)



(symbols for selected observations: list of mines in Appendix) worsen with increasing levels of the ore grade until the latter variable reaches values approximately between 8 and 10 grams per tonne milled, while it subsequently tends to improve. The latter result is, however, to a large extent influenced by the coexistence over the period analysed of a tendentially declining ore grade and deteriorating cost competitiveness for two large mines, Driefontein (in both Western and Eastern sections) and Kloof. This outcome is not registered for other major mines, such as Buffelsfontein, Hartebeestfontein, Randfontein and Western Deep Levels.

b.1.2 Regression analysis on pooled data: hypothesis testing on mineral market characteristics

A dynamic model geared to test the relevance of market-related features and, indirectly, the tax treatment effect, for (net) gold supply behaviour of South African mines, could assume the following functional form:

$$Q_t = f(\underset{+}{Q_{t-1}},\ \underset{-?}{gpusdco_t},\ \underset{-?}{NERUSD_t},\ \underset{+}{grade},\ \underset{+}{G},\ \underset{-}{toc},\ \underset{?}{size},\ \underset{?}{MS});$$

Expected signs are indicated beneath the variables, reflecting some of the hypotheses examined in section 2 (tax treatment effect, under *b*, and market-related characteristics, under *d*), and complemented by remarks in sub-section 2.3 in chapter 5, regarding the net effects on net gold supply of ore grade decreases and ore production increases. Variables are indicated with the same symbols introduced in chapters 3-5, with the gold price variable (GPUSD) in real terms, while they otherwise refer to the list attached to Table 6.7. Besides the international gold price and the nominal exchange rate with the US dollar, these variables include: the grade of the ore, along with other geological (G) and/or location characteristics, a total operating cost or *relative cost-competitiveness* index, defined in sub-section *b.1.1*, the size of the mine, and the market structure. Within the last broadly defined variable, this analysis has specifically considered the role of market diversification in the activities of controlling companies.

Econometric results of double-log equation models testing the hypotheses are reported in Table 6.7: in order to avoid multicollinearity, only separate tests could be carried out, although this is likely to have contributed to a lack of efficiency in OLS parameter estimates and higher probability of type I error, as implied by positive serial correlation (see note 13). The aims and results of these tests are highlighted in the following paragraphs.

(i) In order to test for the alternative use of the international as opposed to the domestic price of the mineral as the more suitable price variable for the assessment of gold supply responsiveness, an autoregressive distributed lag model of the first order, i.e. ADL(1,1), and a Koyck-type distributed lag model, i.e. ADL(1,0), were applied, for both price variables. The former model looks more adequate when the US dollar gold price is used, whereas an ADL(1,0) is to be preferred for the South African rand gold price. Results point to (i) a modest responsiveness of gold supply to the international price, with net elasticity effects being slightly *positive* after a one year lag, and (ii) a definitely *negative* short-term elasticity with regard to the domestic price. The latter result should be considered in the light of the significant negative correlation between the rand gold price and the ore grade, and of the positive elasticity of gold supply to the ore grade (Table 6.7). The hypothesis of a downward-sloping supply curve for South African gold mining, based on the tax treatment (Moll 1992), seems therefore to find empirical support. This is also implicitly evidenced, in a different way, by correlation and regression results in chapters 4 and 5.

(ii) The price sensitivity of gold supply can be expected to fall whenever the controlling finance house happens to be less exposed to gold, and vice versa. Among the six South African mining houses, in 1994, while Gold Fields (GFSA) mainly relied on gold mining for its earnings, AAC and Anglovaal benefited from a more diversified structure, to a large extent based on industry, commerce and financial services. Gencor seems to lie in an intermediate position, with a high exposure to gold as well as other mining activities, and recent attempts towards diversification in various minerals (Gleason 1995: 23; Roskill 1995: 12).

(iii) Once the average responsiveness to changing ore grades is accounted for, different geological and infrastructural conditions linked to the location of the deposits may still have a role in explaining the behaviour of mine supply. Possible distinctions could therefore also consider the Witwatersrand vis-à-vis the rest of the mines, or the South Western reefs (Orange Free State and Klerksdorp) vis-à-vis the Central and Eastern Transvaal (Appendix)[17].

(iv) As far as the size of the mining operation is concerned, section 2 has pointed at some contradictory elements possibly influencing mine supply responsiveness. On the one hand, relatively larger mines may stand out as relatively more responsive to the international price, as apparent from the pooled cross-country results of the preceding sub-section, thanks to economies of scale, or geological and location advantages. On the other hand, as also mentioned in chapter 3, these mines are often more mechanised and capital-intensive than smaller ones, they may have received a higher than proportional share of state assistance and can also be expected to behave more rigidly as a result of the higher fixed cost component.

Dummies on intercept and slope parameters were alternatively applied to test for the possible factors discussed above. AAC- and Anglovaal-controlled companies and mines appear to be slightly less responsive to average cost and gold price changes (for the latter variable Table 6.7 reports regression results). The location of the mines is not found to be a relevant explanatory factor. Finally, the fifteen relatively smaller sized mines, as defined in the list of variables for Table 6.7, appear to be more (negatively) sensitive to the rand price of gold and less sensitive to changes in the ore grade.

As mentioned above, results of partial correlation coefficients between the variables discourage the simultaneous use of (rand or US dollar) price, cost index and ore grade in order to model gold supply, since this would lead to multicollinearity. For instance, the operating cost index is, not surprisingly, highly correlated with the ore grade, with a partial correlation coefficient of 0.64, to a greater extent than with gold supply (-0.31). According to these coefficients, the ore grade appears as the explanatory variable most closely related to supply. If the cost-competitiveness index is added to ore grade as an explanatory variable, supply appears to be negatively affected by above average working costs increases (Table 6.7).

b.2 Supply of selected minerals: statistical and econometric results

The following part of the analysis has tried to test for different supply behaviours across minerals in South Africa. These minerals included: chrome ore, coal, copper, gold, iron ore, manganese ore, nickel, platinum, and silver. If PGMs as a whole instead of platinum are accounted for, the nine selected minerals accounted for nearly 94% of South Africa's mining export earnings in 1992 (Table 6.8). The remaining share was mostly constituted by classified items, such as diamonds, uranium and zirconium minerals. In view of the relevance of the chosen minerals as a source of foreign exchange inflows for South Africa, a simple correlation analysis was carried out, with a view to testing for the presence of *parallel* performances in international price fluctuations. Such an outcome would point to relatively stronger effects on the South African economy, in times of mineral price slumps as well as booms, as compared to the impact of price changes for a single commodity. Obviously, independently from statistical results, the actual effects will also depend on the extent to which sales modalities, such as futures markets or term contracts, can smooth potential revenue losses.

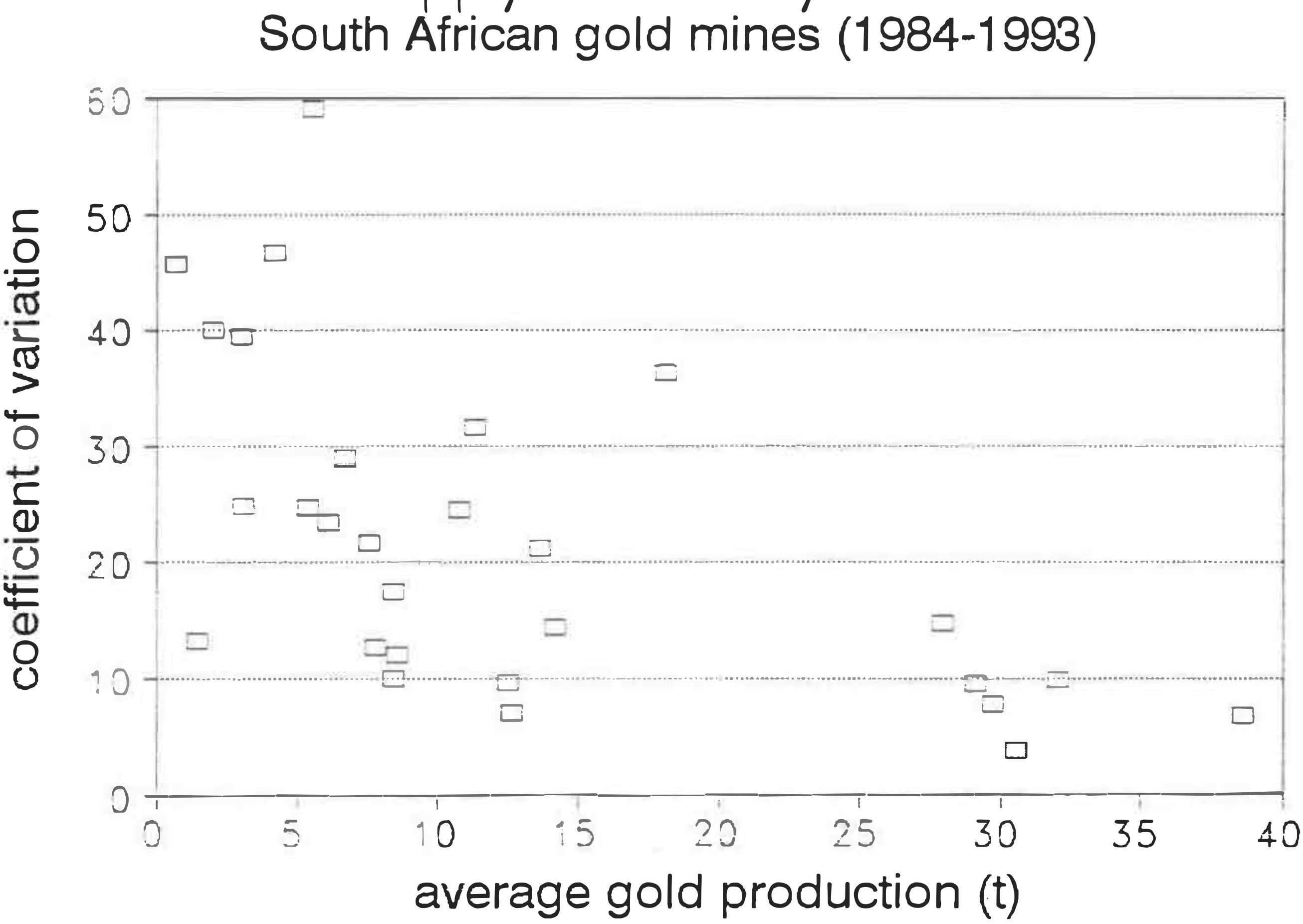
Prices of internationally traded primary commodities are often found to follow *parallel* time trajectories (Leybourne *et al.* 1994). As considered in chapter 3, minerals can be seen as partly institutionally determined, although macroeconomic factors such as inflation and aggregate demand, as well as possible speculative buyers' behaviour (*ibidem*: 31), can determine co-movements in their prices. Simple correlation coefficients between constant (1987) US dollar prices of the minerals examined here over the period 1984-1993 turn out, however, to be insignificant in many cases. The gold price, which is by far the most relevant price factor within South African mineral exports, is found to be unrelated to other mineral commodity prices, except for platinum (0.89), silver (0.77), and, negatively, manganese ore (-0.76). A correlation analysis on the period 1984-1991, allowing the inclusion of the iron ore price (for which no information was available for the last two years of the series), yields similar results. Although limited by the sample size, results do not provide evidence of either *parallel*, or offsetting tendencies in these prices, with the major exception of the three precious metals.

The correlation analysis has been extended to check for the relationship between the price of the mineral in US dollars and rands and the respective supply at the national level, for the period 1984-1993. Results indicate that, except for silver and platinum, supply seems to be more closely related to the domestic price of the mineral. Except for coal, copper and silver, however, the level of statistical significance of these correlation coefficients is lower than 90%. For platinum, no significant correlation is found for either price. The supply of chrome ore, iron ore and, to a more limited extent, nickel appears also to be positively associated with the real producers' price of steel with a one-year lag: this variable has been used to account for demand from the stainless steel industry, to which a large proportion of these minerals is destined (World Bank 1993: 93; *Financial Mail* 1995: 29). Silver and copper supply have been positively interrelated over the period (0.57), possibly due to the occurrence of silver in major copper deposits, particularly at Black Mountain and Palabora (Chamber of Mines 1990: 29; RMG database). However, this result is not true for other possible associations in South African mining operations, such as copper and platinum, with the former mineral often being recovered as a by-product of the latter.

If the coefficient of variation is to be relied on as an approximate indicator of instability, mineral prices in rands generally appear to have fluctuated more markedly than the corresponding national production of the minerals. This is especially so for copper, gold, manganese ore, nickel and platinum (Table 6.8), and is consistent with statistical results for other countries and minerals mentioned in chapter 3. Manganese ore has been the most unstable mineral in terms of both price and supply, closely followed by nickel for price and chrome ore for supply[18].

Apart from the case of silver, which however includes only two companies (RMG data for other mines are mainly estimates), higher production instability seems to be more common among smaller producers, at least for copper and gold (Table 6.8 and Figure 6.3). A major exception to this pattern is represented by fully state-controlled Foskor, for copper (Table 6.8). Obviously, this result can not be sufficient to support an institutional interpretation of different supply responsiveness to market changes in South Africa (besides being limited by the sample size, since for the period 1990-1993 only estimates are available for Foskor). For the South African gold mines listed in the Appendix the rank correlation coefficient between average production and instability over the period examined is -0.7. The scattergram in Figure 6.3, however, shows how this pattern is highly influenced by five large mines, corresponding to the observations in the

Figure 6.3 - Gold supply: instability vs. levels



right-hand bottom sector of the Figure (Driefontein West and East, Hartebeestfontein, Kloof, Randfontein and Western Deep Levels).

The application of a double-log Koyck-type dynamic model, based on the assumption of a geometrically declining influence of the mineral price in rands on supply over time, provides statistically significant estimates for coal only. The short- and long-run price elasticities for coal are estimated to be 0.39 and 0.65, respectively (with the cautionary remarks below for the latter estimate). As an alternative specification, a distributed lag model of order one, using the log-transformed rand price and its one-year lag as regressors, suggests the presence of a negative elasticity for gold, at a 90% confidence interval[19], and a positive price-responsiveness for silver. The long-term price-elastic responsiveness of mineral supply hypothesized by some studies, reviewed in chapter 3, can not properly be investigated due to the limited observation period. On the whole, besides the data constraints, results seem to suggest the importance of market-related features not captured by the price variables used, such as the market integration and organisation, and the prevailing type of sale contracts.

6.4 Conclusions

Mainly relying on company-level statistical information, the foregoing analysis has tried to investigate some issues concerning the supply behaviour of mineral producers, over the period 1984-1993. These issues can hardly be assessed in sufficient depth if only aggregate data are used. The few econometric studies undertaken so far appear to have focused on testing one particular hypothesis, rather than adopting a broader framework of partly alternative explanations. Although they do constitute a useful starting point, these studies do not seem, moreover, to have adequately addressed some methodological problems, such as the representativeness of the sample, the variables to be used and the treatment of the statistical information.

On the whole, estimation results do not appear to support the view of mining SOEs as an instrument for balance of payments equilibrium. SOEs' supply responsiveness is found to differ substantially across gold producing countries, and a similar result is, surprisingly, also obtained for private company supply data. However, this conclusion may be tempered by two remarks. Firstly, the 50% control criterion used to distinguish the SOEs from other companies is necessarily arbitrary, and the same argument might be raised about the RMG model relied upon. Stobart (1985: 96), for instance, treats all companies where the state has some equity interest as SOEs, assuming that in all these cases political considerations would prevail over commercial ones in supply planning decision-making.

Secondly, several LDCs included in this analysis are not highly dependent on gold production as a source of export earnings, nor are they affected to the same extent by foreign exchange constraints and pressures to build up foreign reserves, as revealed by differing debt service ratios and current account deficits. The severity of current account deficits could be a misleading indicator, because of a relatively stronger restraint on imports in certain countries, which might have been exercised to a greater extent than the emphasis on foreign exchange earnings through exports. However, one could still assume that LDCs which have been otherwise unable to contain balance of payments disequilibria, may have tried to alleviate these problems by influencing state-controlled natural resource-based supply and exports. These typically include a large proportion of the mineral sector. If the analysis is limited to LDCs with a high dependence on gold exports and/or high external imbalances, Ghana, Tanzania and Zimbabwe appear to behave according to the *ownership and control* hypothesis. Gold supply in Ghana and Zimbabwe seems to follow a downward-sloping curve even in the private sector, although to a far more limited extent.

An alternative explanation of mineral supply behaviour based on the *role* of the state could not be tested, because this would need a detailed study of country cases. However, unlike the empirical results on long-term growth in chapter 2, the econometric estimates appear to give no support to the hypothesis of a different responsiveness to gold prices of a supposed *enclave-type* mainly African mineral supply, as opposed to a more efficient mining sector management in other regions: no clearcut distinction can be drawn between gold supply responsiveness in different regions. Apart from the individual cases of Ghana and Zimbabwe, a macroeconomic interpretation focusing on such factors as the mineral export dependency, or the level of economic development of the producer country, is also not empirically supported.

Market-related features, such as the size of mine operations or expected tendencies in demand, appear to matter to some extent for both gold and platinum. On a cross-country time series basis, in the short run, and possibly in the long run as well, relatively larger producers tend to be more responsive to international gold price changes. On the other hand, according to a pooled cross-mine time series analysis limited to South African gold producers, supply by smaller mines seems to be more sensitive to rand price fluctuations of this metal, while apparently less responsive to changes in ore grade. Besides the size factor, other market characteristics influencing supply responsiveness for South African gold producers are identified in the level of diversification of the controlling holding, which apparently allows a lesser vulnerability to price fluctuations, and in the relative competitiveness in terms of average working costs.

The sensitivity of South African mines to changes in the gold price in US dollars, revealed by the first part of the analysis, may contrast with the less significant results in the second part, regarding the cross-mine data. These results are not fully comparable. The former approach has included all the mines with complete and reliable statistics over the period 1984-1993, which accounted for almost 96% of national supply in 1990, but only nearly 80% and 89% at the beginning and end of that period, respectively. The latter approach covered (i) 28 mines with full or sufficiently long availability of time series data on working costs and ore grade over the same period, accounting for nearly 60% of total national supply, and (ii) the total national figures. Point (ii), which concern the estimations reported in Table 6.8, presents the disadvantage of not identifying gold output by mine, thus including the figures of mines which were operative only in the first or last few years of the series and which have in some cases contributed substantially to the overall supply. This explains why, for South African gold mining, the correlation coefficient between the supply variable used in the cross-country regressions (Qpr) and the corresponding variable used in the cross-mineral statistical analysis (Table 6.8) is -0.39.

As for the appropriateness of domestic as opposed to international prices for modelling mineral supply, for most of the nine minerals examined in the analysis for South Africa the use of the former prices seems to be more justified, although the evidence is not overwhelming. In the case of gold, although there seems to have been a positive supply impact of the precious metal price in US dollars, supply behaviour appears to have been more strongly, or at least as strongly, influenced by the domestic price in the 1980s and early 1990s. The latter price moved more smoothly than the international price in the 1980s, thanks to the shock-absorbing effect of the South African exchange rate (Bergman *et al*. 1989: 51), and has been accompanied throughout the sample period by a tax treatment effect. This effect determines a downward-sloping gold supply curve in South Africa in terms of rand prices.

Finally, price instability tends to exceed quantity instability for minerals of particular concern to South African mining exports. However, the two minerals characterised by a relatively higher price instability, as measured by a standard deviation amounting to nearly half the value of the average price over the period, i.e. manganese ore and nickel, jointly represent less than 3% of South African mining exports.

Table 6.1 - Mineral supply responses to market changes: hypotheses and empirical findings on different behaviour according to company, country and mineral*

distinction criterion	hypotheses/ empirical findings	minerals/countries	source
(a) ownership and control (state vs. private)	downward-sloping supply curve of SOEs during BoP difficulties	. mineral commodities/USSR . copper/SOEs in non-CPEs and former CPEs	. Wolf (1982) . Dobozi (1990)
(b) *kind* of state intervention (tax treatment and institutional setting)	. *enclave-type* model: market inefficiency, resource misallocation, loss of market share (depletion of min. resources/ lack of incentives for exploration activities and technological progress) . downward-sloping supply curve	. mineral commodities/ sub-Saharan Africa . gold/South Africa	. World Bank (1989) . UNCTAD (1994, 1994a) . Moll (1992)
(c) macroeconomic factors (size of domestic market; level of development; dependence of the economy on mineral production; foreign debt)	relatively more price-inelastic (or negative price-elastic) supply for smaller, poorer and/or more mineral-dependent economies . inflexibility in supply and crowding out of private producers	. mineral commodities/LDCs . copper/eight major producer countries . five base metals/LDCs	. Lewis (1989) . Markowski-Radetzki (1987) . Stobart (1985)
(d) market characteristics (share of fixed costs; labour costs and productivity; quality of deposit/infrastructures; substitution effects; production concentration; exchange rates; sale contracts; production and marketing linkages)	. relatively more price-inelastic supply for mines with a high share of fixed costs . positive externalities of old/large mines for stoping of newly discovered/explored conglomerates . exchange rate and sale contracts as a supply-stabilising element vis-a-vis mineral market fluctuations (possibly downward-sloping supply curve) . relatively more price inelastic (or negative price-elastic) supply for less organised and integrated minerals markets	. copper/eight major producer countries . five base metals/DCs and LDCs . gold/South Africa . gold/South Africa . copper/Chile . copper vs. aluminium/DCs and LDCs . gold vs. diamond/South Africa	. Markowski-Radetzki (1987) . Stobart (1985) . Handley (1990) . Austin (1984) . Adams-Vial (1988) . Stobart (1985) . Handley (1990a)

* excluding standard supply models (Table 3.2 and text)

BoP balance of payments
CPEs (former) centrally planned economies
SOEs state-owned enterprises (more than 50% of equity is owned by the state)

Table 6.2 - Gold and platinum mine production: selected countries and state-owned enterprises (1990)

country	A - private	B - state	B > A	(A+B)/ total nat. (·100)	total national/ world total (·100)	Δ% [total national/ world total] [1984-1993]
gold						
Burkina Faso		Soremib#	x	28.9	0.16	2.6
Brazil	x	CVRD		12.4	4.11	0.2
Chile	x	Codelco#		25.6	1.56	0.5
China		x#	x	100	4.46	0.4
CIS		x#	x	100	12.68	-0.5
Colombia	x			4.2	1.53	-0.3
Dominican Republic		Rosario Domin.#	x	100	0.20	-0.8^
Ethiopia		x#	x	100	0.09*	2.6
Fiji	x			58.0	0.19	0.4
Ghana	x	Ashanti Dunkwa# Prestea Gold#	x	79.5	0.81	2.0
India		x#	x	100	0.09	-0.4
Indonesia	x	Aneka Tamban#		78.4	0.62	11.7
Malaysia		Mamut	x	55.2	0.14	-0.5
Mexico	x	Cananea		22.6	0.45	0.0
Papua New Guinea	x	Ok Tedi	x	41.1	1.58	1.1
Peru	x	Orcopampa Centromin#	x	26.9	0.69	1.6
Philippines	x	(x)		24.4	1.75	-0.3
South Africa	x			95.8	28.21	-0.4
Tanzania		x#	x	100	0.08	30.0^^
Zaire	x	Kilo-Moto#		52.4**	0.21	0.2
Zambia		ZCCM	x	100	0.005	-0.7
Zimbabwe	x	Mhangura Sabi#		29.8	0.79	-0.2
platinum						
CIS		x#	x	100	24.60	-0.4^^^
Colombia	x			100	1.03	3.7
South Africa	x			100	68.10	0.1

* 1989-1991 average (1990 national figure missing)
^ 1993 figure excluded
^^^ 1993 figure missing
** 1989 figures (1990 and 1991 mine-related data missing)
^^ 1984-1985 figures excluded
# 100% state-controlled production

Sources: RMG computerised database (original figures in metric tonnes)

Table 6.3 - Gold mine production: simple correlation coefficients by producer country (1984-1992)

country	Qst-GPUSD	Qst-CA	GPUSD-CA	Qst-Qpr	Qpr-GPUSD	Qpr-CA
expected sign *	-	-	+	?	+	?
Burkina Faso	0.70	0.56	0.72			
Brazil	-0.76	0.46	-0.17	0.03	0.49	0.41
Chile	-0.74	0.20	-0.21	-0.35	0.14	-0.85
China	-0.70	0.67	-0.32			
Colombia			-0.27		-0.48	0.46
Dominican Republic	0.55	-0.30	-0.25			
Ethiopia	-0.79	0.53	-0.71			
Fiji			0.16		0.77	0.14
Ghana	-0.71	-0.85	0.74	0.88	-0.48	-0.57
India	-0.04	0.60	-0.32			
Indonesia	-0.58	0.21	0.12	0.58	-0.63	-0.23
Malaysia	0.71	0.59	0.77			
Mexico	-0.35	-0.51	0.88	0.59	-0.19	-0.54
Papua New Guinea	0.33	0.75	0.04	0.24	0.75	-0.18
Peru	-0.12	0.52	0.27	-0.57	-0.66	-0.69
Philippines	(0.62)	(0.18)	0.18	(0.90)	0.65	0.52
South Africa			-0.03		0.44	0.37
Tanzania	-0.75	-0.58	0.35			
Zaire	-0.63	0.59	-0.54	-0.87	0.38	-0.68
Zambia	0.64	0.64	0.39			
Zimbabwe	-0.62	-0.85	0.81	0.45	-0.30	-0.58
LDCs **	-0.12	-0.47	0.13	0.08	0.09	-0.13

* expected signs for first two columns especially for LDCs with enduring and severe BoP deficits and/or high foreign indebtedness

** ten countries with both private and state-controlled production (including the Philippines)

(for symbols see list of variables following Table 6.7)

Sources: RMG computerised database; Roskill (1994); World Bank (1994)

Table 6.4 - **Gold price and production, balance of payments and foreign indebtedness: Spearman rank correlation coefficients**

SOEs	r_S [17]	private sector	r_S [13]
r(Qst-GPUSD) - r(Qst-CA)	0.39 [+]	r(Qpr-GPUSD) - r(Qpr-CA)	0.45 [?]
r(Qst-GPUSD) - DSX80	-0.10 [-]	r(Qpr-GPUSD) - DSX80	-0.15 [?]
r(Qst-GPUSD) - DSX91	-0.09 [-]	r(Qpr-GPUSD) - DSX91	-0.42 [?]
r(Qst-CA) - DSX80	-0.26 [-]	r(Qpr-CA) - DSX80	0.12 [?]
r(Qst-CA) - DSX91	-0.08 [-]	r(Qpr-CA) - DSX91	-0.02 [?]
r(Qst-GPUSD) - y85	0.15 [+?]	r(Qpr-GPUSD) - y85	0.24 [+?]
r(Qst-CA) - y85	-0.02 [+?]	r(Qpr-CA) - y85	0.21 [+?]
DSX80 - y85	0.48 [+]	DSX80 - y85	0.54 [+]
DSX91 - y85	0.33 [+]	DSX91 - y85	0.33 [+]
DSX80 - DSX91	0.61 [+]	DSX80 - DSX91	0.61 [+]

r(.) simple correlation coefficient (by producer country) (1984-1992)
r_S Spearman rank correlation coefficient (by country groupings and different ownership and control patterns)

in square brackets: number of country sample observations (Philippines excluded from sample of SOEs) and expected signs

(for symbols see list of variables following Table 6.7)

Sources: RMG computerised database; Roskill (1994); World Bank (1993b; 1994; for South African DSX: SARB, v.y.); Summers-Heston (1988)

Table 6.5 - Classification of gold producer countries according to three macroeconomic criteria

level of foreign indebtedness	current account balance/GDP (%)				
	(1)	(2)	(3)	(4)	(5)
debt service ratio (DSX) > 20%	PNG* Tanzania Zambia	Chile Dominican Rep. Ghana* Peru (Philippines) Zimbabwe*	Brazil India Indonesia	Colombia Mexico	
others	Burkina Faso* Zaire	Ethiopia	Fiji*	China Malaysia	South Africa*

(1) current account deficit > 10% of GDP over most of the period 1984-1993
(2) *intermediate* cases: 3% < CA def.< 10%, or strong dispersion over the sample period (ca. 0-12%)
(3) CA def. < 3% over most of the sample period
(4) mixed CA deficits and surpluses over the sample period
(5) clear predominance of current account surpluses over the sample period

DSX 1980 and/or 1991 figure

* high dependence on gold mining (gold production > 10% of merchandise exports in 1989: see text and note 14) (RMG database; World Bank 1994)

Sources: RMG computerised database; Roskill (1994); World Bank (1993b; 1994; for South African DSX: SARB, v.y.)

Table 6.6 - Gold supply response to market changes: cross-country hypothesis testing (1984-1992 pooled data)

ownership and control

country	dependent variable	const.	ln(CA) @	$ln(CA)_{-1}$ @	CA	CA_{-1}			DW F	R^2 n
Ghana	ln(Qst)	0.66 (1.43)	0.76 (3.35)	0.32 (1.20)'#					1.30 9.1	0.67 9
	Qst	-3.64 (-0.97)			-1.90 (-3.37)	-1.00 (-1.37)'#			1.47 11.4	0.72 9
	Qpr	0.24 (1.17)			-0.03 (-1.16)'#	-0.03 (-0.91)'			1.48 2.04'#	0.21 9
Zimbabwe	Qst	0.75 (19.9)			-0.03 (-4.30)	0.02 (1.46)''			2.51 12.2	0.74 9
	Qpr	4.50 (41.1)			-0.02 (-0.73)'	-0.02 (-0.71)'			1.63	0.19 9

dependence of the economy on gold production

countries	dependent variable	const.	$Qtot_{-1}$	GPUSD	CA	d(OUT)	GP(OUT)		DW@	R^2 n
sub-sample A *	Qtot	-3.40 (-0.22)	0.27 (1.86)	0.02 (0.52)'	-0.34 (-1.03)'#	341.6 (4.14)	0.20 (2.13)		2.28	0.99 47

scale of mine operations (1984-1993)

countries	dependent variable	const.	Qpr_{-1}	GPUSD	$GPUSD_{-1}$	GP(FN)	d(OUT)	GP(OUT)	DW@ Dh	R^2 n
sub-sample B **	Qpr [1]	0.88 (0.45)	0.92 (13.9)	0.01 (1.40)''	-0.01 (-1.67)^^	-0.001 (-0.6)'	18.6 (3.8)	-0.04 (-3.21)	- 2.10	0.88 54
sub-sample B + RSA	Qpr [2]	9.55 (1.05)		0.03 (0.97)'#	-0.03 (-1.32)''		478.9 (21.0)	0.23 (3.69)	1.79 -	0.99 70
sub-sample C***	Qpr	1.17 (1.93)	0.87 (8.67)	0.001 (0.50)'	-0.003 (-1.76)^^	-0.0... (-0.12)'			- -1.16	0.61 50
sub-sample B (in natural logarithms)	Qpr [1]	0.29 (0.25)	0.90 (16.2)	0.27 (1.18)'#	-0.29 (-1.27)'#		6.61 (2.30)	-1.08 (-2.20)	- -0.81	0.90 50ˣ
sub-sample C (in natural logarithms)	Qpr	2.36 (1.16)	0.80 (14.5)	0.18 (0.46)'	-0.56 (-1.32)''				- -0.96	0.82 50

* Burkina Faso, Fiji, Ghana, PNG, South Africa, Zimbabwe (see * in Table 6.5)

** Brazil, Chile, Indonesia, PNG, Philippines, Zimbabwe (RSA: Rep. of South Africa) (ˣ 1990-1993 excluded for PNG: Bougainville mine closed)

*** Colombia, Fiji, Ghana, Mexico, Peru, Zaire

(t-statistic in parentheses under the estimated parameters)

' less than 80% confidence interval (# ca. 70-80% conf. interval)

'' 80% confidence interval

^ 85% confidence interval

^^ 90% confidence interval (in all other cases: 95% confidence level or more; confidence levels for intercept estimates are not indicated)

@ DW reported only when no lagged endogenous variable is used as a regressor, or (*) when Dh is invalid (negative number under square root)

R^2 R^2 adjusted for degrees of freedom

n number of observations (missing annual observations for some countries: see text)

(for symbols see list of variables following Table 6.7)

Sources: RMG computerised database; Roskill (1994); World Bank (1994)

Table 6.7 - Gold supply response to market changes: hypothesis testing for South African mines (1984-1993 pooled data)

const.	lny_{-1}	lngp	$lngp_{-1}$	lngpr	lngpr (aac)	lngpr (size)	lngrad	lngrad (size)	lngrad (sw)	lntoc	d(size)	R^2 n
international vs. domestic price												
-0.61 (-1.16)	1.02 (83.5)	-0.14 (-1.19) '#	0.19 (1.84) ^^									0.96 276
0.90 (1.60)	1.02 (83.8)			-0.17 (-2.11)								0.96 276
controlling mine house												
0.96 (1.72)	1.02 (79.5)			-0.17 (-2.15)	0.007 (1.45) ^							0.96 276
size of mining operation												
1.36 (2.41)	0.99 (61.0)			-0.18 (-2.30)		-0.01 (-3.38)						0.96 276
ore grade and location												
-0.06 (-0.55)	0.98 (73.6)						0.10 (3.88)					0.97 265
-0.05 (-0.51)	0.98 (73.4)						0.10 (3.76)		0.007 (0.47)'			0.97 265
0.12 (0.93)	0.96 (60.7)						0.11 (4.15)	-0.04 (-2.13)				0.97 265
operating costs and ore grade												
-0.08 (-0.80)	0.98 (71.2)						0.15 (3.91)			-0.09 (-1.70)^ ^		0.97 265
0.18 (1.10)	0.96 (61.4)						0.12 (3.00)			-0.06 (-1.09) '#	-0.07 (-2.50)	0.97 265

(t-statistic in parentheses under the estimated parameters)

' less than 80% confidence interval (# ca. 70-80% conf. interval)
'' 80% confidence interval
^ 85% confidence interval
^^ 90% confidence interval (in all other cases: 95% confidence level or more; confidence levels for intercept estimates are not indicated)

R^2 R^2 adjusted for degrees of freedom
n number of observations (missing annual observations for some mines)

Sources: Chamber of Mines, RMG and SARB (computerised databases); Roskill (1994)

LISTS OF VARIABLES (Tables 6.3-6.7)

List of variables in Tables 6.3-6.6

CA	current account balance/GDP (%) (in Table 6.6: @ CA variable with reverse sign, see text)
DSX	debt service ratio (total debt service as a percentage of exports of goods and services, for 1980 and 1991)
d(OUT)	intercept dummy for Indonesia (sub-sample B in equation for Qpr [1]) or South Africa (sub-sample A and augmented sub-sample B in equation for Qpr [2])
GPUSD	gold price in constant 1987 US$ (per troy oz.)
GP(FN)	gold price dummy for foreign-controlled enterprises (more than 50% foreign)
GP(OUT)	gold price dummy for Indonesia (sub-sample B in equation for Qpr [1]) or South Africa (sub-sample A and augmented sub-sample B in equation for Qpr [2])
Qpr	gold supply by private enterprises
Qst	gold supply by SOEs
Qtot	total gold supply (fine gold, t)
y85	real per capita income in 1985

List of variables in Table 6.7 (all variables in natural logarithm)

dependent variable

lny	gold supply by mining companies/mines (fine gold, kg)

independent variables

const.	constant term
d(size)	dummy for relatively smaller-sized mines (average production lower than 10 t per year, 1984-1993)
lngp	gold price in constant 1987 US$ (per troy oz.)
lngpr	lngp converted into SA rands
lngpr(aac)	(rand) gold price dummy for mines controlled by Anglo American Corporation or by Anglovaal
lngpr(size)	(rand) gold price dummy for relatively smaller-sized mines
lngrad	ore grade (grams/metric tonne milled)
lngrad(size)	ore grade dummy for relatively smaller-sized mines
lngrad(sw)	ore grade dummy for mines located in the South West of the Witwatersrand (Orange Free State and Klerksdorp)
lntoc	operating cost index (average working costs of the mine/average total working costs of South African gold mining; rands/t)

Table 6.8 - Descriptive statistics for mineral prices and supply in South Africa, by major export minerals and mines (1984-1993)

mineral (units) (% in mineral export earnings, 1992)	coefficient of variation of rand mineral prices	summary statistics of supply by mines (1984-1993) (average supply; coefficient of variation)
chrome ore (Mt) (0.6%)	19.8	total nat. (3.9; 19.1)
coal (Mt) (13%)	13.7	total nat. (47.0; 7.6)
copper (kt) (2%)	31.0	Black Mt. (4.7; 37.6) Messina (7.0; 19.9) * O' Okiep (25.0; 13.3) Palabora (122.2; 4.6) Foskor (13.1; 6.5) ** total nat. (195.2; 3.4)
gold (t) (58.9%)	13.7	28 mines: see Figure 6.3 total nat. (625.4; 4.8)
iron ore (Mt) (2.3%)	12.4 *	Assoman (1.7; 27.8) Iscor (20.6; 10.7) total nat. (26.8; 10.9)
manganese ore (Mt) (1.4%)	51.0	Assoman (1.2; 25.0) total nat. (3.6; 22.4)
nickel (kt) (1%)	50.0	total nat. (30.1; 12.4)
platinum (t) (PGMs: 14.5%)	22.1	Impala (32.1; 5.0) total nat. (81.5; 10.9)
silver (t) (0.2%)	15.3	Black Mt. (109.0; 15.8) Palabora (15.7; 6.3) total nat. (195.3; 10.7)

* 1984-1991
** 1984-1989

coefficient of variation: (standard deviation/mean) · 100

Sources: RMG computerised database; Chamber of Mines (1994a: 52); Roskill (1994)

Notes

(1) If LDCs and industrial mine producer countries, i.e. excluding former centrally planned economies, are classified in four groups, according to the degree of state participation in non-fuel mineral production, between 1975 and 1989 only a few countries shifted to a different group (UNCTAD 1994: 44, 87). Beyond the general trend towards privatisation, relatively stronger efforts in this direction have been observed in countries with state participation below 80%, and even more so below 20%. In Africa two relevant changes in ownership structure are reported by UNCTAD: the partial nationalisation of ZCCM in Zambia in 1979 and the partial privatisation of Iscor in South Africa in 1989.

(2) An example would be represented by Gecamines in Zaire. UNCTAD (1994a: 22-23) extends this concept so as to include, paradoxically, Chile's non-democratic regime in the late 1970s as a more efficient institutional setting than the previous government by Allende, for the goal of fostering a process of diversification and modernisation in the mining sector.

(3) In reality a sliding tax scale is applied, with a maximum tax rate of 55%, to which a surcharge of 15% is added. Moreover, in some fiscal years distinct parameters have been applied in the tax formula depending on the initial year of mine operation. In the mid-1980s the working profit ratio needed to achieve a zero-tax rate was 8% on average (since *a* and *b* equalled 60 and 480, respectively) (Bergman *et al.* 1985: 55). In order to increase competitiveness, the Marais Committee (December 1988) envisaged a phasing out of the surcharge, among other measures (Minerals Bureau 1992: 14-20). Capital expenditure can be written off during the same year of its incurrence, or carried forward for redemption against future income.

(4) The higher proportion of fixed costs would be brought about by (i) the use of similar mining capital equipment worldwide, with most mineral developing economies affected by higher maintenance and transport costs and import duties, and (ii) the comparatively lower level of labour costs and, for major mineral producer countries such as Chile for copper, the near-fixed cost nature of these costs for mines (with high potential restructuring costs and rigid labour legislation in the mining industry) (Markowski-Radetzki 1987: 30).

(5) In spite of being itself a macroeconomic policy-related, rather than a market-related, aspect, the exchange rate has been included here among the mineral market characteristics since its impact tends to vary according to these features. While the macroeconomic debate in terms of the *orthodox*-structuralist controversy has been mentioned in chapter 3, in this chapter attention is paid to the unresolved issue of alternative market-related reasons for using international rather than domestic prices in mineral supply functions.

(6) A futures contract commits the seller and purchaser to a specific quantity of the mineral at a pre-established future time and at a price determined by a futures exchange in open auction. If the sales price is locked into the current price plus a premium based on expected interest rates, storage or insurance costs, the producer is protected against commodity price volatility (Austin

1984: 340).

(7) In the case of Zambia, for the (pre-partial nationalisation) sub-period 1964-1968, and Zaire, the results by Markowski and Radetztki actually point to a better performance of the static estimation (Markowski-Radetzki 1987: 25). The extremely small sample size of some of these estimations inevitably leads to multicollinearity problems in dynamic models, while providing a shaky base for estimation in static models. In Dobozi (1990: 11-12, 14-15), out of six static equations, applied to different country groupings, only one clearly points to a superiority of a dynamic specification, according to indicators of goodness of fit. The *swelling* effect on significance of the estimation due to the introduction of dummies for non-systematic factors is instead clearly detectable in Dobozi's analysis, except when a flexible dynamic specification is used, and is implicitly recognised by Markowski and Radetzki, when considering results of countries other than the United States, Canada and Chile ("our knowledge of countries .... is not sufficient to permit us to account adequately for such factors in the regressions", *ibidem*: 27).

(8) The difference in the current account balance before and after official transfers basically consists of foreign aid. According to the World Bank (1993a: 553), for most LDCs the inclusion of aid inflows would bias downwards the current account deficit as an indicator of financing requirements. For this reason the BoP/GDP ratio recommended by the World Bank uses the current account balance before official transfers. As an alternative BoP variable, the (unweighted) *overall balance* annual figures reported by the IMF (v.y./b) for each country were used, after deflating them by the IMF-estimated CPI for the industrial countries. Econometric estimates using this variable are not significant, even once the substantially different average sizes in the various countries' BoPs are taken into account.

(9) In order to calculate percentage changes in the country's world share over the period examined (last column in Table 6.2), no account was taken of the final year for the Dominican Republic and the first two years for Tanzania, due to null or very low figures. The exceptionally high growth figure obtained for Tanzania is to a large extent the outcome of extremely low levels of production at the beginning of the period. For this country the annual gold supply by the only operating company reported by the RMG database, i.e. the SOE Stamico (100% state control), exactly matches the total national, except for the last four years, for which no data are provided at the company level. For this reason total national figures were preferred (Table 6.2), assuming that the state keeps a complete control over the whole period.

(10) For instance, CVRD in Brazil was partly privatised in 1991, with the state share in control declining from 56% to 51%. In cases of doubt about the control pattern and its evolution over time, as for e.g. Marcopper in the Philippines, the company was left out of the sample for the econometric estimations (although Marcopper could be considered as a SOE according to RMG information for the early 1990s, and is implicitly identifiable by the term and figures between parentheses in Table 6.2 and 6.3).

(11) The correlation analysis was run on 85 observations for this 10-country sample, instead of 90, since a few countries lack observations at the end of the period. In this regard, almost all

correlation coefficients for individual countries concern the period 1984-1992: a remarkable exception is constituted by Zaire, with only six observations available for SOEs (1984-1989).

(12) The analysis is aimed at testing the validity of the *ownership and control* hypothesis, and compares results with regressions testing for other hypotheses suggested by the literature. The presence of a large current account deficit may also be the consequence of a poorly managed economy, dominated by large and inefficient SOEs. The causality pattern implied by the *ownership and control* hypothesis might therefore be questioned. In this case, however, the international price would be expected to be more highly correlated with the current account balance, while no *a priori* assumption could be formulated for the relationship between the latter variable and mineral supply.

(13) As a necessary component of Koyck-type equation specifications and in order to correct for autocorrelation in the residuals, a lagged endogenous variable has generally been used in the pooled regressions, for both cross-country and cross-mine data. Given the pooled nature of the series, lagged endogenous variables had to be constructed manually. With reference to cross-country data, the Durbin-h test points to possible problems of autocorrelation only in the regression with sub-sample B (Table 6.6: Dh = 2.10). In the case of South African cross-mine data, instead, the length of the pooled sample and the limited number of available explanatory variables (further aggravated by the need to avoid multicollinearity problems) does not allow the avoidance of positive serial correlation: the Dh test, computed for a few regressions, fails to reject the null hypothesis of no serial correlation. In the presence of pooled data, procedures for removal of autocorrelation are not strictly applicable.

The time series within each *section* generally cover a nine- or ten-year period (1984-1992 or 1984-1993), and this would also justify the need to check for contemporaneous (across the pool) correlation in the residuals. Testing for this kind of residual correlation for the second equation reported in Table 6.7, by applying an autoregressive model on the residuals with lags of order 1, 2 and 11, leads to a suspicion of 11th order cross-mine residual correlation at a 74% confidence interval. Results should be interpreted with these limitations in mind, as they impinge upon the efficiency of OLS estimates.

(14) As a reference year for gold export dependence, 1989 was chosen since, within the mid-years of the time series (i.e. 1987-1990), that year's current gold price in US dollars (382.6 US$) has the closest value to the overall period (1984-1993) average of 379.9 US$ per troy oz. (Roskill 1994: 85). This avoids an excessive underestimation or overestimation of gold export dependence in value terms due to the mineral price fluctuations. The above figure was obviously converted into metric tonnes. For platinum the period average price was preferred, in view of high mid-period values.

(15) One should notice that this distinction does not necessarily match with the classification of producing countries according to their shares in world supply of gold, as shown in Table 6.2.

(16) PGMs include platinum, palladium, rhodium, rhutenium, iridium and osmium, with the first two accounting for by far the largest

shares in world demand and reserves (Chamber of Mines 1990; Minerals Bureau 1994).

(17) The distinction between gold mines based on geographical location is not necessarily associated either with substantial differences in average starting dates of mine operations, or with differences in expected mine life. Although the Rand and Evander show a larger cross-mine variation in the date of first declaration of gold, the median value of this date for the mines included in the analysis is 1956 for the OFS and Klerksdorp, and 1958 for the Rand and Evander (Chamber of Mines 1990: 5). As for the probable ore reserves, which are based on discrete sampling techniques through the installation of boreholes, they indicate a mine life longer than 20 years for mines located in the West Rand (Driefontein, Elandsrand, Kloof, Randfontein, Western Deep Levels), as well as in Klerksdorp and the OFS (Vaal Reefs, Freegold) (Posel 1989: 148-149).

(18) Unlike the variance and the standard deviation, the coefficient of variation has the advantage of being invariant to the unit of measurement. However, it can be used only as a rough indicator of instability (Appendix A in chapter 2).

(19) A positive price-elasticity is found if the log-transformed US dollar gold price is used instead.

Appendix

List of South African gold mines included in the analysis (sub-section 3.2b.1)

mines	location	controlling mining house
1 Barberton (bar)	Eastern Transvaal	Gencor
2 Blyvooruitzicht	West Rand	AAC-Rand Mines
3 Bracken	Evander	Gencor
4 Buffelsfontein (buf)	Klerksdorp	AAC-Gencor
5 Beatrix	Orange Free State	Gencor
6 Deelkraal	West Rand	GFSA
7 Doornfontein	West Rand	GFSA
8 Driefontein East (dros)	West Rand	GFSA
9 Driefontein West (drws)	West Rand	GFSA
10 Elandsrand	West Rand	AAC
11 Durban Deep	Central Rand	Rand Mines
12 ERPM (erpm)	East Rand	Rand Mines
13 Grootvlei	East Rand	Gencor
14 Hartebeestfontein	Klerksdorp	AAC-Anglovaal
15 Kinross	Evander	Gencor
16 Kloof (klo)	West Rand	GFSA
17 Leslie	Evander	Gencor
18 Libanon	West Rand	GFSA
19 Loraine	Orange Free State	Anglovaal
20 Marievale	East Rand	Gencor
21 Randfontein (ran)	West Rand	JCI
22 Stilfontein (stil)	Klerksdorp	Gencor
23 Unisel (uni)	Orange Free State	Gencor
24 Venterspost	West Rand	GFSA
25 Winkelhaak	Evander	Gencor
26 West Rand Cons.	West Rand	Gencor
27 Western Deep Levels	West Rand	AAC
28 Western Areas	West Rand	JCI

abbreviations in parentheses refer to symbols used to identify the observations in Figure 6.2 (annual observations for selected mines)

AAC Anglo American Corp. Ltd.
GFSA Gold Fields of South Africa Ltd.
JCI Johannesburg Consolidated Investment Company Ltd.

Source: RMG computerised database; Chamber of Mines (1990: 5)

7. Conclusions

7.1 An overview of results

The identification of determinants and effects of mineral commodity export instability and growth for a developing economy poses several controversial questions, concerning theoretical underpinnings, methodological problems, empirical results, and policy issues. In this respect, however, a dearth of recent quantitative analyses contrasts with the frequent appearance of articles of a qualitative nature. This situation may partly be explained by the absence of easily accessible, complete, and systematised statistical information. Another reason possibly lies in a widespread academic interest mainly oriented towards other sectors of the economy, despite the enduring importance of mining for a large number of developing economies.

This study has endeavoured to examine some of the above questions, with particular reference to the interaction between mineral supply and prices, exchange rates and growth. While not restricting the focus of the research exclusively to the South African case, the analysis has especially considered gold and, to a limited extent, other minerals which constitute a relevant source of foreign exchange earnings for this country. Various hypotheses about the role of minerals for a developing economy have been investigated, through the application of statistical and econometric techniques on data at different levels of aggregation, time length and frequency.

For some specific topics, attempts have been made at redressing or improving methodological flaws in previous studies. In this respect, particular attention has been paid to (i) regression models suitable for the analysis of long-term growth patterns across developing countries; (ii) the measurement of mineral price instability and trends; (iii) the analysis of real exchange rate misalignments; and (iv) problems of econometric model building with mineral production data.

Once differences in development levels and human capital are accounted for, and if oil-producing countries in Northern Africa and the Middle East are excluded, significant resource endowments and exports of mineral commodities seem, on average, to neither particularly benefit, nor harm the long-term growth of mineral-dependent developing economies. The analysis presented in **chapter 2** reveals an S-shaped double convergence equilibrium, characterised by a stronger and a weaker *club* for both mineral and non-mineral economies. This convergence is of a weak kind, that is concerning growth *rates*. For Africa, however, no pattern of either convergence or divergence in *levels* of development is identifiable.

Within this double convergence equilibrium, no statistical evidence supports the hypothesis of a higher flex point for mineral than non-mineral economies: a small difference is found between the 1985 income figures corresponding to the inflexion point for the two country groups. The 1985 income threshold figure for the mineral economies is estimated at ca. 460 US$ at PPP-converted 1980 prices. This flex point can be seen as a Leibenstein-type permeable *ceiling* for the lower equilibrium country group. Among mineral economies, the only low-income economies lying in the lower equilibrium level in 1985 are Guinea, Niger, Sierra Leone and Zaire.

The presence of an indirect disincentive effect of mining for human capital formation can not be discounted, although no highly significant result is obtained in the regression estimate. Particularly at low levels of development, mining rents may discourage a sound and diversified allocation of productive resources. Although often overlooked, this argument is reflected in other endogenous growth frameworks, such as in Grossman and Helpman (1990), and Lucas (1988): economic integration, or even more so a distorted pattern of opening to foreign trade, may act as a disincentive to the development of technological and skillsintensive resources in natural resource-rich countries, by encouraging an export specialisation in low human capital-intensive production. This is likely to occur if the scope for dynamic advantages of international trade is limited, due to diseconomies of small scale and technological backwardness, although production cost differentials may induce a reallocation of resources in favour of the human capital-scarce country (Pio 1996: 21).

After accounting for initial development level, and growth or instability of mineral commodity prices (as regressors in alternative equations), sub-Saharan Africa presents a number of relatively more "unexplained" mineral country cases. However, the mineral economies of this region are shown to be, in relative average terms and excluding South Africa, more negatively affected by fluctuations, and less able to draw benefits out of long-term trends, in the international prices of their main mineral export commodities. Inadequate responses to volatility in international mineral prices by several African governments, reflected in monetary and exchange rate mismanagement, and weaker production links with the rest of the economy, appear as possible explanations. Other structural features of the domestic economy, namely size, foreign trade dependence, or export concentration in the most relevant mineral commodity, are not necessarily associated with these problems, as illustrated by such heterogeneous performances of mineral economies as Botswana, Gabon and Nigeria.

Disagreements about the role of mining for a developing economy, reflected in the literature contributions surveyed in **chapter 3**, are to a large extent influenced by, among other factors, different geological conditions, forms of mining operation, producer countries, stages of mineral exploitation, and periods analysed. The remaining part of the study has tried to throw some light on some of these contradictory arguments. In South Africa the arguments about mineral commodity prices, exchange rates, and the links with the rest of the economy partly reflect the above dilemma on long-term growth implications. According to alternative views, schematically outlined here, gold and other minerals have been seen as a factor directly or indirectly contributing to (i) fostering a wide range of development areas and sectors; (ii) a pro-mining bias; or (iii) a pro-inefficient industrialisation bias.

The view under point (ii) appears to have received particular attention, with an assumed mild bout of Dutch disease in South Africa. Although the empirical analysis in chapter 2 does not place this country among the mineral economies most vulnerable to international mineral price fluctuations, this supposition definitely shows the need for further more detailed and robust testing. This is undertaken in **chapters 4** and **5**. At first glance, the econometric analyses in both chapters seem to give credit to some of the arguments implied in the above view.

In chapter 4, unit root tests, and analysis of correlograms for gold price, REER and NERUSD, provide evidence that these variables are likely to be non-stationary, first-order homogeneous. This points to the need for applying co-integration techniques on the chosen 150-month period, that is the 1980s and early 1990s. Variations in the nominal exchange rate during the 1980s appear to have largely protected South African gold producers from downward fluctuations of the gold price in US dollars. Furthermore, boom and slack phases in the international gold price have contributed, respectively, to real appreciations and depreciations of the rand. These patterns appear to be substantially stable throughout the period analysed, as revealed by the Kalman filter and other techniques, although behavioural relationships are found to lose strength towards the late 1980s and early 1990s.

In chapter 5, annual data covering a 24-year period have replaced the monthly observations used in chapter 4. According to various authors (Gelb 1979: 150; Adams-Behrman 1982), the costs imposed on developing countries by high- and medium-frequency changes are less easy to dismiss than very high-frequency (i.e. below one year) export revenue fluctuations. Production structures are likely to face more severe adjustment problems whenever export revenues experience declines not over one or few quarters, but two or a few years, although these costs can be expected to decline again over low-frequency (over at least 5 years) fluctuations.

Within real gold price movements, the analysis in chapter 5 distinguishes smoothed variations from sharp shocks. The former are found to have affected, along with other macroeconomic fundamentals, the equilibrium real exchange rate, while the latter are supposed to have contributed to REER misalignments. The econometric analysis not only provides support for the hypothesis of an influence of the gold price on the REER in South Africa, as indicated by chapter 4, but it also highlights how REER misalignments and volatility appear to have been to some extent negatively associated with economic growth.

These results notwithstanding, the argument of a pro-mining bias, with a standard Dutch disease effect of mining on the South African economy, should be tempered in view of other indications raised by the study. Gold price booms have been accompanied neither by significant expansions in gold exports, nor severe contractions in manufacturing exports. Although some negative responsiveness of industrial exports to real appreciations of the rand does appear in the 1980s, in the early 1990s these exports have been growing despite a slight appreciating tendency in the South African REER. In view of the unfavourable gold price movements of the late 1980s and early 1990s, this result further points to a gradual de-linking of the exchange rate as a policy instrument functional to domestic gold producers' interests, as found also by Barr and Kahn (1995). Moreover, according to causality tests in chapter 4, especially since the late 1980s REER appreciations have been the short-term consequence of inflationary pressures, rather than vice versa.

A strict Dutch disease interpretation would also generally predict an asymmetric response of aggregate demand components, such as domestic consumption and investment, to changes in mineral price and the profitability of gold mining. Overspending in consumption would tend to occur in boom periods to a greater extent than consumption restraint in slump periods, while the opposite would happen in investment. This has been discussed in chapter 3 with reference to business cycle effects, while less common interprations have tended to highlight factors favouring a reversed asymmetrical behaviour. As far as mining investment is concerned, following the analysis in chapter 5, no such asymmetries are noticeable with respect to changes in total gold mining profits.

The Dutch disease model in its conventional pattern is not thoroughly applicable to South Africa. The model presumes a different clearing mechanism for the tradable vis-à-vis non-tradable sectors, as a consequence of the spending and resource movement effects associated with a commodity boom. Tradables are hypothesized to clear through quantities, given world market prices, with a contraction of exports, except for the booming sector, coupled with an increase in imports. Non-tradables, which include import-substitution goods, would instead clear through (higher) prices, given a near-full capacity level and sluggishness in domestic supply adjustments. This dychotomic assumption is not realistic. Particularly in LDCs characterised by excess production capacity, high unemployment, oligopolistic mark-up pricing, and imperfect substitutability between domestic goods and importables, this assumption should be modified. The clearing mechanism can be supposed to operate at least partly through quantities for both tradables and non-tradables (Vos 1989; Daniel 1992), and not all non-booming tradables will necessarily suffer from the shock (Benjamin *et al.* 1989; Nyoni 1993). With a sudden reversal to a non-boom situation, RER misalignments can instead be determined by rigidities in containing government spending, stickiness in domestic costs and prices, and segmentation and wage disparities in the labour market. The latter features can, for instance, prevent an easy reabsorption of redundant mine workers by the agricultural sector.

This revised interpretation of the model seems to suit the South African case more accurately. Holden (1991) distinguishes, for instance, between the real exchange rate effects of gold price upturns in 1979-1980 and in 1983. On the one hand, during the 1979-1980 period, no serious RER misalignment appears to have occurred, since the domestic "supply response to the spending boom was sufficient to outweigh the increase in the demand for non-tradables on their price" (Holden 1991: 10). On the other hand, a real overvaluation did occur in 1983, as a consequence of another sudden, although less significant, gold boom. Following a different approach, similar results for the two periods are obtained from the analysis in chapter 5 (Figure 5.5).

The absence of a high responsiveness of South African gold exports to changes in the international gold price, apparent from the econometric results of chapter 4, entails an even greater necessity to overcome the exclusive reliance on macroeconomic variables, and to investigate the supply behaviour of mineral producers. Whereas chapter 5 examines specific issues of gold mine supply in South Africa with the application of a sector model, the topic is investigated in greater depth in **chapter 6**.

The analysis of the supply behaviour of mining companies has relevant theoretical and policy implications. The identification of determinants of (mineral) commodity export instability, namely whether it is more demand-led or supply-led, has been pursued by some studies through a correlation analysis of mineral unit prices *versus* supply volumes, or following similar procedures (Brook *et al.* 1977; Mainardi 1992). A significant positive correlation coefficient would appear when prices and quantities move in similar directions, and hence possibly imply that demand shifts are the predominant cause of instability, and conversely for a significant negative coefficient. However, this interpretation holds true only as long as standard demand and supply curves are assumed.

The nature of certain hypotheses concerning mineral supply behaviour, including aspects such as the macroeconomic and institutional environment, has led to the use of cross-country data, besides focusing on 28 major South African gold mines with available costs and ore grade data. An understanding of the issues involved may prove useful in view of forthcoming policy options for the mining sector in South Africa. In terms of the supply reactivity to international mineral prices and the exchange rate, the econometric analysis of South African gold mines reveals a relatively stronger negative responsiveness to the gold price in rand terms, in contrast with a statistically less significant positive elasticity to the US dollar gold price. This result fits well into the conclusions obtained from the sector model of chapter 5, which embodies the rand gold price as a factor more directly associated with gold ore production. In the case of South Africa, the downward-sloping gold mine supply (vis-à-vis the real rand price) is explained by the particular tax treatment, coupled with geological and technological factors.

The higher responsiveness to the gold price in domestic currency can be explained by the prevailing market characteristics. All gold produced by the mines is sold to the South African Reserve Bank, normally at a daily price (Posel 1989: 6), or at an average price of the latest bullion fixes. The currency used for these sales has alternated between the US dollar and the rand: the Reserve Bank used to pay entirely in rands for gold purchases until September 1983 and in the 3-year period 1986-1988; 1985 was characterised by mixed payments, with both currencies covering half of the sales; between September 1983 and January 1985, in turn, gold mines received the proceeds of their sales in US dollars, and this modality has been re-introduced since December 1988 (Austin 1984: 325; Meijer *et al*. 1991: 259-260). In practice, however, foreign exchange regulations do not allow South African companies to own accounts in foreign exchange.

Other statistical and econometric evidence, which refers to most gold producers in the developing world in the period 1984-

1992, including South Africa, does not provide strong support for either a macroeconomic, or an *ownership and control* interpretation of different supply behaviours. On a pooled cross-country time-series basis, the responsiveness of gold producers does not appear to be highly influenced by such conditions as foreign indebtedness, balance of payments position, and degree of state or domestic, as opposed to private or foreign, participation. The lack of a consistent pattern of responsiveness according to these and similar criteria may partly be explained by the limited number of developing economies with a very high reliance on gold export earnings: only in Ghana, Papua New Guinea, and South Africa has this dependence recently amounted to 30% or more of merchandise exports.

If the analysis is limited to a group of highly gold export-dependent economies, the *ownership and control* pattern appears to suit only the cases of Ghana and Zimbabwe, which present a negatively sloping supply curve for the state-controlled gold mining sector. Microeconomic and geological characteristics, by contrast, appear to provide a more general explanation for different responsiveness of gold and platinum producing companies, based on both econometric analyses (across countries/groups of mining companies and across South African mines). These features include the scale of mine operations, the diversification of the major controlling holding's activities, the type of sales arrangements, and possibly producers' expectations on mineral demand.

While supplies of different minerals tend to co-vary positively in some cases, possibly in connection with their industrial uses, a correlation analysis discards the presence of parallel performances in trends and medium-term fluctuations in the prices of South African major export minerals. Out of nine mineral commodities analysed, only coal and, to some extent, silver present positive elasticities of supply to their respective mineral price in rands, whereas gold is the only case of a negative price elasticity. In view of these results, mineral price variations are not likely to have directly transmitted serious instability to the level of domestic economic activity of the country.

7.2 An assessment of limitations and critical aspects

It is necessary to bear in mind a number of limitations of the study, and possible criticisms of the methods used. The remarks which follow focus on problems related to (i) the interpretation of empirical results, and (ii) the econometric techniques. The first set of problems refers to the possible omission of variables and the scope for extending the econometric analysis. Problems associated with specific parts of the study, concerning databases, variables and statistical methods (on aspects such as identification of trends), have already been considered in the chapters concerned, and are not reassessed here.

In chapter 2, the analysis of weak convergence fails to confirm the S-shaped double equilibrium pattern once adult illiteracy as an inverse proxy for human capital and *social capability* is introduced as regressor. This may suggest the need to widen the objective of the analysis of long-term convergence to variables other than per capita income. For instance, one could examine whether a similar S-shaped pattern is identifiable with respect to the productivity of expenditures in social sectors such as education and health. The use of control variables accounting for political changes would also improve the understanding of this subject. Proxies which have recently been proposed for historical and political factors can however be misleading and subject to arbitrary interpretations: for instance, the ethnolinguistic fractionalization index, mentioned in that chapter, would envisage the scope for high political stability and institutional efficiency in countries such as Rwanda and Somalia. As for the mineral economy sub-sample, further insights could be acquired through the estimation of trends in and instability of major export minerals in volume terms, analogously to the treatment of mineral prices. Likewise, on a cross-country basis, the econometric analysis on gold supply responsiveness in chapter 6 could be improved if systematised information were available on strikes and accidents occurring in major mines, and changes in tax treatment in producer countries.

Similar to other studies on determinants of RER and equilibrium RER, the ERER equation in chapter 5 does not account for aspects which are difficult to measure with reliability or to model correctly. These aspects concern changes in tariff and non-tariff barriers, and re-allocations in government expenditure between tradables and non-tradables, as mentioned in chapter 3. The role of expectations by investors and asset holders is instead likely to be partly accounted for by the capital inflow variable. The short-term speculative component, not accounted for by the variable used in the analysis, would eventually be relevant for RER (as opposed to ERER) determination. This would entail the need to include variables such as expected money supply growth or inflation, and anticipated returns on investments in South Africa and its major trading partners (Douch 1989), although Gerson and Kahn (1988) find no econometric evidence supporting the relevance of monetary shocks for the South African RER.

The exogeneity of inflation and of the nominal exchange rate in the gold sector model also entails limitations. Improvements in the rand gold price can be achieved by a combination of a favourable dollar gold price and exchange rate devaluations. In view of possible negative effects of devaluations on working costs and imported inflation, however, stable long-term benefits for the sector and the South African economy can derive only from a positive performance of the international gold price (Chamber of Mines 1993: No. 2-3) and adequate macroeconomic policy responses. In this respect, the analyses in chapters 4 and 5 have been limited to the exchange rate, thus ignoring other policy variables (except for the analysis of inflation vis-à-vis money supply in chapter 4). This deficiency prevents the examination in detail of the controversial questions about the effectiveness of the exchange rate policy for economic growth, briefly discussed in chapter 3. A message which seems to emerge from the results on the South African RER, however, is that *overshooting* in order to redress a RER overvaluation can be as ineffective on the economy in the short run as disregarding this exchange rate misalignment.

As for the econometric methods, co-integration techniques are increasingly being used in applications on long time series, in order to deal with problems of spurious regression. However, these techniques have been criticised for (i) ignoring the possible presence of a third "hidden" variable, which may influence the results, and even, in some cases, (ii) constituting "measurement without theory". With regard to point (i), Hendry (1991) stresses the weakness of the unit root test on residuals in the static regression: a negative result may be due not only to a spurious relationship, but also to the omission of a third I(1) variable. The criticism under point (ii) has also been levelled against an excessive use of ARIMA and VAR models (Darnell-Evans 1990). Independently from the validity of these remarks, in the specific case of chapter 4 data constraints and controversial aspects related to multivariate co-integration modelling have discouraged the search for a third variable. The use of non-gold terms of trade as a second regressor produces insignificant results.

Another point of criticism regarding unit root and co-integration analysis is their statistical power over different sampling frequencies and lengths of time. Although increasingly used on annual data, unit root tests are commonly carried out on monthly and quarterly data, as is usual also for ARMA and ARIMA models. Annual data are often considered to be unsuited to a correct application because of the greater likelihood of major structural breaks, besides being frequently unavailable over a sufficient length of time with consistent data series. On the other hand, it is worth noticing that, independently from the frequency used, decreasing the time span of the data has been objected to on the grounds that it would reduce the power of these tests (Campbell-Perron 1991: 153).

With regard to the other procedures mentioned above, in chapter 4 the Johansen method, based on VAR, is used as a tool for checking the validity of the two-step co-integration procedure, in terms of sign and size of the parameters. Although questionable in its model building approach, the Johansen co-integration procedure is considered statistically more powerful. Time series modelling through ARIMA is applied in view of the scarce theoretical knowledge and non-systematic elements in the variables examined, namely gold price and exchange rates. This alternative approach allows a further investigation of non-stationarity and seasonality in the series.

7.3 Policy implications

According to results obtained from the study, South Africa has been relatively less affected by its main mineral price volatility, in comparison to other African countries. Sub-Saharan Africa as a whole, excluding South Africa, receives only 5% of world mining exploration and capital expenditures. In order for the region fully to exploit its potential, provided that absorptive capacity is increased, the World Bank (1992: 12) recommends an increase of this share to at least 14%. Recent changes in legislation in a large number of African countries, as well as increasing costs of mining in more developed mineral economies (including South Africa), have actually determined substantial new inflows of foreign investment in several countries of the region (Rake-Saccoh 1994). The prospects for a recovery of mining activities in the region need a careful monitoring of its future implications for the local economies.

With regard to South Africa, a Chamber of Mines' analysis highlights the high geographical dispersion of this sector across provinces (Chamber of Mines 1994: No. 4). Mining contributes substantially to the development of regions characterised by a relatively lesser diversification or strength in other sectors of the economy. Among the nine provinces, the largest share of mining and quarrying in the respective gross geographic product (GGP) is held by the North West (43%), followed by the Northern Cape (27%). In another three provinces the sector accounts for nearly one-fifth of the GGP (Northern and Eastern Transvaal, and Orange Free State). Even the provinces which do not draw direct benefits from the sector, as typically the Eastern Cape (where the sector represents only 0.2% of the GGP), benefit indirectly in terms of inter-regional transfers of labour, goods and services.

Beyond this geographical dispersion of mining, South Africa has not been able to achieve the growth potential for which its mineral wealth could have allowed. Without being accompanied by a re-orientation of government spending towards a more equitable income distribution, widespread education, and diversified and labour-intensive production, preemptive exchange rate devaluations or a heavier taxation on gold mining in boom times would have been ineffective in improving the growth performance of the economy. In this respect, growth requirements for the near future, within the Reconstruction and Development Programme, are particularly demanding. In view of the expected population growth, a minimum annual 3% economic growth target should be maintained throughout the period 1994-1999. The containment of unemployment would require an even higher growth.

The simulation estimates obtained from the sector model developed within this study lie far below both these growth targets and current official growth projections of the BER and the Reserve Bank. Although the simulation model clearly suffers from not incorporating the positive changes expected for the 1990s (except for BER projections on the exogenous variables), some of the above growth targets have recently been revised downwards. On the positive side, the financial rand was abolished in March 1995, and other financial and trade liberalisation measures are envisaged, including a phasing out of the GEIS. This is scheduled to occur by the end of 1997, unless a rescheduling is granted by the GATT (ABD 1995: 93).

A gradual trade liberalisation should prevent the South African RER from falling into sudden misalignments as in the past. This process may however be accompanied by an even more substantial exchange rate devaluation than that hypothesized by the model. The diminishing contribution of gold exports to South Africa's current account, the tendency of the gold price to experience greater stability and the increasing practice of predetermined forward prices for gold sales entail that exchange rate shocks are likely to be associated relatively more with disturbances on the capital account (Kahn 1993: 146).

Partly alternative strategies have been suggested for the forthcoming development of the mining sector in South Africa. Following the example of countries such as Botswana and Australia, the policy framework favoured by the present government envisages two possible major innovations: (i) stronger involvement of the state in mineral rights, and (ii) establishment of a national marketing board (Minerals Marketing Audit Office), similar to the CSO for diamonds. These initiatives would stimulate exploration activities, thus enhancing the possibility of discovering new seams. Moreover, by allowing a better control of and co-ordination among different mineral marketing activities and by strengthening the potential for mineral beneficiation, the new institutional instruments would help to raise foreign exchange and detect transfer pricing practices (Mineral and Energy Policy Workshop 1994: 25-26). They would moreover redress the present maldistribution of the benefits from mining.

According to another view, the role of the state in South African mining should be limited to discretionary control activities, such as the anti-trust policy. This second argument is defended in view of the specific geological conditions prevailing in the country, with deep level mining, and the recent trend towards more attractive mining regulations in several newly competing producer countries, including other African nations (Chamber of Mines 1994: No. 1). Furthermore, in order to alleviate the fixed burden on working costs, taxation should only be applied to profits, rather than continuing to be partly indirect, that is based on regional levies (Chamber of Mines 1993: No. 2-3).

Regarding the prospects for South African gold mining, different opinions have also been aired. In 1994 South African gold production declined to below 600 tonnes: since 1958 this had occurred only once, in 1991. According to provisional estimates concerning the first half of the year, a further contraction is likely to be registered in 1995 (*Financial Mail* 1995). A pessimistic view, relying on these recent events, foresees a risk of closure in the next few years for as many as one third of the mines, and that "closures are more likely than new mines" (*ibidem*: 26). Even the most recent upward pressures on the gold price are seen to constitute only a provisional buffer against a steady decline of the sector in South Africa (*Financial Mail* 1996: 19). An optimistic view, by contrast, stresses the size of gold reserves and the development of underground mine technologies, which would ensure a gradual strengthening of South African gold mining in total world supply by the beginning of the next century (Handley 1990), despite short- to medium-term competition from producers benefiting from shallow reefs. With regard to the latter, improved productivity conditions and enhanced confidence by investors are believed to have encouraged the development of new reefs towards the end of 1995 (Chamber of Mines 1995a: No. 5, p. 14).

These opposing views on future developments can be better understood in terms of recent trends in pay limits of South African gold mines. A pay limit is defined as the minimum amount of grams of gold to be recovered for each tonne of ore milled, in order for the mine operation to break even (Chamber of Mines 1993: No. 4). In the period 1986-1992 the national average pay limit steadily increased, until it reached the 1992 level of 4.5 grams/tonne. This tendency has implied a progressive widening of the share of uneconomic ore reserves, which were estimated to amount to 41% of total reserves in 1992, and has been accompanied by a decline in capital expenditures to levels below those considered necessary for the maintenance of satisfactory production attainments.

Positive signs of a possible reversal in these trends in pay limit and capital expenditures have appeared in the last three years (e.g., for 1995, Chamber of Mines 1995a: No. 3-4, p. 13). Should the gold price and the average working costs actually evolve according to the simulation accomplished by this study, the average pay limit would gradually return to a level comprised between its 1988 and 1989 figures by 1999 (3.5 grams/tonne). A continuation of the 1986-1992 trend would imply a further dramatic shrinking of economically recoverable reserves (Chamber of Mines 1993: No. 4, p. 3). The outcome envisaged by the simulation, by contrast, would render economically recoverable nearly 70% of South African gold ore reserves, assuming no change in size and grade composition of these reserves (*ibidem*: 2, Diagram B). This would strengthen the chances for recovery in the sector, or at least prevent its rapid decline.

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