CITY UNIVERSITY BUSINESS SCHOOL
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FINANCIAL INNOVATIONS IN A PROGRAMMING FRAMEWORK
(London Clearing Banks 1965-85)

Ph.D Thesis

by

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To my Parents

Στον αγαπητό καθηγητή μου
κ^ο Res, με απέραντη εκτίμηση
και ευχαριστίες

[illegible]

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CHAPTER I

THEORIES OF FINANCIAL INNOVATION

I.1 Introduction

The structure of financial systems is not static but it is under a continuous process of change. Financial innovation is the key word behind these structural changes and a word that is increasingly attracting considerable attention recently. We can observe a rapid acceleration in the pace of financial innovations in the last ten to fifteen years. As Ian Cooper (1986, p.1) vividly puts it:

> *Any measure of the volume of financial innovation would register an explosion in the last ten years.*

This acceleration in the rate of change in the structure of financial systems is also observed in the case of the UK where: *the ... financial system is experiencing change unprecedented in its scope and pace.* (H.Rose, 1986, p.18). The bibliography on the subject has also increased significantly in the last ten years or so. Most of the papers on this subject are dealing with the implications of innovations on monetary policy issues such as the stability of the demand for money and control of the money supply. T.M. Podolski (1986), argues that:

> *The present economic environment both increases the inducement and enhances the capacity of financial agents to innovate and thereby circumvent monetary regulation and control. Current macroeconomic policies based on the presumption of our ability to identify and to control the money supply must, in this situation, be reviewed fundamentally, for financial innovation alters unpredictably the relationships between variables, upon whose stability the effectiveness of monetary control*

depends.

Fewer papers are examining the causes and the whole process of financial innovations. One of the major theories in this area (a more extended exposition of theories and relevant studies on financial innovation will be given in I.3) is Silber's "constraint induced innovations" approach (1975). Ben Horim's and Silber's paper (1977) is one of the very few attempts to empirically test a theory of innovations.

This thesis is concerned with presenting and analysing the microeconomic side of the process of financial innovation and attempts to empirically test the constraint induced innovations hypothesis for a particular group of UK financial institutions, the London Clearing Banks. The remaining of this chapter gives the definition of 'financial innovation' that is adopted in this study and reviews the major issues related to and theories of financial innovations. Chapter II provides a general overview of developments in the UK financial system with particular emphasis on bank innovations appearing in the 1960-85 period. Three main periods are examined: the early period (17th century up to 1960), the 1960s and the 1971-85 period. In chapter III we examine the major constraints on bank portfolio management. A more detailed account of regulatory constraints on liquidity and capital adequacy is given. In chapter IV we review the literature on models of bank behaviour with particular emphasis on asset management models and portfolio models. The methodology and objectives of the study are presented in chapter V. In chapter VI a detailed description of the models is presented while chapter VII summarises the empirical results from the models' simulations. Finally, in chapter VIII an overall appraisal and discussion of the results of the empirical study is offered together with the suggestion of an alternative approach.

I.2. Definition of 'financial innovation'.

The term 'financial innovation' is used so frequently and in so many different contexts that makes its definition a difficult task since a widely accepted criterion does not exist. However, it is essential to give a definition of the term as it will be used in the present study in order to avoid confusion.

In this thesis, 'financial innovation' will be defined in a way equivalent to K.E. Knight's (1967) definition of innovation in the industrial firm. In particular, it will be defined as the adoption of change that is new to a financial firm and to the (relevant) financial environment. Financial innovation comprises: new financial instruments, new uses of existing instruments, and changes in the way of operation of financial institutions. We should note that the innovation of a financial product occurs only when the idea behind it is used and made operational. Another point to notice is that when we say "new to a financial firm and to the (relevant) financial environment", we do not limit innovations to the first known use by mankind but to the reference group where the innovator belongs.

Innovations in the financial sector can be divided, according to Silber, in the following two categories:

(i)Process innovations: are changes in the way and methods of operation of a (financial) firm and are a consequence of changes in scientific knowledge and its applications (e.g. computers in banking for accounting reasons, CHAPS: Clearing House Automated Payment System).

(ii)Product innovations: are the result of individuals' and firms' desires for new products. Certificates of Deposit, financial futures and options, term loans are examples of this category of innovations.

An important aspect of innovations that is found in the literature on the industrial sector is that there are routine and non-routine innovations. Routine innovations are happening continuously and represent minor modifications to the product, mainly in its design (new packaging or new colour, for example), while non-routine innovations happen less often and are a conscious reaction of a firm's management to an exogenous shock that drastically affected some of the parameters in the firm's optimisation system. However, in the case of financial firms it is difficult to separate routine from important innovations. M. Desai (1985) provided a method of separating these two categories. He first suggested a method of identifying and measuring gaps in the variety of available financial products which represent a potentially profitable area for financial firms. Each financial product can be mapped on a two-dimensional characteristics space with yield measured along the vertical axis and liquidity measured along the horizontal axis. Assets with the highest returns and highest illiquidity are found at the top right hand corner while as we move to the origin return tends to zero and liquidity increases. By mapping each asset on the characteristics space and joining each point to the origin we can observe the distance between assets as it can be measured by the angle between the drawn lines corresponding to each one of them. The distance between adjacent assets is an indication, according to Desai, of existing gaps in the financial market at a point of time. Large gaps represent significant profit opportunities. If an innovation reduces significantly the gap between two adjacent products then it is a significant one otherwise it is a routine (or trivial, as it is called by Desai) innovation.

Another way of looking at innovations (or, more generally, structural changes in the financial system) is by examining whether they are:

(a)Demand induced innovations, or

(b)Supply-led innovations.

The above concepts of demand and supply somewhat differ from those employed in price theory. The terms are used here in a way suggested by H. Patrick (1966). Supply leading denotes a calculated deliberate effort for the creation of new financial instruments, services or institutions in advance of the demand for them. Such an effort is usually undertaken by the economic authorities either directly or indirectly through financial institutions that are under their control. Demand induced innovations are those which are developed as a response to demand for financial services by investors and borrowers.

It seems that the majority of innovations in the developing countries are of the supply-led type, while in most developed countries innovations are mainly demand induced. So, the process of change in the financial structure of an economy can follow two directions. The first, is an evolutionary path of structural change which is mainly the result of changes in the demand for financial services and was followed by today's developed countries. The second, is the path of imposed structural change. This process of change is mainly the result of government interventions in the financial system that try to implement innovations already adopted by developed financial systems. However, these two paths of structural change are not independent to each other, but we observe a mixture (whose composition varies from country to country and from period to period) of the two.

One final remark; an innovation appearing at period t, forms the structural reference framework for period's t+1 innovations and so on. Therefore, every element that is forming a financial system at a particular point in time is an innovation of some previous period; hence, by analysing the process of financial innovations we are, at the same time, making a description of the intertemporal process of change in financial systems

<u>Selection of innovations tested in this study.</u>

As we have already seen, selecting which financial instruments are chosen as innovations at a particular time period is not an easy task. In the industrial sector one could classify innovations according to patent data. In the financial sector this is obviously not possible and we, therefore, have to make the selection in a more or less arbitrary way.

The method followed in this study is to consider only non-routine innovations. We therefore examine financial instruments that are aknoweledged as **important** innovations by various authors in similar studies. (Silber, W.L., 1983, Vittas, D., 1986, Cooper,I., 1986, Fforde,J.S.,1983, Hester, D.D., 1981, Rose.,H.,1986).

The major innovations that this study will try to explain are the following (a detailed discussion of these new instruments in a historical perspective is given in Chapter II and Chapter III.1):

On the liabilities side:

Sterling Certificates of Deposit (a discussion of this instrument is given in p.22-24), Foreign Currency Deposits and Certificates of Deposit (see pages 24,25) and interest bearing retail deposits (see p.28).

On the capital side the most important innovations are:

Loan Capital and Floating Rate Notes (see p.25,26) and Perpetual Floating Rate Notes (see p.30 and p.43).

Other innovations considered are: Liability Management (p.22), the introduction of variable rate instruments (p.25), mortgage lending (p.28) and the trend towards securitisation and off-balance-sheet activities (p.28-30).

I.3 Causes and theories of financial innovation.

The majority of studies in this area are describing mainly the macroeconomic factors that stimulate financial innovations and concentrate on examining the effects of innovations particularly on the stability of the financial system and on monetary policy issues (Fforde, J.S. (1983), Gramley, L.E. (1982), Hester, D.D. (1981), Kane, E.J. (1983), Lombra, R.E. (1984), Mayer, C. (1986)).

There seems to be an almost unanimous agreement on the basic causes of the recent acceleration in the pace of financial innovation, among various economists that presented papers on this issue recently.

Using an analytical framework based on the suggestion made by D.T.Llewellyn (1985), it is possible to consider the evolution of the financial system as a whole, or of particular financial institutions, by looking at developments in three main areas:

-A- The general economic, financial and market environment;
-B- Basic flow of funds factors dealing with the volume and sectoral structure of savings, borrowing and financial surpluses and deficits, as well as with the portfolio preferences of savers and borrowers.
-C- The determinants of the supply of and demand for financial products and services provided by financial firms and markets, taking into account the portfolio preferences of financial firms and the constraints they face.

Major causes of innovation that fall into the first two categories are the following:

1. The increase and volatility of nominal interest rates, exchange rates and equity prices. The adoption of short-term variable rate instruments by banks is contributed to this factor. In the UK in particular, as it is pointed out in BEQB (September 1983, p.358)

> ...*this* (the uncertainty generated by high and variable inflation rates) *has contributed significantly to the almost complete replacement of fixed rate corporate bonds by variable rate bank loans and to the marked success of building societies in attracting funds by paying interest rates more closely related to those in the wholesale markets.*

In the USA the growth of Money Market Mutual Funds and of the commercial paper market can be seen as a result of this factor. High and volatile rates led to higher risk exposure for some financial intermediaries. This provided a stimulus for the introduction of risk hedging instruments such as financial futures and options (C. Mayer, 1986).

2. Rapid developments in technology increase the efficiency of delivery systems and organisation and make feasible a range of new financial services by reducing costs. I.Cooper (1986), believes that this factor is the most significant one behind recent innovations. Without the developments in computer and telecommunications technology, he argues, most of the new sophisticated instruments and practices such as financial options traded in highly liquid global markets, the switch from relationship to transaction-based banking or the proliferation of complex securities would be very difficult to operate efficiently, if at all.

3. Changes in regulation and supervision are another important factor stimulating innovations. Regulations can affect the incentives to innovate in two ways. Either by being restrictive (as for example the imposition of interest rate ceilings by regulation Q in the USA) or by being relaxed in a proccess of deregulation (abolition of interest rate or exchange rate controls for example). Most of the innovations of the 1960s and 1970s in the USA were attributed by various researchers to a significant degree to the highly restrictive nature of bank regulation in the USA. The development of the Eurodollar market for example is seen by some authors as a reaction to restrictions on reserve requirements and interest rates (regulation Q) that the banks were facing in their domestic business (D.Hester, 1981). More recently, as it is pointed out in the "Cross Report" (BIS, April 1986), the increased pressure from banking regulators for improvements in bank capital adequacy have contributed to the increase in off-balance-sheet activities by banks since such activities do not require capital backing.

4. Increased competition both domestically and internationally is another factor stimulating innovation. The increase in competition can in turn be attributed to deregulation and

developments in technology that have led to a greater uniformity in the provision of services in the financial sector. The increased sophistication of corporations as well as individuals (this is another factor stimulating innovations according to L.E.Gramley, (1982)) has resulted in greater borrower mobility and contributed to the increased competitive pressures between financial firms for market share.

5. Major developments influencing innovations in international markets that fall into the second category of the analytical framework presented above are: (Llewelyn, 1985)

(a) the rise in the absolute size of international financial imbalances;

(b) the supply of traditional finance did not expand in line with the size of financial deficits;

Furthermore, as it is pointed out in the BIS paper (1986, p.7):

> *A sharp shift during the 1980s in the geographic pattern of net flows of international savings and investment, as reflected in the distribution of current account imbalances, has also been a contributing factor. To the extent that this shift has interacted with the distinct preferences of investors and borrowers in different geographic areas for particular forms of financial assets and liabilities, it can be held at least partly accountable for the changes in the structure of international financial intermediation and the development of new financial instruments.*

Although much work has been done in presenting the major causes and effects of financial innovations, there are still very few theoretical models explaining the process of financial innovation and there are even fewer attempts to empirically test such models.

A significant theory on the process of financial innovation has been offered by W. Silber (1975, 1983) and an empirical test of it was presented by Ben-Horim and Silber (1977). Silber provided a theory of the stimulus to innovate from the point of view of the financial firm. However, in his comment to R. Sylla (1982), he argued that this theory can apply equally well to collective actions from groups of intermediaries or individuals as well as to the actions of the economic authorities.

Silber assumes that financial firms are utility maximisers that operate under a set of constraints. Besides the basic balance sheet constraint that the sum of liabilities and capital must be equal to total assets there are three main categories of constraints:

-i- externally imposed regulatory constraints;

-ii- internally self-imposed policy constraints; and

-iii- market constraints.

Exogenous changes affect the constrained optimisation of the firm and stimulate innovation in two ways: (a) either by causing a reduction in utility or (b) by increasing the cost of adhering to a constraint. In the first case the firm's innovative reaction is a result of its effort to restore its previous level of utility while in the second case it reacts to perceived profit opportunities in order to increase its utility. Silber summarises the major conditions that may stimulate the innovative efforts of a financial firm as following (1975 , p. 69):

(a) imposition of regulatory constraints;

(b) exogenous decreases in its rate of growth;

(c) an exogenous increase in the variability of major items in its balance sheet;

(d) a change in the competitive nature of the markets facing the firm;

(e) sharply rising yields on the assets in the firm's portfolio; and

(f) a technological breakthrough that has the

potential of significantly altering the opportunity set or cost functions of the firm.

In Ben-Horim & Silber (1977), an empirical test of the constraint-induced innovation hypothesis was offered. In that study a linear programming model was specified and applied to a major New York bank as well as a group of four large money market banks. The model explored basically the reaction to profit opportunities aspect of the theory. The shadow prices of deposits and capital were derived for the 1952-70 period and were used as an indicator of the cost of adhering to constraints and the resulting pressure to innovate. The hypothesis tested was that shadow prices should rise before the introduction of an innovation and fall immediately afterwards. The model seemed to explain satisfactorily the innovations of negotiable certificates of deposit in 1961, bank-related commercial paper and loan repurchase agreements in 1969 as well as the introduction of subordinated debentures as part of bank capital in 1965.

In a more recent paper Silber (1983) examines a sample of thirty eight new financial instruments in the USA and he submits them to an informal analysis to identify whether they can be adequately explained by the constraint-induced innovation theory. He claims that this theory explains more than half of the innovations in the sample while the remaining innovations are mostly the result of exogenous changes in legislation and technology.

Another, less general though, approach to the subject is the regulatory theory of innovation that was presented mainly by E. Kane (1981, 1983) and also by S. I. Greenbaum & C. F. Haywood (1971). These theories emphasise the importance of regulations to the innovation process. The "regulatory process" as defined by Kane is a dynamic process of interaction between opposing political powers (imposing regulation) and economic powers of regulatee avoidance. As he points out (E. J. Kane, 1983, p. 97):

In the regulatory dialectic, political processes

> *of regulation and economic forces of avoidance adapt continually to each other like riders on a seesaw. This alternating adaptation is not continuous. Rather it develops as a series of lagged responses. Moreover, because of essential differences in the capacity for creative adaptation (i.e. in the adaptive efficiency) of regulators, regulatees, and unregulated competitors, avoidance lags tend to be shorter than regulatory lags.*

His main argument is that:

> *Financial Innovation is impelled by regulated and unregulated institutions' adaptation to observed changes in their technological, market, and regulatory constraints and by regulatory adaptation to ensuing changes in regulators' own opportunity sets.*

An interesting study on the process of financial innovations, from an international perspective, is given by the Bank for International Settlements (BIS, 1986). Their proposed framework analyses the economics of the demand for and supply of innovations and their interaction. The study focuses on new financial instruments that appeared in the international markets such as: Note Issuance Facilities, Currency and Interest Rate Swaps, Forward Rate Agreements and the general trend towards securitisation, off-balance-sheet business and global integration of financial markets.

Innovations are classified into four major categories:

(i) risk-transferring innovations;
(ii) liquidity-enhancing innovations;
(iii) credit-generating (or debt-generating) innovations;
(iv) equity-generating innovations;

Major forces on the demand side that lead to innovations are identified to be the following:

- Perceptions of increased vulnerability of financial positions to asset price risk;

- Perceptions of greater vulnerability of existing financial positions to deteriorations in creditworthinesss;
- Greater demand for liquidity in the economy;
- Stronger demand for credit;
- Stonger demand for equity finance.

On the supply side four broad factors are identified as important in the process of financial innovations:

- Technology;
- Regulation (mainly bank capital adequacy regulations);
- Greater competition;
- The historical dynamics of the financial innovation process itself;

The interaction of the above supply and demand forces through time leads to the introduction of new financial instruments and practices.

Finally, D.Blake (1987), has presented a theory of financial innovations based on a characteristics framework that provides a more general approach to the process of financial innovation and attempts to provide a unified framework where all existing innovation theories (constraint-induced, regulation-induced and technology-induced theories of innovation) can fit.

The various financial instruments are defined in terms of internal characteristics. Financial intermediaries are seen as transforming the supply-side characteristics of securities that they borrow into demand-side characteristics of the securities that they lend. In this approach, both demand-side as well as supply-side of the innovation process is examined. According to D.Blake (1987, p22):

> *Whether a security was produced or not depended on the cost and demand relationship underlying the set of characteristics. In a particular period, securities are either marketed because the balance between supply of and demand for characteristics indicates an interior equilibrium,*

> *or they are not marketed because they are positioned at a corner.*

The process of financial innovation is seen as the interaction of forces on the demand as well as on the supply side. In particular (D. Blake, 1987, p.23):

> *A financial innovation occurs when the equilibrium for a given security moves from the corner to the interior. This is a matter of shifting costs and demand. On the supply side, the main motivating forces of financial innovations have been changing technology and the incentive to avoid constraints and regulations of various kinds.*

CHAPTER II

THE EVOLUTION OF THE BRITISH BANKING SYSTEM AND THE RESULTING INNOVATIONS

Having examined the major theories on the process of financial innovation and before getting to the details of the empirical models and methodology of the research, it would be useful to get a more general view of the evolution of the British banking system and in particular of the relative growth of the London Clearing Banks which are the focus of this empirical study. It is interesting to see how banks reacted to changing constraints (legal, regulatory, market or technological) that led either to increased profit opportunities or reduced their utility in particular periods.

II.1 The early period.

The british banking system followed an evolutionary path of development that reflected changes in the economic and social environments. These changes created a need for new types of financial instruments and institutions. In the 17th century significant changes in the financial structure took place. Despite civil war, economic development and industrialisation continued. The most important contributors in financial development at this phase were the goldsmiths; their main function, however, was not that of a banker but through evolutionary steps they ended up as true bankers. This point is clearly demonstrated in Carter & Partington (1981):

> *By 1660 the goldsmith-bankers were in effect providing current account services to customers since receipts for deposits were being presented for part payment, in accordance with the needs of the customer, and the convenience of using the receipts as a means of direct payments (rather*

than encashing the receipt) had also become established. The use of these receipts, or promissory notes, marks an important step towards the proper banking function. Such notes were the precursor of the modern bank note...The middle of the seventeenth century also marks the origin of the cheque. Not only were the promissory notes of the goldsmith-banker in circulation but 'drawn notes also appeared which authorised the goldsmith to pay the creditor the appropriate sum due to him.

In 1694 the Bank of England was established. It raised a loan to the government to aid the prosecution of the war with France and in exchange it received the right to issue notes and a few other rights. The profitability of the Bank of England depended heavily on the acceptance and circulation of its notes.

During the eighteenth century we see a spread of bank notes for coin since they were far more convenient; we also see an expansion of private banking in London and a gradual move from goldsmithing activity to more specialised real banking activities. There were two main groups of banks in London (Kindleberger, 1984, p77):

(a) those of the "City" of London, who were in the financial district of the town and were dealing mainly in government "stock" (bonds) and the shares of the Bank of England, East India Company and South Sea Company, and

(b) those of the West End who were near the houses of Parliament and near the homes of nobility and aristocracy; they did most of their business with the aristocracy, lending on mortgages or overdrafts.

In the 17th century banks had kept running accounts with each other which permitted them to cancel offsetting claims (Sheppard, 1971, p.72). In 1773, this activity was transferred to a newly established "Clearing House" in Lombart street. By

1873 settlement took place in Bank of England branches which spread over the country after 1826, as an Act introduced in 1826 permitted the Bank of England to open branches anywhere in Britain. This Act also permitted joint-stock banking with the right of note issue, but imposed the restriction of unlimited liability and the proscription of business activity within a radius of 65 miles of London. (Carter & Partington, 1981, p. 101). In 1833 joint-stock banks were allowed to be established in London, provided that they did not undertake note issuing; in addition, cheques drawn on these banks were legalised. The Bank Charter Act gave the Bank of England the exclusive right to issue notes. The result of this legal constraint to the other banks, was to encourage the use of the bank deposit as the medium of exchange and payment.

The important difference between the earlier private banks and the joint-stock banks was in the main source of their profits. While, note issuing was the main source of profits for the former, joint-stock banks' profitability depended mainly on the attraction and use of deposits. Joint-stock banks used branching as a means of expanding their activities and increase their profits. Provincial banks that needed a London correspondent adopted a strategy of mergers with London banks. This strategy had the advantage of internalising the benefits of access to sources of funds that were offered in London and eliminating the cost of paying correspondents for the services. For individual banks, a branch network internalised profits that would have otherwise gone to correspondents and reduced the danger of being cut off from outlets with excess funds when there was an increased demand for them. (Kindleberger, 1984, p. 88). Furthermore, branch banking offered the customer greater security, better service and financial expertise. Joint-stock banks ultimately became the dominant banks in the British financial system: by 1913 there were 43 such banks with almost 6,000 branches. By 1918 due to an increased rate of mergers there were only five major banks controlling two-thirds of deposits. By 1936 the "big five" primary banks (Barclays, Lloyds, Midland, National Provincial and Westminster) held 87% of total clearing bank deposits.

Until the 1960s, the UK banking system remained relatively stable, following a normal path of structural evolution. In 1955 the cartelised oligopoly of the Clearing banks was dominating the financial scene, holding 85% of commercial lending. In terms of products and services offered to individuals or companies the banking system was not very different from what it was at the beginning of the 20th century. It was highly structured, strictly regulated for monetary policy reasons and there were clear demarcation lines between various institutions and their "appropriate" operating strategies and businesses.

II.2 The 1960's.

The 1960-70 period was influenced by the report of the Radcliffe Committee on the Working of the Monetary System. The main policy suggestion of the report was that the monetary authorities should monitor and control the liquidity of the economy as a whole rather than the money supply even if the latter was possible. This, could be achieved through liquidity ratios supplemented by direct controls on lending in an emergency.

Major developments in the 1960s were the spectacular growth of secondary banks and parallel money markets for inter-bank loans, Certificates of Deposit, Eurodollars and Local authority debt. An important factor leading to these developments has been government regulation that was discriminating between the clearing banks (they had to observe liquidity ratios) and secondary banks. These new markets and especially the Euro-dollar market had an important indirect influence on the UK financial system by providing the basis for the development of innovations in financial techniques. As

J.Revell (1972) puts it:

> *...all the major innovations in banking technique and structure can be traced back to the euro-dollar market - the phenomenal growth of the secondary banking system and of parallel money markets for unsecured deposits (although the initial impact came from the forcing of local authorities on to the market in 1955), term deposits, term loans and certificates of deposit. Many of these innovations came to Britain from American banking practice, although, except in CDs, the American banks in London were not necessarily the innovators.*

The entry of foreign banks towards the end of the 1960's intensified the competitive pressures in the financial system. The Clearing banks could satisfy the rapidly growing demand for credit mainly by reducing their holding of government stock [which was a substantial £1,500 million at the start of 1960 (BEQB, 1962)] and rearranging the asset side of their portfolios rather than by bidding for deposits in the wholesale markets. (In Table 1 the data for the proportion of public and private sector debt in banks' assets are shown). Nevertheless, they responded to these competitive pressures by establishing subsidiaries that were not subject to the liquidity regulations and which would give them unrestricted access to the new money markets. During this period there was a wave of mergers that reduced the number of the London Clearing banks from eleven to six [Barclays, Lloyds, National Westminster, Midland, Coutts and Co. (subsidiary of National Westminster) and Williams & Glyns (owned by the Royal Bank of Scotland].

The strict 1965-70 quantitative and qualitative credit control measures led to a credit squeeze. As a reaction to this situation, companies had to find other ways to get the necessary funds. The results were (J.Revell,1972) the

TABLE 1
Proportion of UK banks' assets held in public- and private-sector debt

London Clearing Banks

	Public	Private
At end-December		
1939	31.7	44.9
1946	60.0	19.0
1950	49.1	27.7
1955	47.1	28.9
1960	26.7	44.5
1965	17.6	53.2
1970*	12.1	61.0

Public-sector debt comprises British government securities, and Treasury bills and Treasury deposit receipts. Available sources included local authority debt as private-sector debt. Certain items, notably cash, special deposits, money at call and short notice, premises and other fixed and working capital, etc., are excluded from this table, so the figures do not add to 100 per cent.

*Average of mid-December 1970 and mid-January 1971.

Source: C. A. E Goodhart, *Monetary Theory and Practice. The UK Experience*, London, Macmillan Press, 1984.

following:

(1) Large companies turned to the overseas sector to provide the finance they could not obtain domestically. They also started to borrow from UK banks in euro-currencies for their medium term domestic needs.

(2) A market of inter-company loans appeared. Banks began to direct customers whose demand for credit they could not satisfy to this market and they often even provided guarantees for the borrowing.

(3) Non financial companies obtained the use of physical assets through leasing or renting.

(4) The last method of avoiding the credit squeeze was factoring, which grew quite rapidly during this period.

II.3 Competition and Credit Control and after.

The introduction in September 1971, by the Bank of England, of Competition and Credit Control marks the beginning of an era of deregulation and increased competition in the British financial system by removing some important elements of discrimination between financial intermediaries. As D.T.Llewellyn (1985) points out:

> *... banks in the 1970s became more growth orientated, more competitive and aggressive for new and diversified business, more profit conscious and less tied to traditional norms of behaviour. This was manifest in their domestic business but also in their increasingly important international business operations where the competitive climate has always been more intense. The nature of banking changed in the process. Banks became more innovative in funding strategies and developed and perfected new techniques of liability management.*

The new arrangements permitted the Clearing banks to enter into the inter-bank and certificates of deposit markets; this had important effects on the management of their balance sheets. Before 1971, the Clearing banks did not participate in the parallel money markets to attract wholesale deposits. This ment that their liabilities were given (the amount was determined by the public's demand for deposits at the going administered rate) and their main concern was the best allocation of the constrained funds to various asset categories as well as the maintenance of adequate liquidity through the purchase and sale of assets (asset management). In the 1970s a major innovation in the managerial behaviour of the London clearing banks took place in the form of liability management. The banks could accommodate increases in loan demand by competitively bidding for wholesale deposits in the money markets and therefore portfolio management was not dealing only with asset management but it was extended to include the active management of liabilities as well. This development undermined the authorities' ability to control the growth of broad money and caused problems in some of the countries whose monetary authorities were focusing on such aggregates (Goodhart, 1984).

Behind these innovations in managerial techniques we can see some important product innovations that were used for the first time by the London Clearing banks. The most important of these new products was the sterling certificate of deposit. Other new products appearing in the London Clearing banks' balance sheets during that period were dollar certificates of deposit, eurodollar deposits and loans and variable rate loans.

Certificates of deposit were first introduced in New York by the First National Citybank as a reaction to interest rate restrictions imposed on time deposits by Regulation Q. Certificates of deposit attracted back to New York banks the funds that were previously diverted to the money markets. Dollar certificates of deposit were introduced in London in May 1966 again by the First National Citybank with the permission of the Bank of England. The London market for dollar certificates of deposit followed a stable growth path throughout its life. However, the London Clearing banks actively engaged in the market from 1972 (see Table 2).

The market in London for sterling certificates of deposit was established in 1968. It would be useful to describe this new instrument and outline some of its main features, as they appear in the BEQB, December 1972, p.487.:

TABLE 2

LONDON CLEARING BANKS CERTIFICATES OF DEPOSITS

£million

Year*	£ Certificates	$ Certificates
1971	147	-
1972	761	18
1973	1,780	64
1974	1,721	119
1975	774	321
1976	788	311
1977	903	289
1978	1,434	288
1979	1,266	291
1980	1,303	508
1981	1,332	846
1982	2,417	1,449
1983	3,615	1,640
1984	5,459	1,643
1985	4,766	3,164

* Figures are calculated twelve-month averages.
Source: Bank of England Quarterly Bulletin, various issues.

A sterling certificate of deposit is a document, issued by a UK office of a *British or foreign bank, certifying that a sterling deposit has been made with that bank which is repayable to the bearer upon the surrender of the certificate at maturity. It also states the rate of interest and the date of repayment, and is negotiable by simple delivery. A sterling certificate of deposit may be issued in multiples of £10,000 with a minimum of £50,000 and (normally) a maximum of £500,000, and with a term to maturity of not less than three months and not longer* *than five years. The rate of interest is fixed by the issuing bank, but is usually closely related to the current market rate on sterling inter-bank deposits of the corresponding maturity. For certificates of a year or less, interest is paid at maturity; on longer-dated certificates it is normally payable annually to the bearer of the certificate at the time, and at maturity. Certificates are usually issued at par. But the secondary market price takes account of accrued interest and current market rates.*

Before the new arrangements for credit control that were introduced in 1971, the London Clearing banks did not issue sterling certificates of deposit in their own names because of the interest rate cartel and other restrictions that were in force then. After that date, however, they entered the certificates of deposit market and attracted considerable amounts of funds. As it is shown in Table 2, Clearing banks' holdings of sterling CDs grew significantly between 1971-85, with the exception of the 1975-80 period when the operation of the "corset" was restricting banks' portfolios.

As it was mentioned earlier, other new instruments appearing in the London Clearing banks' balance sheets in 1972, were foreign currency liabilities and assets. It is well known (E. R. Shaw, 1984) that the Eurodollar market appeared basically from 1957 as a result mainly of the relaxation of exchange controls in West European countries and the restrictive monetary policies adopted in the United States (regulation Q ceilings on interest rates on deposits). The market grew significantly in the 1960s and the early 1970s. It was observed that the market grew faster in periods when credit restrictions have been most severe in the United States. The oil price shock in 1973 resulted in excessive holdings of US dollars by the oil producing countries. A large proportion of these holdings was directed to the Eurodollar market giving it a further growth impetus.

Although the market is very competitive and margins between deposit and lending rates are narrower than in the domestic dollar market, profitability is high because of lower transaction costs and the absence of reserve requirements and deposit insurance costs. This led the London Clearing banks to entering the market in 1972. Since then, foreign currency liabilities represent a growing percentage of their total liabilities (see Table 3).

High and volatile levels of inflation in mid 1970s led to the adoption of variable rate instruments. The introduction of medium-term lending by the banks with rates that varied in line with the interbank rates was a significant innovation that met successfully the companies' demand for flexible rate borrowing. The introduction of the Floating Rate Note in the

TABLE 3

Foreign currency liabilities of the London Clearing banks

Year	Amount (£million)	% of total liabilities
1971	361	3.0
1972	902	6.1
1973	1,724	8.7
1974	2,695	10.9
1975	3,962	12.9
1976	4,596	15.1
1977	5,186	16.1
1978	5,900	15.5
1979	7,085	15.8
1980	10,006	18.5
1981	15,952	24.2
1982	21,253	26.2
1983	23,891	25.8
1984	27,342	26.3
1985	40,036	31.8

Note: Figures are calculated 12-month averages.
Source: Bank of England Quarterly Bulletin, various issues.

Eurodollar bond market in 1970 succeeded in attracting back investors who were driven away from the market because of the increased uncertainties and risks associated with fixed-interest securities (due to rising and volatile interest rates). The London clearing banks entered the floating rate note market in 1975 for the first time. The spectacular growth of loans in the 1970s had exercised significant strain on banks' capitalisation; furthermore, the Clearing banks expanded their eurocurrency lending activities during that period and the issue of floating rate notes could ease the excess strain on their balance sheets with a relatively low cost. The pace of technological change began to accelerate during the later part of that period. A whole new and sometimes confusing variety of technical terms and of acronyms has appeared. There are three major areas affected by developments in technology: internal organisation of banks, cheque clearing and funds transferring between banks and retail banking services and payment systems. The common target behind the adoption of new technologies in the three above areas is the reduction of operational and transaction costs.

The key word behind the new technological developments is Electronic Funds Transfer (EFT). The basic applications of EFT are the supply of information regarding customers' accounts and the possibility to transfer funds between various accounts. Of course, depending on the particular system and area of application, there are many other specialised sub-functions that can be performed. The most common application of the new technologies in the payment system is the Automatic Teller Machine (ATM) which offers banks' customers a variety of services such as: cash dispensing, ordering cheque books and statements, transferring funds between accounts, etc. The earlier and simpler machines that offered only the first facility were known as Cash Dispensers (CD). As is shown in Table 4, the growth in the number of ATMs installed by banks and building societies has been spectacular.

Other applications of new technologies in banking are:

TABLE 4

Cash dispensers and ATM's

end-December	UK banks	Building Societies
1975	1,173	-
1976	1,881	-
1977	2,185	-
1978	2,166	-
1979	2,171	-
1980	2,489	-
1981	3,212	-
1982	4,075	6
1983	5,628	112
1984	6,524	291
1985	8,199	652

Source: Abstract of Banking Statistics, Vol. 3, May 1986, Statistical Unit, Committee of London and Scottish Bankers.

point of sale (POS) machines that can directly debit a customer's account whenever he makes a payment at a retail outlet (which has a POS system installed) with his debit card; home banking which gives the customer access[1] to his branch's computer via a keyboard connected to his television set; finally, the installation of CHAPS (Clearing House Automated Payments System) which is a sophisticated electronic interbank payment service is another process innovation aimed at reducing the costs of paper handling in interbank transactions.

II.4 The 1980s.

In the 1980s a second wave of deregulation in the UK took place, competition among financial institutions intensified both domestically and abroad and the developments in technology accelerated even further. As a result, the pace of innovation accelerated considerably.

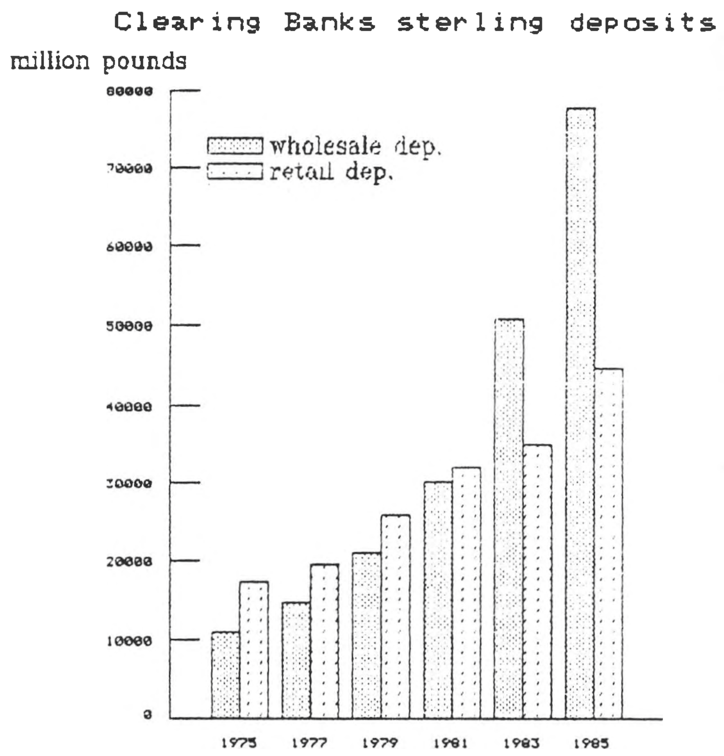
The major measures of the financial deregulation program were: (a) The abolition of exchange controls in 1979, (b) the abolition of the "corset" in 1980 and (c) the introduction of a new monetary control regime which abolished the minimum reserve assets ratio and the minimum cash ratio that were imposed upon the clearing banks from 1971 (Competition and Credit Control).

In the domestic market the increased competition for retail deposits between the clearing banks, the building societies[2] and the commercial banks pressed the clearing banks to offer interest-bearing sight deposits from 1984. As is shown in Figure 1, the clearing banks' (including their subsidiaries) proportion of retail deposits to total sterling deposits declined continuously from the 1970s reflecting up to a certain extent their engagement in liability management and their efforts to attract wholesale deposits. The proportion of retail deposits to total sterling deposits fell from 61% in 1975 to 36.5% in 1985. Competitive pressures combined with the removal of the restictions imposed on clearing banks' credit expansion during the 1975-80 period[3] led to another innovation; the clearing banks' entering the mortgage market. Mortgages represent a relatively safe and profitable lending instrument since the risk of default is outweighted by the obvious security of the mortgage.

Many new instruments that appear during this period (such as note issuance facilities[4], currency and interest rate swaps[5], forward rate agreements[6], foreign currency and interest rate options[7]) have their origin in the euromarkets and are the reflection of three main trends in international financial markets (BIS, 1986): securitisation, off-balance-sheet operations and global integration of financial markets.

Major influences to the trend of securitisation were (BIS, 1986, p. 12):

Figure 1



Firstly, the gradual decline of long-term interest rates from the abnormally high levels of several years ago and the restoration of positive-sloped yield curves have clearly enhanced the appeal of long-term marketable instruments and facilitated the recovery of bond markets. Secondly, the impact on banks' portfolios of the international debt problems has stimulated banks to improve the liquidity and marketability of their other assets and has encouraged them to strengthen their balance sheets by funding themselves through longer-term bond issues. Thirdly,

> *the highly publicised problems of a few banks in various countries and the weakening of banks' balance sheets more generally because of the exposure to problem debtors at home and abroad have impaired banks' comparative advantage as a channel for lending, at least to prime borrowers with recourse to securities markets.*

As a result of the above, many sizeable corporations found themselves in a much better credit risk rating position than many banks and thus established their own treasury departments that resemble to in-house banks and borrowed directly from the euromoney markets by issuing fixed or floating rate bonds. These developments led the banks to offer contigent services to customers that were using the new instruments via note issuance facilities (NIF) or revolving underwritting facilities (RUF) in the international as well as domestic commercial paper markets.

A by-product of the securitisation process is the development by banks of fee-earning off-balance-sheet activities. Most of the new instruments mentioned so far represent off-balance-sheet business. The attraction of these instruments is that they allow banks to hedge risks as well as expand their profits without expanding their balance sheets and putting pressure to their capital adequacy ratios. However, it is worth mentioning at this point that the UK banks' capital position had weakened significantly after 1982 and the pressure on them to improve their capital ratios was increasing. Raising new capital was not popular among the banks' management because of the high costs involved. Issuing loan capital did not offer a radical solution to their undercapitalisation problem since they were approaching the upper limit on the proportion of debt that can be included in the capital base for the assessment of capital adequacy. As a reaction to these constraints the clearing banks introduced a new type of debt the Subordinated Perpetual Floating Rate Note which was basically a floating rate note that incorporated a number of special features that would allow it to be seen by regulators as a near substitute to equity.

Finally, there has been a sharp acceleration in global integration of financial markets. This is the reflection of a wave of deregulation of financial markets and the resulting competitive forces, combined with technological developments that led to a dramatic reduction in transaction costs. As a result:

> The borderlines between international and individual domestic markets are becoming increasingly blurred. Securities markets as well as the banking sector are becoming globally integrated, fostered in part by the growing international diversification of investment.

(BIS, 1986, p. 14)

CHAPTER III

CONSTRAINTS ON BANK PORTFOLIO MANAGEMENT

A central problem in the management of a bank's portfolio is the issue of balancing profitability, risk and liquidity considerations (Cohen, K.J. & Hammer, F.S., 1967, p.148). Banks try to maximise their objective function subject to a set of constraints. As it was mentioned in Chapter I, these constraints can be either externally imposed or internal self-imposed management constraints. Government regulation represents an important source of externally imposed constraints and it is of particular relevance for the formulation of the programming models of this study. It would, therefore, be useful to present an account of the major issues involved and the historical changes in the framework of bank regulation and supervision in the UK.

III.1 <u>The need for and forms of regulation.</u>

By regulation we generally mean the intervention of some government or other supervisory authority in the free market mechanism in order to achieve some perceived social goals*. Regulation is often confused with Supervision; as Mullineux (1987), points out:

> *Regulation entails the imposition of rules and restrictions whilst supervision entails the monitoring of the banking and financial system to ensure that the rules are adhered to.*

In each advanced financial system there is a framework of regulations that is usually supervised by the central bank. However: (Mullineux (1987), p.3)

> *Commonly the supervisors are not responsible for establishing regulatory systems although*

they may use moral suasion to impose certain restrictions. Finance or trade and industry ministeries are usually responsible for formulating and revising regulations and ensuring compliance.

The financial system, and banks in particular, have always been subjected to higher degrees of regulation than any other sub-sector of the economy. This is a reflection of the perceived uniqueness of banks compared to other firms. The banking industry plays an extremely important role in the economy because it operates the payments mechanism, it is a channel for the conduct of monetary policy, it has a significant influence on the overall allocation of resources in the economy and also because it is thought to be very vulnerable due to the risk of illiquidity caused by runs on the banks' deposit liabilities in periods when the public's confidence to the system is lost.

Bank regulations are used for two main reasons:

(a) Economic management and in particular, monetary control purposes. Major regulations in this area are the imposition of cash and liquid assets ratios, interest rates mechanisms, quantitative or qualitative lending or interest rate controls, open market operations and discount facilities. The particular measures adopted depend on the monetary authorities' beliefs about the transmission mechanism of monetary policy and on the government's hierarchy of objectives.

(b) Prudential purposes. Banks and other deposit taking institutions face three main types of risk (J. Grady and M. Weale, (1986)):

-i- They may face a run on their deposits, which they lack the liquidity to meet.

-ii- Some of the advances they make may not be repaid, leading to a position in which liabilities exceed assets.

-iii- They are exposed in foreign currency fluctuations and other adverse movements in the price of their assets which may lead to significant losses.

The first of the above risks may lead to illiquidity, while the other two may lead to insolvency; however, fears about solvency (due to interest rate volatility leading to capital losses, or due to an increased rate of banks' creditors' defaults on loans) may lead to a rapid withdrawal of wholesale funds and thus create liquidity problems.

Bank prudential regulation aims (a) to protect depositors from fraud or incompetent and carelessly aggressive management behaviour and (b) to preserve the soundness and stability of the banking system and maintain a high level of public confidence to the financial system in general.

The major benefits as well as costs of prudential regulations are described in M.Hall ((1987),p.3-4); in particular:

> *The economic benefits are perceived to lie in an improvement of the allocative efficiency of the financial system, due to both increased investor confidence and the improvement of information. Associated costs of regulation, however, are potentially high, and include: the direct costs of compliance with, and enforcement of, regulatory requirements; resource missallocation (to the extent that the regulatory authorities may judge a requirement to support 'non-viable' institutions to be in the interests of maintaining stability in the financial system as a whole); possible reductions in consumer choice (through the imposition of restrictions on the range of business activities); and operational inefficiency.*

Major regulations in this area deal with capital adequacy, liquidity, foreign currency exposure and deposit insurance by using various ratios and controls for assessing the general position of banks through their balance sheets.

Bank capitalisation is thus receiving great attention by the regulatory authorities. In the absence of regulation, the authorities fear that the banks would be undercapitalised and exposed to socially intolerable levels of risk. This issue reflects two distinct views about the function of bank capital (H. Howcroft, 1985):

•the "regulatory" view emphasises the loss-absorption function of capital and encourages the imposition of relatively high levels of capital for prudential reasons.

•the so called "banker" view emphasises the portfolio management aspect of capital, which is concerned with maintaining the lowest possible capital in order to maximise profits subject to an acceptable level of risk.

It is important, to know the set of banking regulations prevailing during the 1965-85 period in the UK in order to be able to formulate the corresponding constraints in the models used in our empirical study.

III.2 Bank regulations and supervision in the UK.

Since the Second World War regulation of banks in the UK has been based on a self-regulatory basis, with the Bank of England exercising an informal style of supervision based on 'moral suasion' rather than enforcement. The relative stability of the British banking system for a long period (until the 1970s) dimed the importance of supervisory issues regarding capital adequacy and balance sheet management.

Until 1979 there was no formal bank regulatory legislation in the UK. However, there was a plethora of legislative Acts that were adopted over time to deal with statutory regulation[9] and grant banking status to financial institutions. To be fully recognised as 'banks', financial institutions had to acquire a series of individual recognitions that would ultimately lead them to acquire the highest recognitions required for being granted 'bank' status.

One main flaw of the system was that only the financial institutions that were regarded as 'banks' (mainly the clearing banks) by the Bank of England were subject to regulations. During the 1960s, the clearing banks were subjected to strict monetary controls. Economic growth led to an increased demand for credit which intensified competitive pressures among financial institutions. These developments provided an incentive for the creation of financial institutions that would achieve only the minimum required recognitions in order to avoid the burden of coming under the Bank of England's regulatory framework. As it is pointed out by E.P.M. Gardener (1986, p.72):

> *This state of affairs was the breeding ground for the development of the fringe banks.*

Until the early 1970s supervision was informal and based on frequent meetings between the management of banks and the Bank of England. The Bank of England observed some ratios both for prudential and for monetary control reasons, but there were no strict minimum limits required. The main prudential ratios observed were: (a) the ratio of free resources to public liabilities (gearing ratio) and (b) the ratio of all immediately liquifiable assets to deposits (quick assets ratio). The first ratio was used as a tool for judging a bank's solvency, while the second was focusing on liquidity. For non-clearing banks in particular the Bank preferred to use a ratio of free resources to public liabilities. Free resources were defined as capital resources less the book value of the infrastructure[11]. The basic guideline for accepting houses and similar banks was 10%. Additional ratios imposed for monetary policy reasons were the cash ratio and the liquid assets ratio. Supervisory functions were performed by the Discount Office of the Bank of England until the summer of 1974.

During the 1970s developments in the financial system accelerated. The number of new banks in London increased significantly and competition intensified. As a result, the informal system of regulation was under increasingly strong pressure. The introduction of Competition and Credit Control measures in September 1971 was dealing basically with monetary policy issues and was aiming to improve competition in the financial system and promote efficiency and consumer welfare. A landmark in the reappraisal of supervisory measures in the UK was the 'fringe' (or secondary) banking crisis in 1973.

What happened in 1973 was that a number of fringe banks[10] were unable to renew deposits from the money markets and faced severe liquidity problems.

> *The Bank thus found themselves confronted with the imminent collapse of several deposit-taking institutions, and with the clear danger of a rapidly escalating crisis of confidence. This threatened other deposit-taking institutions and, if left unchecked, would have quicly passed into parts of the banking system proper... In the circumstances ... the Bank felt it essential to meet their responsibility for fully-recognised banks by mounting a rescue operation for the benefit of the depositors of a group of institutions which were not fully-recognised banks, but whose otherwise inevitable collapse would have threatened the well-being of some recognised banks. (BEQB, June 1978, p.233)*

As M.Hall (1987, p.85) points out:

> *The immediate causes of the fringe banking crisis were over-exposure in property on the assets side of the balance-sheet, undue reliance on the wholesale money markets as funding source, maturity mismatching of assets and liabilities and abrupt changes in government policy with respect to monetary policy and rent controls.*

These developments made it clear that there was an urgent need to reconsider and adapt the supervisory framework to the new circumstances. The Bank of England responded by introducing a series of measures that: *marked the emergence* *of the modern banking supervisory function in the UK.* (E.P.M. Gardener, 1986 , p.74). However, the general supervisory philosophy of the Bank of England remained unchanged. The emphasis placed on flexibility, instead of the strict imposition of rigid guidelines enforced by legislation, in the operation of the supervisory functions remained.

Supervisory responsibilities that were previously exercised by the Discount Office, were transferred to a new Banking Supervision Division within the Chief Cashier's Department at the Bank of England. Supervision was extended to cover the most important deposit taking institutions. As a result, there was a significant increase in the volume of required statistics, and the regular meetings between bank management representatives and Bank of England officials were extended to include interviews with managers of secondary and foreign banks.

The issues of capital adequacy and liquidity became gradually more important in the regulatory authorities' operations. In 1974 the Bank of England established a Joint Working Party with the London and Scottish clearing banks to address the issue of capital and liquidity adequacy of banks. The results were published in 1975 (BEQB, September 1975, p.240).The report identified two reasons which determine the need for capital and reserves:

(i) to provide the infrastructure of the business, and

(ii) to protect depositors from losses as a result of business risks and to engender the confidence of potential depositors and trading partners.

Under the new proposals the bank should place more emphasis on a capital adequacy ratio that would take into account the risks involved in different asset categories, rather than relying solely on the gearing ratio. The proposed ratio would relate capital to assets weighted according to their risk. In essence they proposed a risk assets ratio. Assets such as cash and balances with the Bank of England, advances to, or guaranteed by, the UK public sector and advances to UK listed banks were regarded as risk-free. The remaining assets were subject to risk; forced sale risk, credit risk, or both.

The assessment of capital adequacy of banks, though, remained flexible and no strict value was attached to the relevant ratios.

> *The acceptable relationship of free capital resources to risk assets to be sought will vary for different categories of banks and even from bank to bank within a category. It will need to take account of each bank's historic experience, the spread of business and other special factors which might affect future profits.* (BEQB, 1975, p.242)

Finally, to be eligible for inclusion in the capital base, loan capital should be subordinated and of medium or long-term maturity. Its function was seen as financing part of the infrastructure rather than absorbing losses.

As far as liquidity is concerned, the Bank of England recognised the need for broader indicators, instead of the quick assets to deposits ratio, that would take into account the increased involvement of banks in liability management and foreign currency business.

A combination of growing public demands for consumer protection measures and the requirements of harmonisation of banking laws in the EEC led to the introduction of the 1979 Banking Act. This Act represented a landmark because it was the first time that the Bank of England's regulatory powers were endorsed by specific legislation.

The most important point of the Act was that each financial institution (existing or new) had to obtain authorisation from the Bank of England before being able to take deposits. There was a distinction between recognised banks and licenced deposit taking institutions. This distinction was mainly based on differences of services offered by the various firms and implied no distinction in the eyes of the bank of England.

Supervisory concern about bank capital adequacy was reinforced even further in recent years due to the internationalisation of banking business and a declining trend in bank capitalisation. As we can see in Table 5, the ratio of capital/liabilities for the London clearing banks begun to deteriorate from 1979.

TABLE 5

LONDON CLEARING BANKS GROUPS
(Barclays, Lloyds, Midland, National Westminster)

End-December	Total capital (1)	£million Total liabilities (2)	Ratio (1)/(2) %
1975	3,410	51,208	6.6
1976	4,147	59,948	6.9
1977	4,869	68,102	7.1
1978	5,765	76,302	7.5
1979	6,978	96,819	7.2
1980	8,049	116,847	6.8
1981	10,180	156,109	6.5
1982	12,157	190,316	6.3
1983	14,049	208,955	6.7
1984	15,399	243,825	6.3
1985	19,021	239,543	7.9

Source: Abstract of Banking Statistics, Vol.3, Statistical Unit, Committee of London & Scottish Bankers.

In 1980, the Bank of England issued the definitive paper on capital adequacy which further developed the principles put forward in 1975. The flexibility of the supervisory approach was reafirmed but a more detailed description of the recommended ratios together with a reappraisal of the role of loan capital was offered.

The major objectives of capital ratios were identified as:
(i) to ensure that the capital position of an institution is regarded as acceptable by its depositors and other creditors;
(ii) to test the adequacy of capital in relation to the risk of losses which may be sustained. (BEQB, 1980, p.324)

It was suggested that the first objective was satisfied by the 'free resources' or 'gearing ratio' (capital resources to current liabilities), while the second could be met by a risk assets to capital ratio.

In the 1980 paper there was a change in the Bank's approach to loan capital due to a redefinition of the purposes for which capital was required. The most important of these purposes were:

(i) to provide a cushion to absorb losses;

(ii) to demonstrate to potential depositors the willingness of the shareholders to put their own funds at risk on a permanent basis;

(iii) to provide resources free of fixed financing costs;

(iv) to be a suitable form of finance for the general infrastructure of the business.

While shareholders' funds were suitable for all the above purposes, loan stocks were thought to be less suitable since:

> *They do not provide a reserve against losses for a business which continues to trade. they do not demonstrate to depositors a willingness of the shareholders to put capital at risk on a permanent basis; nor do they provide the same flexibility as that provided by shareholders' funds to pay or not to pay servicing costs.*
> *(BEQB, 1980, p. 326)*

However, it was recognised that provided they are fully subordinated, they offer depositors protection against loss in the case of liquidation. The importance of loan capital as an additional source of protection available to depositors was emphasised:

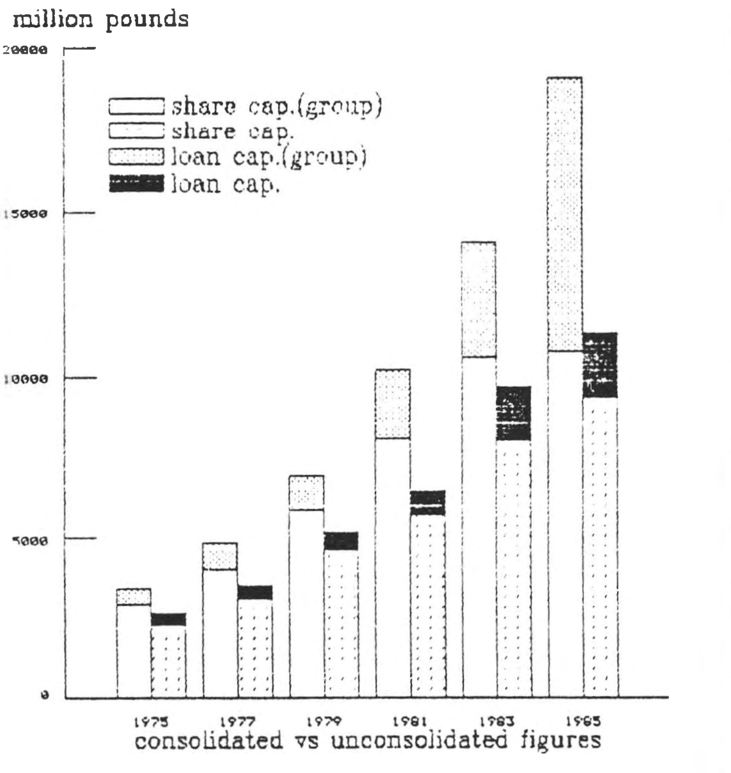
> *There is, in a going concern, some reassurance to be gained from the presence of loan stocks, provided that they are medium or long-term, during periods of temporary loss: although they cannot be written down to absorb losses, their presence could enable the losses to be absorbed*

by ordinary capital and reserves with less threat to creditors' confidence in the institution. An incidental advantage of loan stocks is that where they are long-term and denominated in foreign currencies, they may improve the maturity and currency match between a bank's banking assets and liabilities. (BEQB, 1980, p.326)

In Figure 2 we can observe the increased proportion of the capital base that is represented by loan capital in the balance sheets of the London clearing banks. We also observe that this proportion is higher if we look at consolidated balance sheets (including subsidiaries) than it is in each individual bank's balance sheet.

The risk asset measure for the assessment of capital adequacy was defined in more detail. The ratio used was capital base/risk adjusted assets. in particular, the capital base was defined as comprising the following:

Figure 2
LONDON CLEARING BANKS



(i) Share capital;

(ii)Loan capital fully subordinated and subject to a maximum of one third of the total capital base.

(iii)Minority interests;

(iv) Reserves;

(v) Provisions;

However, the following deductions from capital base were made in the calculation of the risk assets ratio:

- Investments in subsidiary and associated companies;
- Trade investments;
- Goodwill and
- Investment in plant and equipment.

Seven major categories of assets were identified and were given weights varying from 0 for the most liquid assets up to 2 for the most illiquid ones[13]. Finally, it was pointed out that the capital adequacy ratios should be applied to both consolidated balance sheets and the individual deposit taking companies' balance sheets.

In the 1980s, banks' capitalisation was weakening and they needed extra capital. Since they were already approaching the maximum 1/3 allowed to loan stocks (to be included in the capital base), they had to find another way of raising funds. Their reaction was the introduction of a new debt instrument; the perpetual floating rate note. Major features of the instrument were that:

(i) it was fully subordinated;

(ii) the principal amount never had to be repaid;

(iii)interest payments could be suspended and, as long as the isssuer had not paid or announced a dividend payment in the previous twelve months, this is not considered as an event of default.

The banks thought that these features were satisfying the Bank's requirements for top quality equity capital and hoped that they would be accepted by the Bank as a close substitute for equity.

In November 1984 the Bank of England issued a discussion document with new proposals concerning capital adequacy. These proposals covered, among others, the conditions under which perpetual debt could qualify as primary capital. In particular, it was argued that for perpetual floating rate notes to be counted as part of the capital base they should carry, in addition to the requirements for subordinated debt, the provision that they could be automatically converted to ordinary shares if a bank faced problems. Furthermore, the amount of perpetual debt which could be included in the capital base was limited to 1/2 of share capital.

The banks found the new proposals too restrictive and thought that perpetual floating rate notes incorporating the convertibility requirement would be almost unsaleable. Finally, in 1985, the Bank of England and the banks reached an agreement that was allowing the perpetual FRNs to be counted as part of capital if they incorporated a feature of convertibility to preference rather than ordinary shares.

Finally, a formal Deposit Protection Scheme was introduced in February 1982 following the 1979 Act , as the result mainly of the increased influence of consumerism. The Scheme provided insurance for 75% of the amount deposited by a single depositor up to £ 10,000. The fund was financed by obligatory contributions of all authorised institutions which were proportionate to their deposit base.

CHAPTER IV

THEORIES OF THE BANKING FIRM

A substantial literature has been developed over the years, attempting to model bank behaviour. Yet, considerable divergence can be found among the various approaches. A lot of confusion is present in the issue of how to determine a financial firm's inputs and outputs. Pesek (1970) and Towey (1974) view banks as producing money by employing loans as inputs; Hyman (1972) and Melitz and Pardue (1973) on the other hand, describe them as using deposits as inputs to produce credit. Nyong (1987) presents a more general view of the banking firm by defining its output as a set of financial services offered to the firm's depositors and borrowers through the process of financial intermediation.

Three major types of financial services were identified by Klein (1971):

(i) administration of the payment mechanism for demand deposit customers;

(ii) intermediation services to depositors and borrowers;

(iii) portfolio management .

IV.1 **Why do banks exist**?

Following the work of Santomero (1984) we can distinguish three main approaches that deal with the fundamental issue of the reason for the existense of banks:

(a) the role played by banks as asset transformers;

(b) the particular characteristics of banks' liabilities and their central function in a monetary economy;

(c) the two-sided nature of bank operations.

The asset transformation function of banks is subdivided into:

- Models that emphasise the asset diversification aspect. One of the most important roles of intermediation is the transformation of large denomination financial assets into smaller units. Klein (1971) is emphasising the fact that a financial firm can offer a better risk-return combination in its finacial products than an individual, even after allowing for the bank's profit. Divisibility problems associated with higher transaction costs seem to favour the use of a financial intermediary.
- Models dealing with asset evaluation. These models emphasise the role played by financial intermediaries as evaluators of credit risk, a function which is recently attracting considerable attention. *Banks function as a filter to evaluate signals in a financial environment with limited information.* (Santomero, 1984). Leland and Pyle (1977) were the first to propose this view of financial intermediation. There is a need for a set of firms that would provide as their main output to the market, signal evaluation. This need is the result of a lack of adequate information on the quality of financial assets. Therefore, financial firms are the better equipped ones to fulfill this function. However, the output from such firms is fragile because it has the characteristics of a public good (i.e. once resources are used to obtain such information, it becomes freely available to the market). It is, therefore, difficult for the firm to obtain the return associated with its value. So, it is argued that by becoming an intermediary that holds assets of sufficient value, the firm that gathers the information can overcome the problem of achieving a return to information.

D.Diamond (1984) elaborates on this view. In particular, he views banks as agencies that are delegated the task of monitoring information useful for solving incentive problems between borrowers and lenders. He emphasises that such monitoring is costly, a fact that should be taken into account in theories attempting to explain the reason of the existence of financial intermediaries. Financial intermediaries should have a net cost advantage relative to direct borrowing and lending in order to justify their existence. By using two models of optimal lender contracts with information assymetry (ex-post) between potential lenders and an entrepreneur who needs to borrow funds to finance a risky project, he concludes that diversification within an intermediary is the key to a possible net advantage of intermediation. In the first model, with risk neutral agents:

> ...*diversification is important because it increases the probability that the intermediary has sufficient loan proceeds to repay a fixed debt claim to depositors; in the limit, this probability is one, and the probability of incurring necessary bankruptcy costs goes to zero.* (D.Diamond, 1984, pp.409).

The second model introduces risk aversion and concludes that:

> *divesification increases the intermediary's risk tolerance toward each loan, allowing the risk bearing necessary for incentive purposes to be less costly* (D.Diamond, 1984, pp.409).

The second reason given to explain the existence of banks is the important role played by their demand deposits as a medium of exchange. The literature in this area concentrates on the issue of determining positive money holdings as a function of transaction costs, relative interest rates and uncertainty. *The monetary mechanism, along with bank pricing decisions, offers the financial firm the opportunity to attract deposits, which may be reinvested at a positive spread. The extent of this profit will depend upon the nature of competition and the nature of the transactions network itself.* (Santomero, 1984).

The third approach is trying to combine the previous two functions of banks into a unified framework. According to

Santomero (1984), Pyle's (1971) model is the most well-known approach of this kind based on the general portfolio theory. The aim of this model is to highlight the conditions under which intermediation will take place. The firm maximises expected utility of profits. Risk aversion is assumed (Concave utility function), there is a choice between only three securities: a riskless security and two securities with uncertain returns over the model's decision period namely loans and deposits; liquidity and solvency considerations as well as operational costs are not taken into account. The question is under which conditions is the firm willing to sell risky deposits to buy risky loans. Pyle's conclusion is that *covariance between the return on loans and deposits fosters intermediation by encouraging the risk-averse maximiser to transform deposits into loans* provided there is a positive expected yield difference between assets and liabilities. Therefore, intermediation is possible because of arbitrage opportunities accross markets that have different, though uncertain, interest rates. However, Baltensperger E. (1980, pp. 27) points out that :

> *...This raises the question of what gives rise to these differentials in the first place.... Why will the bank find customers willing to hold a financial asset ('deposits') at an expected rate below the one which the bank can obtain itself, and others which are willing to indebt themselves to the bank at an expected rate exceeding the one which the bank has to pay itself? That is, the approach does not really, in this basic sense, make clear what makes the intermediary come into existence, and thus what function it performs.* .

The introduction of specialisation and transaction and information costs would provide an explanation for the persistence of rate differentials; since, however, these factors are not taken into account in Pyle's model the answer to this problem is given in terms of risk aversion.

> *For every individual it will then be "profitable" (in terms of expected utility) to engage in arbitrage up to a certain point only (determined by its degree of risk aversion)...* (Baltensperger, 1980, pp.27).

IV.2. Alternative approaches to bank asset selection.

Financial firms are presented in the literature as microeconomic firms that maximise an objective function. However, the specification of the firm's objective, its control variables and the assumed market environment is model specific. Financial firms are presented either as expected-value maximisers in which case the objective function is linear in terminal wealth or as risk-averse investors selecting a mean-variance efficient portfolio.

In the remaining of this chapter a brief account of the various approaches to bank asset management as they evolved during time will be given, because they play an important role in the way banks' management **perceive** economic forces and thus react to them by, perhaps, innovating new instruments. The degree of profitability or potential growth of a particular source of funds may differ depending on the analytical framework that is used each time. There are two major ways of looking at the problem of managing a bank's porfolio. The first way is by using various forms of asset allocation or balance sheet management techniques, while the other way of looking to the problem is by applying portfolio theory.

IV.2.a. Management programming models.

Operations Research methods were developed in the late 1940s to early 1950s and were initially used for military purposes and later they were used in business as well. Banks started to use O.R. techniques in the early 1960s in the USA. Before that, the techniques used were (Cohen, K.J. & Hammer, F.S., 1967, p.149):

> *... nothing more than a cataloguing of traditional rules of thumb, tempered by the non-operational observation that such rules must be continually modified by ill-specified quantities of "management judgement".*

One popular technique used by banks was the Pooled-Funds approach, where loans and investments were made from a common pool of funds without calculating the cost or the velocity of each particular fund category and therefore differences in liquidity requirements and profitability between the various sources of funds were not taken into account.

The technique of Asset Allocation was an improvement that allowed recognition of differences as well as liquidity needs for the various funds categories. This technique allows funds to be allocated to assets according to the nature of the fund in a way matching velocity of the source of funds to the appropriate maturity of the assets to which it is allocated. Thus, for example, money from relatively stable funds (time deposits, for example) can be invested in longer term funds while funds obtained through current accounts which are more volatile are invested in shorter term assets. Although this technique was an important improvement over the Pooled-Funds approach it was criticised along a number of dimensions by Cohen K.J. and Hammer F.S. (1967, p.149):

> *... the belief that available funds should be used to support assets appropriate to the velocity of these funds mistakenly overlook the important diferrence between the volatility*

> *of any particular dollar of deposit and minimum amounts and stability of these deposit balances. In, addition by sole attention of velocity as the main criterion for earmarking funds, Asset Allocation implicitly assumes that sources of funds are determined independently of their uses. Thus, the dynamic feedback links which characterize current loan decisions and future deposit flows are ignored.*

More sophisticated techniques were introduced in the early 1960s, termed "Asset Management" techniques, using as their main tool linear programming models in various forms and degrees of detail. These techniques aim to provide a bank's management with a tool that could offer a common basis for discussing and testing the alternative policy options that are open to them. Such models can isolate the most important variables upon which management attention should be focused and save banks' executives precious time that is consumed in endless discussions about possible future developments in an ad hoc basis.

Cohen and Hammer (1972)· presented a sophisticated model for bank asset management that was used by large US banks as a tool of determining optimal asset allocation and the profitability of various sources of funds. The model was presented in a very general form in order to (Cohen, K.J. & Hammer, F.S., 1972, p.388):

> *...provide the user in a practical situation with a relatively complete kit of alternative approaches to various parts of the problem which can be melded together to fit the actual requirements of a given situation.*

It was an intertemporal (dynamic) linear programming model. There were various types of assets, deposits and capital that came from a breakdown of the portfolio into a joint distribution of class and maturity. The main types of constraints imposed were: (a) Intra-period constraints, including risk constraints, funds availability constraint, liquidity constraints, market restrictions, and (b) Inter-temporal constraints. The possibility of using alternative criterion functions and using time periods of varying length was also examined.

D. Walker (1972) presented a recursive programming model as a tool of bank asset management. In a recursive model an optimal solution for each year is derived by using as known the model's parameters and data for the particular period as well as the optimal allocations in the previous period. The difference between a recursive and a dynamic model is, as D.Walker points out, that:

> *The solution to a dynamic problem must be optimal for the sequence as a whole, but this solution is not necessarily a series of succesive optima as are the recursive optima.*

The general form of his model is:

maximise $w_t = f_t(x_t)$

subject to:

$$h_t(x_t/x^*_{t-1}) \lesseqgtr b_t$$

where:

the objective function $f_t(x_t)$ is a function of m variables; $x_t = [\ x_{1t}, \ldots, x_{mt}]$

$h_t(x_t/x^*_{t-1})$ b_t is a set of n constraints where each variable x_{t-1} has a prespecified value x^*_{t-1} for the problem in period t, which is the optimal allocation for period t-1.

b_t is a column vector of n elements.

This is a profit maximising problem subject to constraints. The behavioral constraints' parameters were estimated by applying single equation least-squares regression while the parameter values of the other constraints were set equal to the values imposed by law or by the regulatory authorities.

J.C. Fortson and R.R. Dince (1977) presented a goal programming model. In contrast to conventional linear programming where it is assumed that the bank's management has to choose one among the various goals facing it as its objective to be maximised and treat the remaining goals as constraints, goal programming is a specialised form of linear programming that distinguishes goals from constraints. So, in a goal programming model (Fortson, J.C & Dince, R.R., 1977, p.313):

> Management must decide upon its goals and a satisfactory level of performance for each goal. Thus, rather than attempting to find an optimum solution, the goal programming algorithm attempts to find a solution that is satisfactory in terms of the goals and does not violate the environmental constraints.

They are using a model where they minimise the objective function, which represents the penalties (costs) associated with deviations from each particular goal, subject to a set of "environmental" constraints.

IV.2.b. Portfolio theory.

The other major way of looking at the problem of managing a bank's portfolio is traditional portfolio theory.

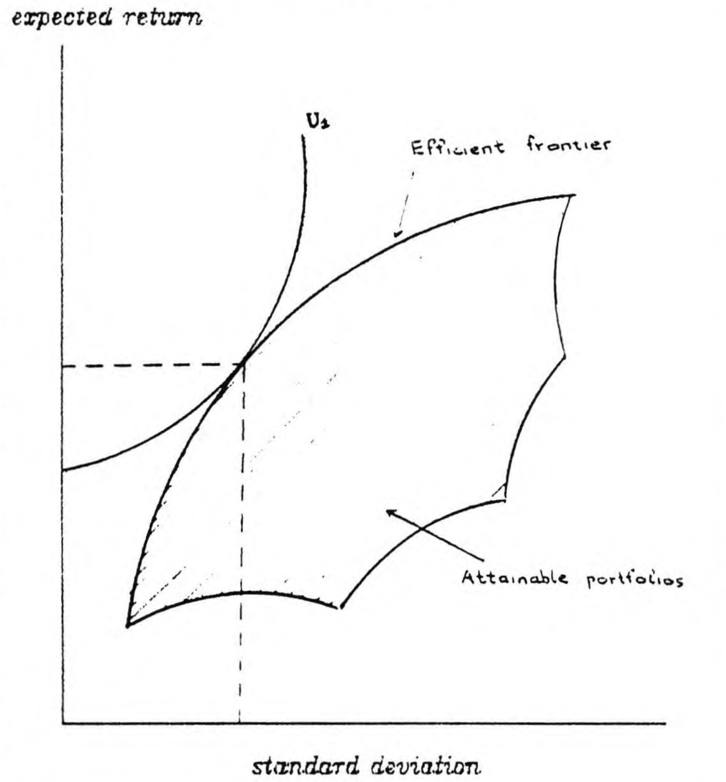
One of the most important ideas in modern portfolio theory is that the expected return of a portfolio is directly related to its riskiness. Risk relates to the volatility of an expected outcome, the dispersion or spread of likely returns around the expected return. The standard deviation is a measure of dispersion or spread. It measures the total risk of an investment. However, total risk is the sum of market risk (which is unavoidable) and specific risk (which can be avoided by diversification). Specific risk is sometimes called diversifiable risk, avoidable risk or non-market risk, and one important idea of modern portfolio theory is that an investor can not expect a reward for taking on risk which can be avoided. A reward can be expected only for unavoidable or market risk. Market risk is the risk associated with changes in the state of the economy as a whole and affects all quoted companies to some extent. We expect that for any given level of risk, the rational investor would select the maximum expected return, and for any given level of expected return he would select the minimum risk.

Whereas in traditional consumer behaviour theory the objective is utility maximisation, in portfolio theory the corresponding objective is maximisation of expected utility (under uncertainty).

One of the founders of modern portfolio theory was H. Markowitz who presented an analytical framework for selecting securities for an investment portfolio (H. Markowitz, 1959). Based on the basic maxim of the Markowitz approach, i.e. that, the rational investor prefers maximum expected return for any given level of risk, and the minimum risk for any given level of expected return, we derive the efficient frontier (fig.3) which identifies those portfolios with the maximum expected return for any level of risk and those with the minimum risk for any level of expected return. Having defined the efficient set of portfolios, the investor can select the portfolio on the efficient frontier that suits his risk-return preference. (which is the point of tangency between the efficient frontier and the investor's highest possible utility curve).

One major problem in the applicability of the Markowitz approach is that the investor must form expectations about the future performance of all securities in his universe.

Figure 3



These expectations include the expected return and variance of return for each security as well as the covariances between all possible pairs of return. Therefore, there is an enormous amount of data required. For example, an analysis of a 100-security universe would require 100 expected returns, 100 variances and 4,950 correlation coefficients between returns of different securities.

A major breakthrough in the practical utilisation of portfolio theory came with Sharpe's (1963) development of the market (or single-index) model. The basic assumption of this model is that the movement in the price of each security can be related to the price of the market portfolio (that is a portfolio comprising a weighted average of all the securities traded on the market). The returns of the various securities in the asset universe are assumed to be related to each other through their common dependence upon this market index. In that way, the data preparation problem is simplified since the need to specify the covariance of returns between every pair of securities is eliminated.

One major empirical application of portfolio theory to the London Clearing Banks is found in J.M.Parkin, M.R.Gray and R.J.Barret (1970). The main objective of this paper, as well as others in this area[17], is to explain portfolio behaviour for monetary policy reasons rather than present a normative framework for bank management.

To conclude this analysis it is useful to point out that in portfolio models the emphasis is on the combination of risk and return for a particular allocation of funds that satisfies liquidity needs while bank asset management models (Walker, D.A., 1972, p.2056):

> *...must provide for control of liquidity, returns and risks in addition to allowing for bank growth, satisfying stockholders' demands and meeting legal requirements on bank operating procedures.*

Portfolio models use as objective function an utility function that embodies a degree of risk aversion of the financial institution, while linear programming models usually have a risk neutral objective function and the introduction of risk is achieved through the imposed constraints.

Two alternative models of bank asset selection will be presented as tools of explaining financial innovations. The first one will be a simple linear programming management model, while the second model will be a quadratic programming model where the objective function will embody risk aversion (as in portfolio models), while the necessary legal or regulatory constraints on banks' choices will also be present.

CHAPTER V

METHODOLOGY AND OBJECTIVES

As we have already seen in Chapter II, an acceleration in the pace of innovation in the late 1960s, the mid 1970s and the early 1980s can be observed. The aim of this study is to present an analytical framework that will make possible to identify the innovative pressures that were experienced by a particular group of financial institutions during these periods. The group of the London clearing banks was chosen for the empirical study since the London clearing banks represent an important proportion of the UK banking sector and they appear to show a degree of homogeneity in their operations.

Two models will be presented: a linear programming model of asset management and a quadratic portfolio management model. By simulating these models with data for the 1965-1985 period we will analyse the structure and optimal allocation of assets as well as the shadow prices of the constraints and identify periods of increased incentives for innovations.

This study follows W.Silber's (1973) constraint-induced innovations theory and presents an empirical test of this theory for the UK, in a way similar to the Ben-Horim & W.Silber (1977) empirical study of innovations in the USA. The majority of studies on the issue of financial innovations are applied to the US financial system while very few attempts have been made to test a financial innovations model for a European economy. The present study is trying to explore the applicability of the management modelling approach adopted in the USA to the UK financial system. In other words we have a control experiment to compare how well the managerial approach fits to the UK system.

Although we make some similar assumptions with Silber's model, a number of modifications in the structure of the selected assets and liabilities as well as in the form of the constraints are introduced to take into account the special characteristics of the UK financial system. Many of the regulatory details found in models applied to the US system have to be substituted by self-imposed rules in the case of the UK where, as we have seen, the style of regulation is less of the law-enforced variety and more of the moral suasion type. Furthermore, the effects of incorporating risk aversion behaviour in the firm's objective function will be explored by formulating a quadratic programming model.

Two simplifications will be made in line with Ben-Horim's & Silber's (1977) model:

(a) We assume "*a one period (year) model where no reallocation of funds is allowed within the period.*"

(b) We assume that "*the level and composition of the liabilities and capital funds are exogenously determined in each period. They are set equal to their actual levels on the balance sheet.*"

As Ben-Horim and Silber point out "*similar assumptions are made by several authors who presented bank asset selection models in recent years.*"

The models impose various linear constraints on the allocation of banks' funds to the various asset categories. These constraints interact and limit the asset proportions in the portfolio in a certain range of values (it is called the "feasible region"). By solving the models we find the asset values that maximise the objective function over the feasible region. To maximise profits, banks can act in two (not mutually exclusive) ways: (a) to maximise the objective function over the feasible region or (b) to increase the proportions of the feasible region by trying to alter existing constraints mainly by creating new products and services.

The main point of interest of this study is the second type of action by banks. In this case banks are trying to circumvent the imposed constraints by innovating new products and practices. The main categories of constraints facing the banks' management are: (α) regulatory, (β) self-imposed policy constraints and (γ) market constraints. Regulatory constraints are the more rigid ones and can become a major factor towards financial innovations (This is the case particularly in the USA where there is a high degree of government regulation as far as banks are concerned). However, market and self-imposed constraints can, during some periods, turn to be limiting factors in banks' choices and thus induce financial innovations.

By solving both models for each consecutive year from 1965 up to 1985 a series of shadow prices of the models' constraints will be derived. The basic assumption that will be tested is that shadow prices should rise before the introduction of an innovation and fall immediately afterwards. Shadow prices are a reflection of the pressures created by constraints. They represent the marginal profit that can be obtained by violating a constraint. The rising (in an historical context) shadow price of a particular source of funds is an indication of an increasing pressure on banks' portfolios with respect to this particular constraint. The banks could increase the value of the objective function by circumventing this constraint (by introducing a new instrument; for example: Certificates of Deposit). The sharper the increase in the shadow prices the higher the incentive for banks to innovate; we can expect that whenever shadow prices pass a certain threshold value an innovation will be generated. After the introduction of the new instrument we would expect the shadow price of the particular constraint to fall since the new instrument should ease the pressure that existed before its introduction. This approach is of the "profit opportunity" type as opposed to the "adversity-induced" type of approach (which can be seen as complementary rather than opposing to the profit opportunity approach).

There are many instruments or practices that can be considered as financial innovations depending on one's reference framework. In this study, the reference framework is limited to the London clearing banks in order to be able to carry out a more detailed empirical investigation of the process of financial innovation. A significant enlargement of our reference area (that would include a larger part of the British financial system) would pose very serious problems in our attempt to test empirically the constraint induced financial innovations hypothesis. The heterogeneity of financial institutions and the inconsistency in data series would make difficult the formulation of linear constraints for the models. However, the empirical testing of the constraint-induced financial innovations theory in the London Clearing Banks group can give us a useful insight in the process of financial innovation and provide the basis for similar tests in other groups of financial institutions.

The major innovations that this study will try to explain by tracing the dual values of the linear constraints of the models, are[13]: sterling certificates of deposit in 1971, foreign currency ($) deposits in 1971, foreign currency ($) Certificates of Deposit in 1972, interest bearing retail deposits in 1981 and 1984, loan capital in 1968, floating rate notes in 1975, perpetual floating rate notes in 1984-85. Prior to their introduction dates the above variables enter in the model with their values set equal to zero. The shadow prices of these variables are the most relevant in identifying the pressures to innovate since they take into account the particular characteristics of that instrument. Finally, another set of innovations that can not be directly related to a particular shadow price but can nevertheless be related to an overall assessment of shadow price pressures are: the introduction of variable rate medium-term loans in the mid 1970s, liability management from 1972, mortgage lending from 1981 and the trend towards securitisation and off-balance sheet activities from 1982.

The linear model (model 1) is of the following general form:

objective function: $\max \Pi = \sum_{i=1}^{m} c_i x_i - \sum_{j=n+1}^{n+k} c_j x_j - \sum_{y=n+k+1}^{n+k+\mu} c_y x_y$

subject to:

(a) minimum assets constraints (liquidity considerations) $\Sigma a_{wi}x_i - \Sigma a_{wj}x_j \geq 0$

(b) maximum assets constraints (risk and capital adequacy) $\Sigma b_{ui}x_i - \Sigma b_{uy}x_y \leq 0$

(c) equality constraints (exogenous levels of funds) $x_j = \varepsilon_j$, $x_y = \varepsilon_y$

where:

x_i: are asset categories, $i=1,2,\ldots,n$

x_j: are deposit funds categories, $j=n+1,n+2,\ldots,n+k$

x_y: are capital funds categories, $y=n+k+1,n+k+2,\ldots,n+k+\mu$

c_i, c_j, c_y: are interest rates on assets, deposits and capital respectively.

$a_{wi}, a_{wj}, b_{ui}, b_{uy}$: are coefficients of each variable for the various constraints (such as capital adequacy ratios, cash and reserve ratios, risk coefficients, etc.); $w=1,2,\ldots,m$ and $u=1,2,\ldots,l$.

$\varepsilon_j, \varepsilon_y$: are the levels of the exogenously determined fund categories.

<u>Duality and shadow prices: interpretation and examples</u>.

Shadow prices are derived by solving the dual program of the original linear program (which is called primal). The relation between primal and dual programs can be seen in the following example (in matrix notation):

Primal	Dual
Maximise $\Pi = r'x$	Minimise $\Pi^* = \varepsilon' y$
subject to:	subject to:
$Ax \leq \varepsilon$	$A'y \geq r'$
and $x \geq 0$	and $y \geq 0$

To understand the economic interpretation of the dual program consider the above simple maximisation problem, where:

r' is a (column) vector of net revenues of unit levels of a set of financial instruments available to a financial firm.

x is a vector of the number of unit levels of each financial instrument in a productive program.

A is a matrix of the combinations of various scarce resources (funds) needed by the unit levels of the financial instruments.

ε is a vector of available amounts of the scarce resources (funds).

In the primal, Π denotes total profits in pounds. Taking into account the fact that the solution of both programs should be equal we deduce that $\Pi*$ in the dual is also expressed in pounds which means that $\varepsilon' y$ is expressed in pounds as well. The objective function in the dual measures the total value of the available resources (funds). This value is equal to the sum of the amount of each resource times the value of a unit of that resource; that is $\varepsilon' y$; where y is a vector of the unit values or shadow prices for the various resources. These values, however, are not market prices but they are rather values to be imputed to the resources since these resources are already in the firm's possesion and they are not bought at the price y in the market.

If we now turn to the constraints in the dual we can see that a_{ij} denotes the amount of the i-th resource used in producing a unit of the j-th product. So Ay shows the total opportunity cost of producing a unit of each of the financial products and ε denotes the per-unit gross profit of each of the financial products.

It is clear that a resource allocation in which the opportunity cost of production for a particular financial product exceeds the profit is nonoptimal since by dropping this product we release resources that can be used to better advantage elsewhere.

Therefore, the correspondance between primal and dual suggests that to maximise profits by finding the optimal output levels (fund allocation) is equivalent to minimising the total imputed value (or opportunity cost) of the available funds, subject to the constraint that the opportunity cost of production of each financial product must be no less than the gross profit from that product.

We have seen that dual choice variables y_i represent shadow prices or imputed values. It can be demonstrated (see A.C.Chiang, 1984 p.699) *that in the optimal solution, they play the same role in linear programming as Lagrange multipliers do in classical optimisation problems, namely, they serve to measure the sensitivity of the optimal value of the primal objective function to changes in the primal constraint constants.*

The shadow price of a constraint takes a non-zero value only if the constraint is effective (i.e. it interacts with the objective function). However, shadow prices have a certain range of validity. It is possible that by relaxing a particular constraint (by a different specification) by a certain amount we move into a new corner solution in which a previously non-active constraint (with zero shadow price) becomes active.

Consider the following example of a simple two-variable linear programming model.

$$\text{Max } F = 5y + 10x$$

subject to:

$$3x + 4y \leqslant 120 \quad (1)$$
$$4x + 2y \leqslant 80 \quad (2)$$
$$y \leqslant 15 \quad (3)$$
$$x \leqslant 10 \quad (4)$$

In figure 4, an illustration of the above example is given. All four constraints are drawn at their limit. Following the arrows a closed region is defined; the shaded area is the feasible region. Only this area meets all the specified constraints. The optimal solution is found by moving the objective function (represented by the dashed line in figure 4) parrallely to the right (maximisation) until it meets the outermost part of the feasible region. The optimal point in figure 4 is point a. We observe that at this point only two constraints are effective (constraints (2) and (3)) while the remaining constraints have zero shadow prices. However, if constraint (2) for example moves to the right up to b, the optimal solution is now represented by point b. At the new optimum constraint (1) is now also effective and its shadow price jumps from zero to some positive value.

This point is important for the present empirical study since some of the self-imposed policy constraints are rather

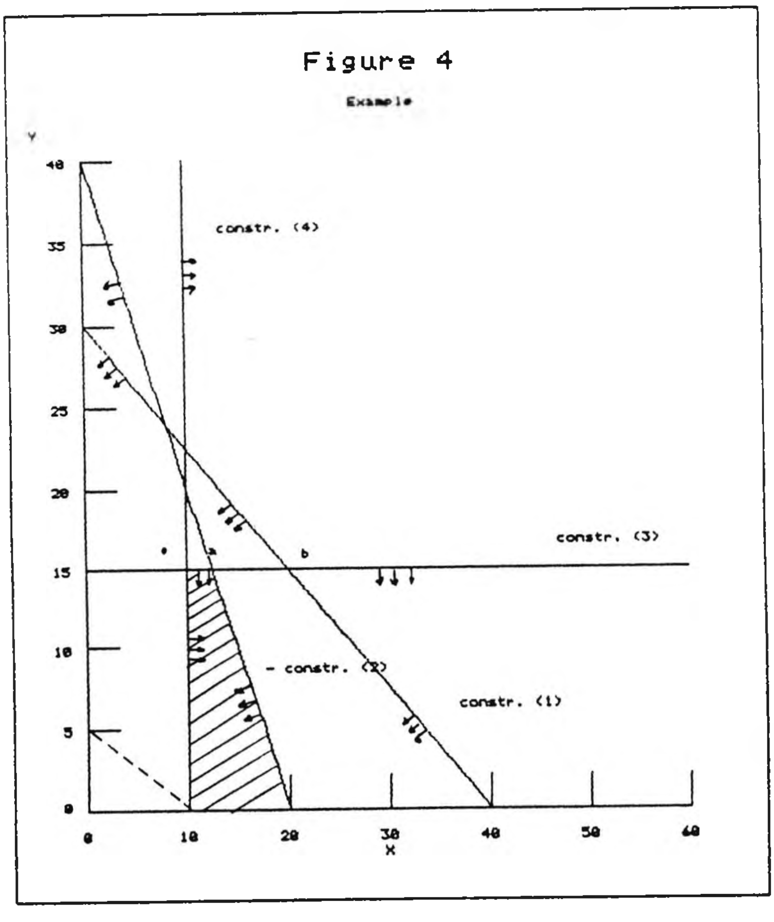


Figure 4

Example

rigid and a sensitivity test is required to check what is the effect on shadow prices if some flexibility is allowed in their specification.

The second model used in this study is a quadratic programming model of the general form:

$$\text{maximise} \quad E(U^*) = r'x - (b/2)x'\Sigma x$$

subject to the constraints:

$$Tx \leq \varepsilon$$
$$x \geq 0$$

where:

r : is a vector of returns of assets and liabilities

x : is a vector of assets including liabilities wich are treated as negative assets.

T : is a matrix representing the coefficients for each asset category as they appear in the constraints.

ε : is a vector of the available funds for each constraint.

Shadow prices in this case are represented by the values of the lagrange multipliers of the constraints and are similar to those produced in the linear programming procedure; they indicate by how much the objective function to be maximised will increase if the value of a constraint is increased by one unit. The shadow prices in the second model depend, in addition to the interaction of the linear constraints with the objective function, also on the degree of risk aversion b of the firm and on the riskiness of various assets as depicted in the variance-covariance matrix Σ.

CHAPTER VI

THE MODELS

VI.1. MODEL 1

As it was mentioned before, this is a simple one period asset allocation model, similar to that used by Ben-Horim and Silber (1977). In chapter IV it was made clear that there are various forms of programming models that were presented by various authors attempting to provide a tool of evaluating and implementing an efficient asset allocation for a bank's management. The linear programming model presented here, however, is used in a different way. In this thesis, linear programming is used to analyse historical data for the 1965-1985 period. The specification of the model is much simpler than the models mentioned above since the aim of the present model is not to offer a tool for a bank's management but rather to identify major trends in the shadow prices of the various categories of funds.

A more detailed description of the model will be given in the following pages. A list of the notation used for the various parameters of the model is given. Assets comprise cash, liquid assets (money at call, treasury bills and other bills), investments (government stocks and other investments), loans, other currency loans (mainly in dollar) and other assets. Liabilities consist of sight deposits, time deposits, sterling certificates of deposit, dollar certificates of deposit, dollar deposits and other liabilities. Capital consists of share capital and reserves, subordinated loan capital and perpetual floating rate notes. Each asset category is given a revenue factor r_i, $i=1,2,\ldots,8$ in the objective function (interest rate) and each liability and capital category is assigned a cost factor $r_i = 10,11,\ldots,18$.

ASSETS

C1	:	cash(notes, coin and balances with the Bank of England.)
MC2	:	money at call.
TB3	:	Treasury bills discounted.
OB4	:	Other bills (Trade & Prime bank bills)
GVS5	:	British government stocks.
OTI6	:	other investments.
LA7	:	loans and advances.
OCL8	:	other currency loans.
OTAS9	:	other assets.

LIABILITIES

SD10	:	sight deposits.
TD11	:	time deposits.
CD12	:	sterling certificates of deposit.
OC13	:	other currency($) deposits.
OCCD14	:	other currency($) certificates of deposit.
OL15	:	other liabilities.

CAPITAL

SRC16	:	share capital and reserves.
LC17	:	loan capital.
PFRN18	:	perpetual floating rate notes.

(A more detailed explanation of the derivation of the time series data for these variables can be found in Appendix 5)

THE MODEL

(a) $Max z = r_2 MC2 + r_3 TB3 + r_4 OB4 + r_5 GVS5 + r_6 OTI6 + r_7 LA7 + r_8 OCL8 - r_{10} SD10$
$- r_{11} TD11 - r_{12} CD12 - r_{13} OC13 - r_{14} OCCD14 - r_{15} OL15 - r_{16} SRC16$
$- r_{17} LC17 - r_{18} PFRN18$

subject to:

(1) $C1 + MC2 + TB3 + OB4 + GVS5 + OTI6 + LA7 + OCL8 + OTAS9 - SD10 - TD11 - CD12 - OC13 -$
$OCCD14 - OL15 - SRC16 - LC17 - PFRN18 = 0$

(2) $C1 - \alpha_1 (SD10 + TD11 + CD12 + OC13 + OCCD14) \geq 0$

(3) $k_1 C1 + MC2 + TB3 + OB4 + k_2 GVS5 - \alpha_2 (SD10 + TD11 + CD12 + OC13 + OCCD14) \geq 0$

(4) $k_3 OB4 - \alpha_3 (SD10 + TD11 + CD12 + OC13 + OCCD14) \leq 0$

(5) $GVS5 - \beta_1 (SD10 + TD11 + CD12) \geq 0$

(6) $GVS5 + OTI6 - \beta_2 (SD10 + TD11 + CD12 + OC13 + OCCD14) \leq 0$

(7) $(1 - k_2) GVS5 + OTI6 + LA7 + OCL8 + OTAS9 - \mu_1 (SRC16 + LC17 + PFRN18) \leq 0$

(8) $LA7 + OCL8 - \mu_2 (SRC16 + LC17 + PFRN18) \leq 0$

(9) $OCL8 - \mu_3 (OC13 + OCCD14 + OL15) \leq 0$

(10) $LA7 + OCL8 \leq \varepsilon_1$

(11) $OTAS9 = \varepsilon_2$

(12) $SD10 = \varepsilon_3$

(13) $TD11 = \varepsilon_4$

(14) $CD12 = \varepsilon_5$

(15) $OC13 = \varepsilon_6$

(16) $OCCD14 = \varepsilon_7$

(17) $OL15 = \varepsilon_8$

(18) $SRC16 = \varepsilon_9$

(19) $LC17 = \varepsilon_{10}$

(20) $PFRN18 = \varepsilon_{11}$

The model's constraints.

(a): is the objective function. Banks are trying to maximise the difference between their revenues (interest earned from their assets) and their costs (interest paid on their liabilities and capital). The marginal rate of substitution between risk and return is not the focus of attention (as in the case of Model 2). The specification of the objective function follows one of the two main directions in the literature of bank modelling (Models by Klein(1971), Porter(1961), Orr and Mellon(1961) are typical of this approach). Equity investors are assumed to be the motivating force behind bank decisions and it is argued that: *a risk-neutral objective function should be selected for the banking firm to assure its investors efficient allocation, without regard to the risk level that may be hedged elsewhere in the investor's portfolio.* (Santomero, 1984).

The operational costs attached to each source of funds are not taken into account because such data are not available for the British banking system. However, this omission does not affect significantly the results because the status of UK banks' internal management accounting systems during the period spanned by this thesis suggests that it is very probable that the banks' management does not calculate the operational cost of each particular source of funds separately but they rather calculate total operational costs. In this case we can assume that these costs are equally distributed among the various sources of funds and thus they do not alter the position of the relative costs among them. Furthermore, a great part of the operational costs is covered by operational income (charges for services) and therefore the operational costs and income do not have a significant influence in our model and our financial innovation hypothesis[14]. In the objective function r_i, $(i=2,3,\ldots,7)$ stand for the revenue (interest rate) obtained by the i-th asset category and r_i, (i=9, 10, ..., 17) stand for the cost (interest rate paid) on the i-th source of funds.

Constraint (1): This is the portfolio constraint; it requires that total assets are equal to the sum of the liabilities and capital accounts. The shadow prices of this constraint can give a general picture of the pressures felt by the balance sheet as a whole during particular periods.

Liquidity constraints.

One area generating constraints on bank choices is regulations for monetary control purposes. These take usually the form of the imposition of minimum ratios of cash and liquid assets to deposits.

The major liquidity ratios that the clearing banks were expected to adhere to in 1960 were:

(a) a cash ratio of 8 per cent of gross deposits; and

(b) a liquid assets ratio of 30 per cent of gross deposits. Liquid assets comprised notes, coin and balances with the Bank of England, money at call or short notice with the discount market, and Treasury as well as commercial bills.

As it is pointed out by various authors (J.Grady & M.Weale (1986), H.Carter &I.Partington (1981)) an examination of these ratios prior to 1960 shows that banks were already using the required ratios as prudential self-imposed constraints and the Bank of England's request was merely a regularisation of the banks' established practice. From 1963 the liquid assets ratio was reduced to 28 per cent since the monetary authorities were adopting expansionary policies.

From the end of 1971, with the operation of Competition and Credit Control there was a change in the required liquidity ratios. Under the new arrangements the liquid assets ratio imposed on the clearing banks and other quantitative controls imposed on all listed banks were replaced by a new reserve assets ratio that applied to all reporting banks. In particular, banks had to maintain a minimum ratio of reserve assets to eligible liabilities of 12½ per cent.

Reserve assets included:

1. Balances at the Bank of England.
2. British Government and N. Ireland Treasury bills.
3. Company tax reserve certificates.
4. Money at call with the London money market which must be secured and callable with:
   - -a- Members of the London Discount Market Association.
   - -b- Discount brokers and the money trading departments of certain banks.
   - -c- Certain firms directly connected with the overnight finance of the gilt-edged market, i.e. money brokers and jobbers on the London Stock Exchange. The money at call with jobbers has to be secured on British Government stocks or stocks guaranteed by the British government.
5. British government stocks and nationalised industry stocks guaranteed by the British government, with one year or less to maturity.
6. Local authority bills eligible for rediscount at the Bank of England.
7. Commercial bills eligible for rediscount at the Bank of England, up to a maximum of 2 per cent of total eligible liabilities.

Eligible liabilities included:

1. All sterling deposits, of an original maturity of two years and under, from UK residents other than banks and from overseas residents other than overseas offices. All funds due to customers or third parties which are temporarily held in suspense accounts.
2. All sterling deposits -of whatever term- from banks in the UK, less any sterling claims on such banks.
3. All sterling CDs issued -of whatever term- less any holdings of such certificates.
4. The bank's net deposit liability in sterling to its overseas office.

5. The bank's net liability in currencies other than sterling.
6. Less 60 per cent of the net value of transit items in the bank's balance sheet.

Furthermore, banks had to maintain an 1½ per cent of eligible liabilities cash ratio. However, notes and coin were not included in the list of eligible reserves.

The rapid increase in bank lending combined with the adoption of liability management by banks led to an acceleration in the growth of the money stock. As a result the supplementary special deposits scheme (or the 'corset' as it became known) was introduced in December 1973. It operated on various occasions until 1980 when it was finally abolished. It resembled a progressive tax imposed on bank liability growth since it obliged banks to make non-interest-bearing deposits with the Bank of England if their interest-bearing deposits grew above a specified rate. From August 1981, a new monetary control regime was implemented. As a result, the 12½ per cent minimum reserve assets ratio and the 1½ per cent cash ratio were abolished and were replaced by an obligation on all institutions in the monetary sector to maintain at least ½ per cent of their deposits in non-interest-bearing balances at the Bank of England. These balances were put in special non-operational accounts and the banks had to hold an additional amount of balances in ordinary accounts at the Bank for clearing purposes.

Constraint (2): This constraint specifies a minimum level of cash which relates to the size of total deposits (Total sterling + foreign currency deposits including Certificates of Deposit). α_1 sets the minimum percentage allowed by the authorities. Until 1971 the Clearing banks were obliged to maintain an 8% cash ratio. From 1972 this ratio became 1½%. After 1982 when new arrangements were introduced and no specific cash ratio was required, the values for α_1 are set equal to their actual (calculated) values since the observed value should represent the banks' management decision in the light of the introduction of the new arrangements with respect to the desired holdings of cash.

Constraint (3): This constraint imposes a minimum level of liquid assets (or reserve assets) which relates to the size of total deposits. Until 1971 the London Clearing Banks had agreed to observe in addition to the 8% cash ratio a liquid assets ratio. This ratio was informally established in 1951 and was set between 28% and 32% of total deposits. From 1963 the ratio imposed was 28%. The full effects of the introduction of "Competition & Credit Control" start from 1972, since it was introduced formally in October of 1971. The value of α_2 will be set equal to 0.028 until 1972. k_2 is set equal to 0 up to 1972 since government securities are not considered as part of liquid assets. After 1972 (introduction of "Competition and Credit Control") k_2 represents the (calculated) percentage of government stocks of one year or less to maturity to total government securities[15]. From 1981 k_2 is again set equal to 0 due to the introduction of new arrangements. k_1 is set equal to 0 for the period 1972-1980 when "Competition and Credit Control" arrangements were in force, because cash reserves were not part of the reserve assets ratio; in all the other years it is set equal to 1. For the period 1972-1980, a_2 is set equal to 0.125. The value of a_2 for the period 1981-1985 is set equal to the actual (calculated) value of the ratio $(C1+MC2+TB3+OB4+k_2GVS5)/(SD10+TD11+CD12+OC13+OCCD14)$, by putting the value of this ratio equal to its actual value each year (after 1981) we allow for the fact that this constraint represents also a self-imposed aspect of prudential behaviour adopted from the banks.

Constraint (4): This constraint appears only for the period 1972-1980 during which the "Competition and Credit Control" arrangements were in force. Prior to 1972 and from 1981 we set $k_3=0$, $\alpha_3=0$. From 1972, commercial bills (OB4) were not allowed to be over 2% of total eligible liabilities, (in our model they are represented as: SD10+TD11+CD12+OC13+OCCD14). So α_5 is set equal to 0.02 from 1972-1980.

Self-imposed policy constraints.

Bank's management is usually observing some ratios as part of its own portfolio strategy. Even in the absence of strict regulations regarding liquidity requirements or capital adequacy ratios the banks usually observe such ratios as a matter of prudence and in recognition of the fact that if the public is sensitive to changes in the values of such ratios, then there is a danger of adverse reaction from depositors or shareholders in the event of a significant deterioration in the values of any of these ratios. This point is made clear by K.Cohen & F.Hammer (1967, p.153):

> *There are many time-honored and well-established heuristics used to gauge bank safety and liquidity, e.g. the ratios of governments* (i.e government securities) *to assets, capital to risk assets, loans to deposits, etc. Sophisticated observers have long realized that each of these heuristics involves only a limited, narrow view of the overall portfolio balance problem... Nonetheless, so long as such heuristics remain in vogue, bank management must be sensitive to possible adverse reaction by stockholders, depositors, and others to balance sheet positions which imply ratios which greatly deviate from "accepted" ranges.*

However, when such constraints are imposed in a linear programming context, the exact value that a bank's management attaches to each particular constraint must be known. Such a constraint is not rigid since if it becomes binding the bank's management may be able to redefine it in a way that would reduce the pressure. Furthermore, if we want to establish ex-post the value for the self-imposed constraints by a bank's management (as it is the case in the simulation models used in this study) we are faced with a difficult task. In the linear model, they are set equal to their observed actual values for each year;

It should be stressed that the model is not used as a tool for the determination of optimal asset allocation by the banks' management. In effect, in the case of self-imposed or capital adequacy constraints whose exact values are not known we adapt (ex post) the model's parameters to observed behaviour by banks in order to determine the existing profit opportunities as depicted by the series of shadow prices of particular sources of funds. Therefore, even if the use of actual (observed) values for certain parameters in the model make it useless as a management tool (since these values may be the result of management decisions made under another set of unobserved real constraints) we can still get an indication of existing profit opportunities assuming that the model provides a picture of the perceived (by management) optimal asset allocation for each consecutive year in the 1965-85 period.

The ratio of government securities to sterling deposits and the imposition of an upper limit on investments are the two self-imposed constraints that are used in the linear programming model. These ratios have been used by various authors who presented bank management models (K.Cohen & F.Hammer,(1972), K.Cohen & S,Thore, (1970), M.Ben-Horim & W.Silber (1977), D.Walker, (1972)) and reflect management's desire to conform to externally imposed conventional standards.

In particular, the government securities to deposits ratio is important, since it shows a bank's ability to shift assets from relatively low risk assets (government stock) to relatively higher risk assets (advances) to satisfy increased demand. As is pointed out by C.Goodhart (1984):

At the end of Second World War, banks in certain major countries, notably the USA and the UK, emerged with swollen holdings of public-sector debt, proportionately much larger than they had normally held in their balance-sheets, and equivalently much lower holdings of loans to the private sector; this was a result of the pattern of financing during the war... These 'excess' holdings of public sector debt provided the banks with a cushion with which to absorb the growing demands of private-sector borrowers... enabling the banks to adjust to the changing demands of borrowers, while at the same time continuing to respond passively to inflows of deposits obtained at interest rates constrained...by oligopolistic arrangements (as in the cartel in the UK until 1971...).

Constraint (5): This constraint imposes a minimum level of the UK government portfolio (bonds) which relates to the size of sterling deposits. It has been suggested by various authors that banks keep a certain amount of their assets in the form of government bonds mainly for liquidity requirement reasons and as a guarantee for part of government liabilities in their portfolios. The problem is how to define the ratio of government securities to sterling liabilities, β_1, in our model, because we have to find the precise self-imposed value of β_1 that the management of London clearing banks has applied in various years.

One way of dealing with this problem would be to impose an historical standard and keep it invariant throughout the entire period. The problem with this approach is that we will have to identify a "normal" period where government securities were at their desired levels in the average banks' portfolios. Another problem is that this assumption is very rigid and does not allow any changes in the banks' management attitudes towards the "government securities to sterling deposits ratio". As we have seen in chapter II (table 1), the ratio of public to private assets was abnormally high by the end of the second World War and begun to decline thereafter.

The other way of dealing with this problem is by taking into account any changes in the banks' management decisions with respect to the above ratio. So, in our model we set β_1 equal to its current period's calculated value. In that way the problem of rigidity of the constraint is minimised. In Table 6 the values of b_1 that are used in the simulations of the linear model for the 1965-85 period are shown.

TABLE 6

Values for the parameter b_1
(used in Model 1)

Year	b_1
1965	0.117
1966	0.117
1967	0.135
1968	0.128
1969	0.107
1970	0.094
1971	0.117
1972	0.111
1973	0.070
1974	0.060
1975	0.068
1976	0.070
1977	0.067
1978	0.068
1979	0.051
1980	0.029
1981	0.051
1982	0.042
1983	0.040
1984	0.034
1985	0.030

Constraint (6): This constraint imposes a maximum total investment portfolio (GVS5+OTI6). The rationale for imposing a maximum constraint is that the investment portfolio is regarded as a residual item on the banks' balance sheet while the banks' primary objective is to make loans. Even in periods when the rates on investments exceed the rates on loans the banks do not allocate all available funds to this category of assets. It is observed that the amounts allocated to this category fluctuate within a lower and an upper bound. In Model 1 the values of β_2 are estimated by calculating the ratio of total investments (GVS5+OTI6) to total deposits (SD10+TD11+CD12+OC13+OCCD14) for the 1965-1985 period and set β_2 equal to the maximum estimated value for the whole period which is 0.35.

Capital adequacy constraints.

The concept of capital adequacy is important in analysing bank operations. Capital adequacy is generally assessed by using various ratios (gearing ratio, risk assets to capital ratio etc.).

C.L Lackman (1986) has examined the impact of capital constraints on the portfolio of banks in a simple two-asset, one liability model of bank behaviour in order to explore the economic rationale behind the imposition of such constraints. His main conclusions are that: (a) the imposition of a capital/deposits ratio leads to a shift in a banks' portfolio away from relatively "safe" assets towards "risky" assets and at the same time reduces the variance of return on equity as well as the expected return; (b) the imposition of a capital/risky assets or an adjusted risky assets ratio causes a shift in a bank's portfolio towards "safer" assets. At the same time expected return as well as variance of return on equity are also reduced.

A study by Santomero & Daesik (1988) comes to similar conclusions by using a single period mean-variance model. It is demonstrated that the popular uniform capital/assets ratio is not an effective way of reducing insolvency risk because *it ignores the individual banks' different preference structures and allows "risky" banks to circumvent the restrictions via financial leverage and/or business risk.* The use of a risk adjusted ratio is preferable. Such a ratio is effective provided that the weights are chosen optimally. These optimal weights are derived and it is shown that they depend only on three factors: (i) expected returns, (ii) their variance-covariance structure and (iii) the upper bound on the allowable (by the regulators) insolvency risk.

From the above results it is clear that the imposition of a risk adjusted capital/assets ratio has an effect towards the desired, by the regulatory authorities, direction while the gearing ratio has adverse effects on the riskiness of a bank's portfolio.

These ratios were very popular over the years since it was generally believed that they provided the only sure test of soundness. This belief was seriously weakened during the recent years. The issue that has been concerning the minds of bank regulators as well as bank managers is what evidence do we have to prove that bank failures are related to low capital base.

A number of empirical studies dealing with this issue seem to support the view that the use of simple capital ratios is not at all satisfactory in recognising a possible bank failure. Capital ratios give a static picture of a bank's balance-sheet while optimal capital policies should be future-oriented dealing with expectations of future loan demand, deposits and costs.

According to Vojta (1973):

> *The weight of scholarly research is overwhelmingly to the effect that the level of bank capital has not been a*

> *material factor in preventing bank insolvency, and that ratio 'tests' for capital adequacy have not been useful in assessing or predicting the capability of a bank to remain solvent. Further, the documented insolvency experience of the banking system suggests that the most important causal factors relating to solvency are competence and integrity of management.*

A study conducted by Koehn and Santomero (1980) supports the above view. This study investigated the effect of regulation by capital ratios on the portfolio behaviour of commercial banks. The results suggest that the use of capital ratios as a tool for controlling bank risks is not an adequate method since it is demonstrated that a binding constraint on bank leverage forces the firm to absorb greater risk in its portfolio than before regulation.

Recognising the above weaknesses E.P.M. Gardener (1981) suggested a complementary forward looking approach that uses a computer simulation model to test a bank's strength in dealing with uncertainty. This method was termed contigency testing and its main advantage is that it can *expose the financial consequences of a bank's planned risk exposure in a dynamic setting*.

Concluding the above analysis, it seems that a necessary condition for regulation to be effective is an adequate understanding of the behavioural response of banks to the regulatory authorities' measures. Furtheremore, there is almost unanimous agreement that the quality of management is the most important safeguard against insolvency and bank failure. Honesty and competence in management are reflected in the soundness of internal control systems, the prevention of fraud and the ability to manage liquidity. However, as long as the various capital adequacy ratios are used by the regulatory authorities as well as investors one has to take them into account when formulating a model of bank management behaviour.

Constraint (7): This constraint sets a maximum ratio of "risk assets" to capital, in line with the regulatory requirements prevailing during particular periods as discussed in chapter III. Before 1972 and from 1981 $(1-k_z)=1$ since $k_z=0$; government securities were not part of liquid assets during these periods and they therefore become part of the risk assets category. After 1972 k_z is estimated (the percentage of government securities of one year or less to maturity to total government stock); $(1-k_z)$ gives the percentage of government securities that are part of risk assets.

The value of μ_1 is not known with precision since the supervisory authorities in the UK have adopted a flexible approach, as we have already seen. However, it will be estimated in various ways that will offer a range of values that allow us to make a sensitivity analysis. (a) The first major way of estimating μ_1 is by assuming that each year's ratio is constrained by its previous year's (average) level for the whole group. In this case we calculate the actual ratios observed for the group as a whole and set each year's value equal to the previous year's calculated value. This method of estimation may be more appropriate since the "average" Clearing Bank might behave in a more conservative way than each individual bank in the group; calculating μ_1 in this way would be more faithful to the attitude of the "average" Clearing Bank that is represented in this model; (b) The other major way of dealing with the problem is to estimate the actual ratios for the four largest Clearing Banks (Barclays, Lloyds, Midland, National Westminster) for the period 1965-1985 and then set μ_1 equal to the actual maximum across the four banks for the previous year. It is reasonable to assume that a bank's management is keeping a close eye to its direct competitors' attitudes and will not chose a "risk assets to capital" or "loans to capital ratio" that will be a great deal out of line with its main competitors' policies. There is a widespread belief that banks' important clients always check these ratios when deciding which bank to do business with. Commenting on the results of a survey on the way treasurers of large firms in the USA choose the banks they want to do business with, Staats W. (1971, pp. 267-68) says that:

> *... the financial condition of a bank is of first importance to most treasurers than is any other selection factor ... To keep tab on banks' financial conditions, about 40 percent of the treasurers used ratio analysis techniques. Favorite financial ratios were loans to deposits, capital to loans, loans to assets and capital to total deposits.*

A similar view is expressed for the case of the UK by the Committee of London Clearing Banks in its evidence to the Wilson Committee (regarding one particular ratio, namely the ratio between total capital resources to total deposits), in particular:

> *The banks are aware that such a ratio is in practice monitored by many of their depositors (especially overseas banks) and it is important for that reason.*

(Evidence by the Committee of London Clearing Bankers to the Committee to Review the Functioning of Financial Institutions (CLCB, 1978, pp. 63)).

Finally as part of a sensitivity analysis we will test the effects of a change in the values of μ_1 to the model's results, by setting the value of μ_1 for each particular year equal to the average estimated value for the whole period and finally we will set it equal to the calculated averages for three separate periods (1965-1971, 1972-1980, 1981-1985); the particular periods were chosen because they represent major landmarks in the regulatory framework of financial institutions in the UK.

Constraint (8): This constraint imposes a maximum "loans to capital ratio" for the group. This constraint complements the risk assets ratio in evaluating the banks' capital adequacy. The same arguments apply here as in constraint (7). In table 7 the actual average capital ratios for the London clearing banks for the 1965-85 period are shown.

TABLE 7

Actual average capital ratios*
(London clearing banks)

Year	Risk assets/capital	Loans/capital
*1965	13.19	9.05
*1966	13.07	8.95
*1967	13.60	9.02
*1968	12.42	7.90
1969	6.93	5.14
1970	6.68	4.73
1971	7.55	5.16
1972	9.55	7.41
1973	8.21	6.66
1974	8.87	7.15
1975	8.48	6.48
1976	7.77	6.52
1977	8.06	6.25
1978	7.78	6.03
1979	7.98	6.28
1980	9.24	7.19
1981	10.37	7.86
1982	9.64	7.24
1983	9.54	7.00
1984	10.10	7.15

Notes:

*: calculated from data taken from the Annual Reports and accounts of: Barclays, Lloyds, Midland and National Westminster banks.

*: data for these years are calculated from Annual Reports and accounts of: Barclays, Lloyds and Midland banks only.

Constraint (9): This constraint represents a prudential constraint on foreign currency risk exposure. It imposes a maximum level of foreign currency loans which relates to foreign currency and other liabilities (OC13+OCCD14+OL15). The values of μ_5 are set equal to the actual calculated values for each year. Prior to 1971 μ_5 is set equal to the calculated average for the 1971-1985 period. By setting the values of μ_5 equal to their actual levels each year we take into account any changes in the management's attitudes towards foreign exchange risk exposure and reduce the problems created by the rigidity of the constraint.

Market constraints.

The basic market constraint imposed in this study is the demand for loans constraint. Banks cannot make more loans than they are demanded at prevailing market terms. Sometimes demand for loans may be weak in which case banks will hold an excess amount of liquid assets and as a result face relatively low profitability. Another possibility is that the interaction of other constraints limits the amount of funds available by banks for loans to be lower than the actual demand.

Constraint (10): This constraint is a market restriction to loans. They cannot exceed market demand. We assume that market demand is equal to the loans actually made in each year. In all periods we can expect that the level of loans actually made (L^m) is equal or less than the level of loans demanded (L^d). In our model, however, the value of ε_1 is set equal to L^m. Cohen and Hammer (1972, p.404) note:

> *"Under normal economic conditions, there is a limit on a bank's ability to make, at prevailing market terms, loans of a particular type and quality. Thus* (a constraint like (10)) *constrains the rate at which the bank can make new loans of various types to be*

> *no greater than the forecasted demand for them. In a tight monetary environment[18], of course, it may appear that the bank can make all the new loans for which resources can be mustered, i.e., that loan demand for the banks is far higher than funds available. In these circumstances, these demand constraints become redundant and the rate at which the bank makes new loans is determined through interaction with other parts of the model."*

Constraints (11)-(20): These constraints set other assets, liabilities and capital equal to their actual values each year (ε_1-ε_{11}); since we assumed that the level and composition of liabilities and capital funds are exogenously determined in each period. By setting the value of other assets equal to their actual level in each period, the model's use as a tool of determining optimal asset allocation is very limited; however, this assumption does not severely affect the shadow prices of liabilities and capital which are the main concern of this study).

In a linear programming model of bank asset management, the imposition of a given constraint is rather inflexible and thus can be criticised in cases where the constraint does not have to be strictly met. However, we should bear in mind, that bankers cannot ignore regulation standards altogether, and as a deviation between the actual and the required (or recommended) ratio increases, the bank can expect to face greater pressure from both the regulatory authorities and from depositors. Finally, in the linear programming model the bank's management is assumed to maximise profits subject to constraints on risk, liquidity and various other factors. Since the liabilities and capital as well as the costs and revenues of each asset and liability category are assumed to be exogenously determined, the management will try to allocate as much funds as possible (given the risk, liquidity and other constraints) to the highest yielding asset which is usually loans.

Example of an application of the Model

Let us now consider an example of the optimal asset allocation and the derivation of shadow prices by using Model 1A and data for 1967.

Liabilities and Capital

	amount(£ millions)	Cost
SD10	5,084	0.000
TD11	3,769	0.042
CD12	-	0.062
OC13	-	0.064
OCCD14	-	0.059
OL15	1,246	0.075
SRC16	569	0.044
LC17	-	0.076
PFRN18	-	0.067
TOTAL:	10.668	

Assets

OTAS: 1,612 (£ millions)

	Return (%)
C1	0.000
MC2	0.051
TB3	0.074
OB4	0.068
GVS5	0.067
OTI6	0.068
LA7	0.092
OCL8	0.077

Model's 1A constraints for 1967 are:

(2) C1 ⩾ 0.08(SD10+TD11)	⇒ C1	⩾	708.24
(3) C1+MC2+TB3+OB4 ⩾ 0.28(SD10+TD11)	⇒ MC2+TB3	⩾	1,770.6
(5) GVS5 ⩾ 0.135(SD10+TD11)	⇒ GVS5	⩾	1,195.155
(6) GVS5+OTI6 ⩽ 0.35(SD10+TD11)	⇒ OTI6	⩽	1,903.395
(9) OCL8 ⩽ 0.614(OL15)	⇒ OCL8	⩽	765.044
(10)LA7 ⩽ 4,725	⇒ LA7	⩽	4,725
(7) GVS5+OTI6+LA7+OTAS9 ⩽ 13.07(SRC16)	⇒ OTI6+LA7	⩽	4,629
(8) LA7 ⩽ 8.95(SRC16)	⇒ LA7	⩽	5,092

The optimal asset allocation for 1967 will now be derived.

Total funds that are available for distribution amount to: 10,668 (£ millions). After satisfying constraint (11) that sets other assets equal to 1,612, remain 9,056 to be distributed. The minimum constraints must be satisfied first. So, we allocate 708.24 to C1, 1,770.6 to TB3 (they offer a higher revenue than MC2, or OB4) and 1,195.155 to GVS5. After satisfying the minimum (liquidity) constraints remain 5,382.005 to be allocated. The banks will try to allocate as much as possible (i.e. as much as it is allowed by the other constraints of the model) to the highest yielding asset (which is LA7 in 1967). Loans are constrained by the market constraint (10) not to exceed 4,725; the loans to capital ratio constraint (8) does not allow loans to exceed 5,092 and finally the risk assets to capital constraint (7) sets a maximum of 4,629 for loans. We can see that the limiting constraint for loans is, in 1967, the risk assets to capital constraint (7). After allocating the highest possible amount to the highest yielding asset we proceed by allocating as much, of the remaining 753, as we are allowed by the constraints to the second highest yielding asset (OCL8, for 1967). As we can see it is not possible to allocate the remaining sum to OCL8 since we allocated the maximum amount permitted by constraint (7) to LA7. So, we examine if it is possible to allocate the remaining amount to the next highest yielding asset (i.e. TB3). As we can see it is posssible to allocate the remaining amount (753 £ million) to TB3.

So, the optimal asset allocation is:

	Optimum	Upper limit	Lower limit
C1	708.24	-	708.24
MC2	0.00		
TB3	2,524.00	-	1,771.000
OB4	0.000		
GVS5	1,195.155	3,098.550	1,195.155
OTI6	0.000	1,903.395	-
LA7	4,629.000	4,629.000	-
OCL8	0.000	765.044	
OTAS9	1,612.000		

Let us now examine how the shadow values are derived for a particular type of deposit (assume SD10) and a particular type of capital (we choose SRC16). We start by deriving the shadow price for SD10. If one additional pound of SD10 is raised it will be allocated as follows: 0.08£ will be allocated to C1, 0.135£ will be allocated to GVS5, 0.28 will be allocated to TB3 and the remaining 0.505£ will be allocated to TB3 (so, a total of 0.785£ will be allocated to TB3). The shadow price for SD10 will be calculated as following: the cost of the additional one pound is 0.00£. The return is 0.067£ on the 0.135£ of GVS5 and 0.074£ on the 0.785£ of TB3. So, shadow price of SD10 = (0.067x0.135) + (0.074x0.785) -0 = 0.067135.

Calculation of the shadow price of SRC16. An additional pound of capital can be allocated to the highest yielding asset which is loans in 1967. Furthermore since the capital adequacy constraint (7) is effectively restricting loans, an increase of capital by £1 permits the reallocation of 13.07 (-1) pounds from treasury bills to loans. The cost of the additional pound of SRC15 is 0.044£ and the revenue from it is: 0.092 for the pound allocated to loans plus the profit derived from the reallocation of funds which is equal to: 12.07 x (interest rate differential between LA7 and TB3) = 12.07 x 0.018 = 0.217. Therefore the shadow price of SRC16 is 0.092 + 0.217 - 0.044 = 0.265.

The above example illustrates the process of derivation of shadow prices and the trade-offs involved. In general, shadow prices of deposits will tend to be higher if the additional funds can be allocated to the highest yielding asset. Shadow prices of capital funds tend to be higher when constraints (7) and (8) are effectively constraining loans.

VI.2. Model 2

In model 1, a risk neutral objective function is used allowing for risk considerations to enter through the model's constraints. Model 2 attempts to enrich the asset management model by introducing elements of traditional portfolio theory. In particular, a new objective function that embodies risk aversion will be maximised and the constraints will be limited to only environmental ones (regulatory, legal or market imposed constraints), excluding the previously self-imposed policy constraints. The new model will, thus, be a quadratic programming model. The various asset and liability categories that were used in the previous model will be reduced, for computational reasons, from 18 to 13 and the notation will be adjusted for purposes of easier presentation; in particular, the various assets and liabilities will be noted as x_i (i=1,...,13) and the corresponding interest rates will be noted as r_i. Constraints (4), (5), (6) and (9) used in Model 1 will be eliminated.

The major asset categories in Model 2 are: cash, money at call, bills (including treasury bills and other bills), investments (comprising government securities and other investments), loans, foreign currency loans and other assets. Liabilities consist of sight deposits, time deposits, sterling certificates of deposit and foreign currency liabilities. Finally capital is aggregated in one variable representing total capital resources (share capital and reserves plus subordinated loan capital and perpetual floating rate notes).

In particular, the notation used in Model 2 is:

ASSETS

x_1 :Cash (coins, notes and balances with Bank of England). Equivalent to C1 of Model 1.

x_2 :Money at call. Equivalent to MC2 of Model 1.

x_3 :Bills. Equivalent to TB3+OB4 of Model 1.

x_4 : Investments. Equivalent to GVS5+OTI6 of Model 1.

x_5 : Loans and advances. Equivalent to LA7 of Model 1.

x_6 : Foreign currency loans. Equivalent to OCL8 of Model 1.

x_7 : Other Assets. Equivalent of OTAS9 of Model 1.

LIABILITIES

x_8 : Sight deposits. Equivalent to SD10 of Model 1.

x_9 : Time and deposit accounts. Equivalent to TD11 of Model 1.

x_{10} : Certificates of deposit(£). Equivalent to CD12 of Model 1.

x_{11} : Foreign currency deposits. Equivalent to OC13+OCCD14 of Model 1

x_{12} : Other liabilities. Equivalent to OL15 of Model 1.

CAPITAL

x_{13} : Total capital. Equivalent to SRC16+LC17+PFRN18 of Model 1.

The corresponding interest rates are shown below in relation to the rates used in Model 1:

INTEREST RATES

Model 2		Model 1
r_2	=	r_2
r_3	=	$(r_3+r_4)/2$
r_4	=	$(r_5+r_6)/2$
r_5	=	r_7
r_6	=	r_8
r_8	=	r_{10}
r_9	=	r_{11}
r_{10}	=	r_{12}
r_{11}	=	$(r_{13}+r_{14})/2$
r_{12}	=	r_{15}
r_{13}	=	$[r_{16}+(r_{17}+r_{18})/2]/2$

Using the new notation, the linear programming model that was used before can be presented in the following way:

$$\text{Maximise} \quad \Pi = r'x$$

subject to:

$$Tx \leqslant \varepsilon$$

$$\text{and } x \geqslant 0$$

where:

r : is a vector of returns r_i $(i=1,\ldots,13)$ of assets and liabilities

x : is a vector of n=13 types of assets x_i $(i=1,\ldots,7)$ including liabilities x_i $(i=8,\ldots,13)$ which are treated as negative assets.

T : is a matrix representing the coefficients for each asset category as they appear in the constraints.

ε : is a vector of the available funds for each constraint.

In the new quadratic programming model risk aversion behaviour will be introduced in the banks' utility function. In particular, we will assume that the banks possess a utility function of the form:

$$U(\Pi) = a - ce^{-b\Pi}$$

where: a, b, c are parameters $(a \neq 0;\ b, c > 0)$. In particular, b, indicates the banks' degree of risk aversion; large values of b indicate conservative behaviour.

This utility function has been used by several authors that presented portfolio behaviour models in previous years[17]. Marginal utility of profits is always positive $[U'(\Pi)>0]$, but decreases as profits increase $[U''(\Pi)<0]$, and in addition it has the property of possessing an upper bound.

We will assume that profits (Π) under conditions of uncertainty about asset yields and costs of liabilities are represented by a random variate which follows some probability distribution. In particular, we will assume that they are normally distributed:

$$\Pi \sim N(\mu_\pi, \sigma_\pi^2)$$

The banks are maximising expected utility which, given the normality assumption, is :

$$E(U) = a - c\exp[-(b/2)\mu+(b/2)^2\sigma^2]$$

We can see that maximising E(U) is achieved if we maximise the function: $E(U^*) = \mu_\pi - (b/2)\sigma_\pi^2$

Actual profit Π is defined as:

$$\Pi = r'x$$

where, as we have seen:

r' is a 1x13 vector of yields and costs, and

x is a 13x1 vector of assets (with liabilities treated as negative assets).

Actual yields r are defined as:

$$r = \hat{r} + u_r$$

where:

$\hat{r}$ is a 13x1 vector of expected yields, and

u_r is a 13x1 vector of forecasting errors.

Using these definitions we can write:

$$\Pi = (\hat{r} + u_r)'x$$
$$= \hat{r}'x + u_r'x$$

Since: $\mu_\pi \equiv E(\Pi)$

then $\mu_\pi = \hat{r} + E(u_r')x$

We assume

$$E(u_r) = 0.$$

therefore

$$\mu_\pi = \hat{r}'x$$

The variance of profit is

$$\sigma^2_\pi \equiv E[(\Pi - E(\Pi))^2]$$
$$= E[(u_r'x)^2]$$
$$= x'E(u_ru_r')x$$

We define the covariance matrix $\Sigma \equiv E(u_ru_r')$

Therefore

$$\sigma^2_\pi = x'\Sigma x$$

Taking into account the above relationships the maximisation of expected utility is achieved by maximising:

$$E(U^*) = r^{e\prime}x - (b/2)x'\Sigma x$$

where Σ is the covariance matrix of interest rates.

subject to the constraints:

$$Tx \leq \varepsilon$$

$$x \geq 0$$

Expected interest rates $r^{e\prime}$ as used in the simulations of Model 2 are expressed in terms of actual interest rates. In particular, we assume:

$$r^e = r + e$$

e is a random variable wich is assumed to follow a random walk and tends to zero. Therefore expected interest rates are substituted by actual interest rates (12monthly averages) for each year.

The constraints of Model 2 are in more detail the following:

(1) $x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 - x_8 - x_9 - x_{10} - x_{11} - x_{12} - x_{13} = 0$

(2) $x_1 - a_1(x_8 + x_9 + x_{10} + x_{11}) \geq 0$

(3) $k_1x_1 + x_2 + x_3 + k_2x_4 - a_2(x_8 + x_9 + x_{10} + x_{11}) \geq 0$

(4) $x_4 + x_5 + x_6 - \mu_1 x_{13} \leq 0$

(5) $x_5 + x_6 - \mu_2 x_{13} \leq 0$

(6) $x_5 + x_6 \leq \varepsilon_1$

(7) $x_7 = \varepsilon_2$

(8) $x_8 = \varepsilon_3$

(9) $x_9 = \varepsilon_4$

(10) $x_{10} = \varepsilon_5$

(11) $x_{11} = \varepsilon_6$

(12) $x_{12} = \varepsilon_7$

(13) $x_{13} = \varepsilon_8$

Description of Model's 2 constraints.

A brief description of Model's 2 constraints which are similar to the constraints of Model 1 will be given.

(1) is the portfolio constraint setting assets equal to the sum of liabilities and capital.

Liquidity constraints.
(2) is the required cash reserves constraint.
(3) is the liquidity constraint.

Capital adequacy constraints.
(4) is the risk assets to capital constraint.
(5) is the loans to capital constraint.

Market constraints.
(6) is the demand restriction to loans.
Finally, constraints (7)-(13) set other assets, liabilities and capital equal to their actual values each year.

The detailed values of the various parameters used in the simulations of Model 2 are given in APPENDIX 3. The model will be solved for each consecutive year and a series of shadow prices of the constraints will be derived. The variance covariance matrix Σ will be calculated for each year from 10year moving averages of the annual rates of the previous years ; in this way we take into account the management's changes in perceived riskiness of the various fund categories. The hypothesis we wish to test remains the same; i.e. that shadow prices rise before the introduction of an innovation and fall immediately afterwards. Since the exact value of the risk aversion parameter b used in the objective function cannot be directly observed, a range of different values were imposed in the various simulations of Model 2.

Shadow prices depend on the interaction of various constraints, interest rates , attitudes towards risk aversion and the degree of perceived risk of each paticular asset category.

CHAPTER VII

EMPIRICAL RESULTS

In this chapter a summary of the empirical results of the simulations of the models for the London clearing banks group will be given together with an evaluation of their explanatory power. There are in total four variations of Model 1 and five variations of Model 2 that were estimated in this study. The detailed values of the shadow prices of the various simulations are given in special tables in Appendices 1 and 2. Graphical representations of shadow prices are also presented. The results are presented as three year moving averages in order to eliminate normal cyclical fluctuations in shadow prices and identify major trends which are important for the constraint-induced innovations theory. Graphical representations of the results without smoothing are also offered. Finally, details about the computer programs used are given in Appendix 7.

VII.1. Model 1.

As part of a sensitivity analysis four versions (labeled Model 1A, Model 1B, Model 1C, Model 1D) of the model were estimated each one attached a different set of parameters for the capital adequacy constraints (7) and (8). Since the exact values of these ratios are not known precisely and in view of the importance of these constraints on the derived shadow prices, the estimation of four different plausible specifications will give us greater accuracy in the evaluation of shadow prices. Special tables will be included in the discussion of the various models' results; in these tables it can be observed which constraint is effectively restricting the allocation of funds to the highest yielding asset each year for each of the four variations of Model 1.

The notation used is:

H^{liq}. : Maximum funds available after satisfaction of liquidity requirements: (2)-(5)

H^{mar} : Maximum funds available from market constraint (10).

$H^{loan/cap}$: " " " " loans/capital ratio (8).

$H^{risk/cap}$: " " " " risk assets/capital ratio (7)

In general, if the liqudity constraint is effective, then the shadow prices of deposits will tend to be higher; if the loans/capital or risk assets/capital ratios are effectively restricting the allocation of available funds to the highest yielding asset, then shadow prices of capital will tend to be higher.

Model 1A.

In this version of the model the capital adequacy parameters μ_1 and μ_2 are set for each year equal to the previous year's actual average ratio of the "big four" London clearing banks. The exact values of these parameters are presented in Table 8. Table 9 shows available funds allowed for allocation after the satisfaction of the liquidity constraints, as well as the maximum funds that can be allocated to loans and other risky assets without violating the market and capital adequacy constraints. Before proceeding with the discussion of the results, Tables 8 and 9 as well as a graphical representation of the shadow prices of Model 1A will be presented in the following pages.

TABLE 8

Capital ratios used in MODEL 1A*
(London clearing banks)

Year	μ_1	μ_2
b1965	14.65	9.47
*1966	13.19	9.05
*1967	13.07	8.95
*1968	13.60	9.02
*1969	12.42	7.90
1970	6.93	5.14
1971	6.68	4.73
1972	7.55	5.16
1973	9.55	7.41
1974	8.21	6.66
1975	8.87	7.15
1976	8.48	6.48
1977	7.77	6.52
1978	8.06	6.25
1979	7.78	6.03
1980	7.98	6.28
1981	9.24	7.19
1982	10.37	7.86
1983	9.64	7.24
1984	9.54	7.00
1985	10.10	7.15

Notes:

*: calculated from data taken from the Annual Reports and accounts of: Barclays, Lloyds, Midland and National Westminster banks.

b: data for 1965 are calculated from aggregate data (for 1964) for the london clearing banks group.

*: data for these years are calculated from Annual Reports and accounts of: Barclays, Lloyds and Midland banks only.

TABLE 9

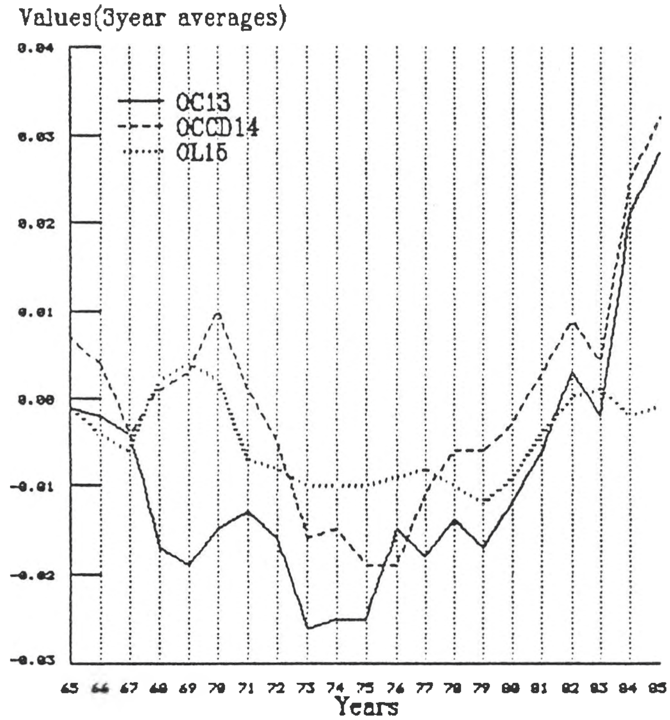
Available funds after satisfaction of liquidity requirements (2)-(5), ($H^{liq.}$);

Maximum loans permitted by the market constraint (10), (H^{mar}) and the capital adequacy constraints (7), (8), ($H^{risk/cap}$, $H^{loan/cap}$ respectively).

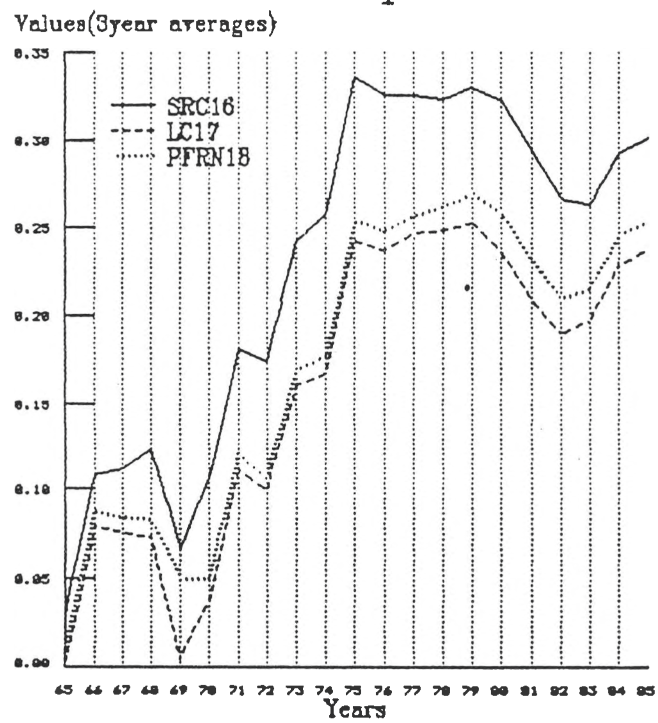
Years	Model 1A			
	$H^{liq.}$	H^{mar}	$H^{loan/cap}$	$H^{risk/cap}$ £millions
1965	5265	**4653**	4858	5290
1966	5406	**4732**	4923	4774
1967	5382	4725	5092	**4629**
1968	5751	**5075**	5962	6009
1969	6001	**5328**	5948	6319
1970	6264	**5623**	6532	5830
1971	6730	5991	6683	**5814**
1972	10280	9081	8075	**7746**
1973	13156	**12460**	15160	13613
1974	16050	15586	18328	**14567**
1975	23423	22738	19061	**17548**
1976	23022	22537	21111	**21070**
1977	**24461**	24078	23009	**20466**
1978	29318	28718	27087	**26824**
1979	35218	34976	**31193**	31475
1980	43171	43381	**35161**	35195
1981	56283	54356	**46670**	48409
1982	71517	69181	**65843**	73502
1983	82645	79962	**69909**	79065
1984	93295	90381	**75096**	86722
1985	112564	110648	**103017**	124330

MODEL 1A
Shadow prices

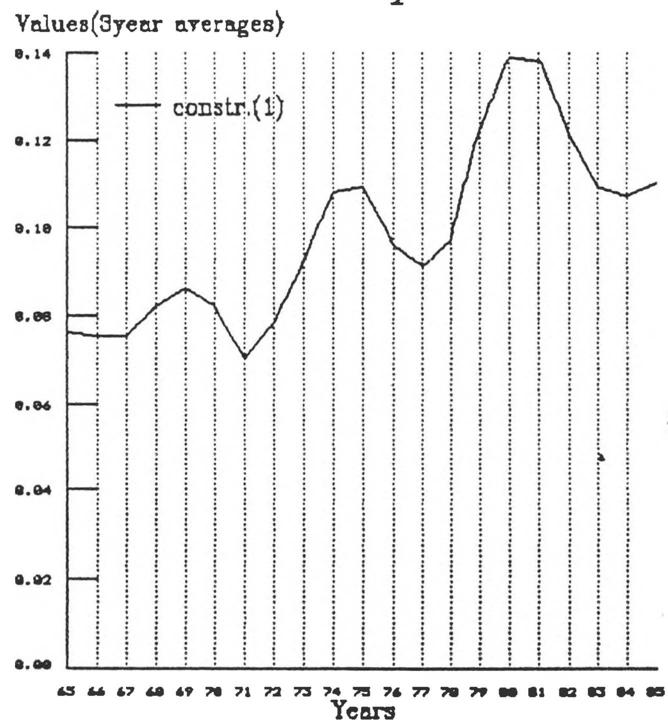
MODEL 1A
Shadow prices



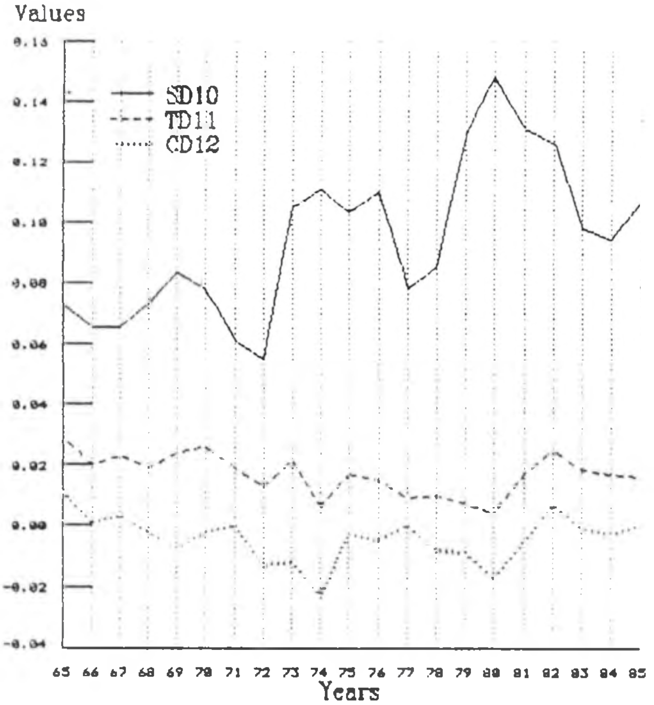
MODEL 1A
Shadow prices



MODEL 1A
Shadow prices



MODEL 1A
Shadow prices



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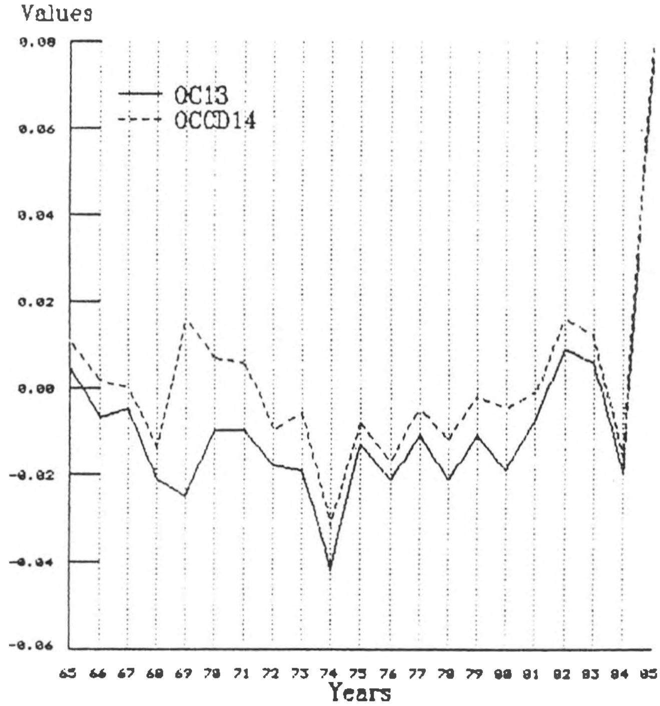
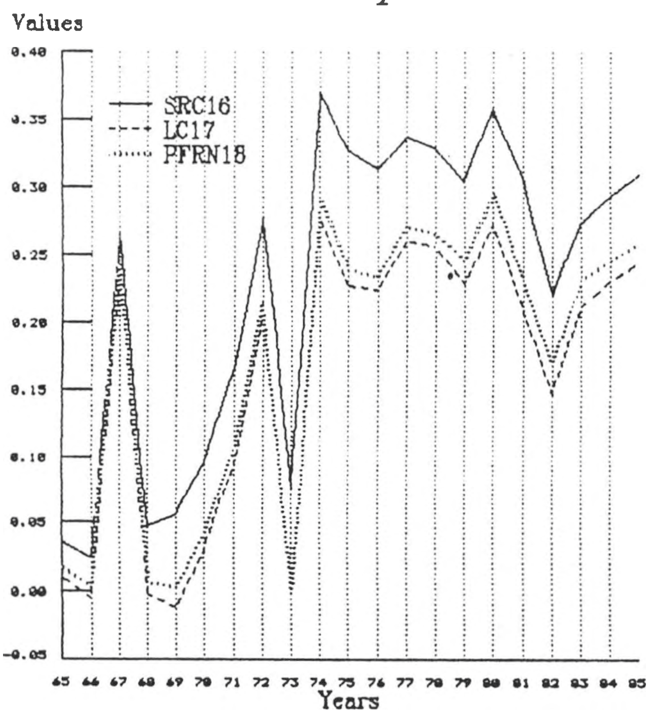
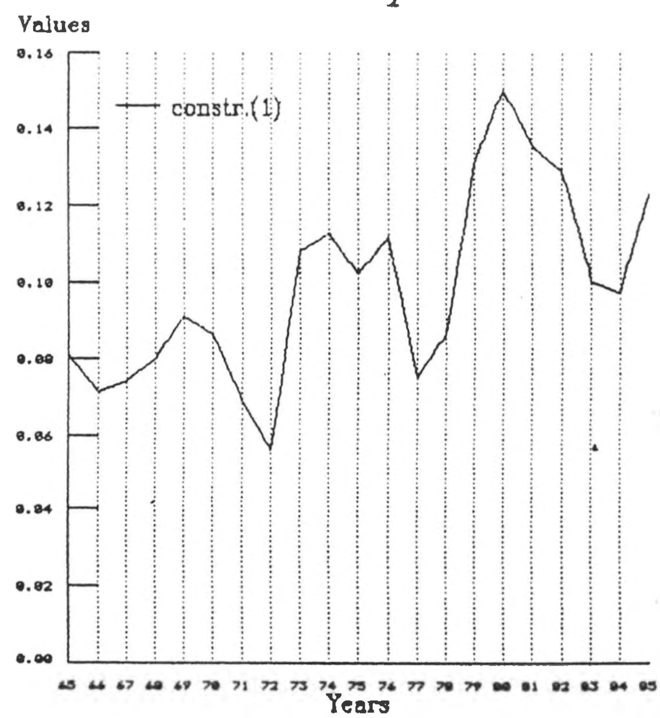
Shadow prices



MODEL 1A
Shadow prices



MODEL 1A
Shadow prices



The results from the simulation of Model 1A will now be presented. In Table 9 we can observe which of the previously mentioned general categories of constraints are effectively restricting loans each year. In general we observe that capital adequacy constraints have been binding in 1967, 1971, 1972 and continuously from 1974 up until 1985. In 1977 the allocation of funds to the highest yielding asset is restricted by the liquidity constraints, while in all remaining years the market demand for loans is the effective constraint.

(a) By looking at the shadow prices of sterling deposits first, major peaks can be observed in 1969, 1975-76 and 1980-81. The main innovations that we want to examine in this graph are sterling CDs in 1971 and interest bearing sight deposits introduced in 1981 by the clearing banks' subsidiaries and in 1984 by the clearing banks. The peak in the shadow price line representing sight deposits in 1981 seems to tell the story of the pressure to introduce interest bearing sight deposits. This pressure is indirectly reflected in the peak in the time deposits shadow price line in 1983 that put the extra pressure before the introduction of the same deposit instrument by the parent companies. The shadow price line for sterling certificates of deposit does not show the 1971 pressures before the introduction of £ CDs; there is however a peak in the sight deposit shadow price line in 1969 indicating the existence of some degree of pressure on banks' liabilities. Shadow prices of deposit liabilities are reflecting the effects of high nominal rates in the marginal profitability of sight deposits. A rise in interest rates inreases the interest rate differential in current accounts whose rates are fixed (to zero) relatively more. This is the so-called "endowment effect". The peaks in the shadow prices of sight deposits in 1974 and 1980 (both these periods are experiencing high inflation rates) reflect this.

(b) If we now turn to the shadow prices of foreign currency ($) deposits, we observe an upward trend between 1967-1971 and a significant drop afterwards. This seems to explain the 1971 and 1972 innovations. However, the other currency deposits shadow price line is not reflecting these pressures so adequately since although it reaches a peak in 1971, it takes negative values.

From 1976 shadow prices of foreign currency liabilities show a continuous upward trend until 1985. This upward trend coincides with a period of a rapid expansion of foreign currency business undertaken by the London clearing banks. The amount of eurodollar loans made by them more than trebled from 1974 to 1976 while at the same time their dollar deposits almost doubled. Finally, there is an acceleration in the rate of increase of the shadow prices starting in 1980 up to 82 and another one from 1984 to 1985. This seems to reflect up to a certain point the increased internationalisation of banks' liabilities during the 80s. The amount of dollar CDs has increased in 1982 by 72% over the previous year, while in 1985 the increase was 93%.

(c)Let us now turn to the shadow prices of capital. In all three shadow price lines of various capital categories there is a similar trend. There is a rise in shadow prices from 1965 up to 1968 when they reach a peak. In that year the clearing banks begun issuing subordinated debendures in order to improve their capital positions. There is a fall in the shadow prices immediately afterwards that indicates the success of the new instrument in easing the pressures. From 1971 shadow prices show a continuous upward trend up to 1975; they remain at that high level until 1979 when they begin to show a decline; in 1985 they reach another peak. These trends reflect quite accurately the capital adequacy problems that the banks were facing in these periods. In 1975 the introduction of floating rate notes and in 1985 the introduction of perpetual floating rate notes coincide with the pressures depicted by the shadow prices of capital.

(d)Finally a picture of the overall innovative pressures on banks balance sheets can be obtained by examining the shadow prices of constraint (1); the balance sheet constraint. There are three major peaks; in 1969, in 1974 and in 1980. The rising shadow prices from 1971 up to 1975 can be seen as a reflection of the banks' increased involvement in liability management. High and variable interest rates during that period are largely responsible for the high shadow prices. Variable rate instruments that were introduced during that period can be considered as a response to these high shadow price levels. Banks begun to offer short-term variable rate loans and were involved in large foreign currency syndicated loans. The rising shadow prices from 1979 reflect the pressures for the development of off-balance-sheet activities and the internationalisation of the clearing banks' business that we witness in the 1980s. Another innovative instrument introduced in 1981 was the adoption of mortgage lending by the London clearing banks. The peak in the shadow prices of the balance sheet constraint in 1980-81 can be seen as explaining up to a point the pressures for the introduction of this innovative instrument.

Model 1B

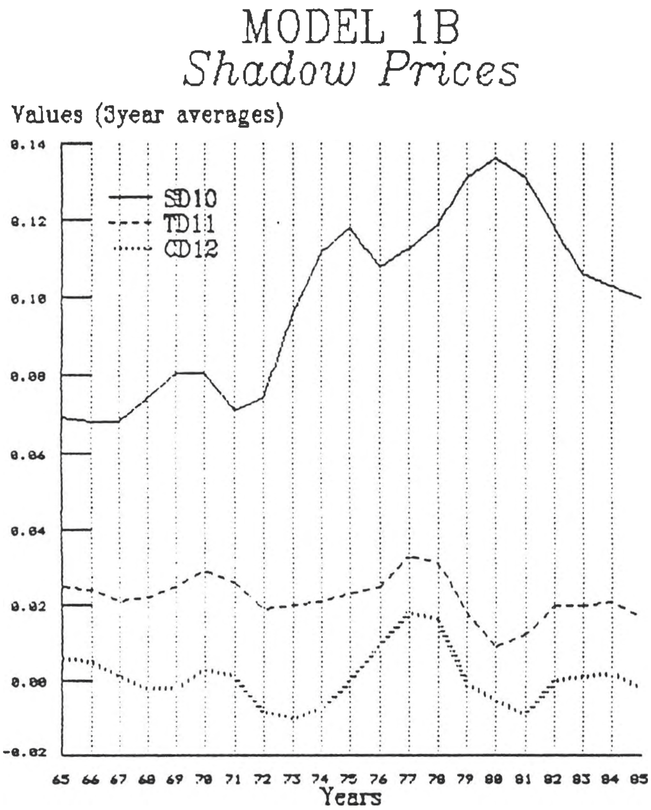
In this version of the model the capital adequacy parameters μ_1 and μ_2 are set equal to the calculated average values for three particular periods: 1965-1971, 1972-1980, 1981-1985. In 1971 and 1980 there were significant changes in the regulatory framework of financial institutions and we can assume that management attitudes were relatively stable within each period but changed up to a certain degree between periods.

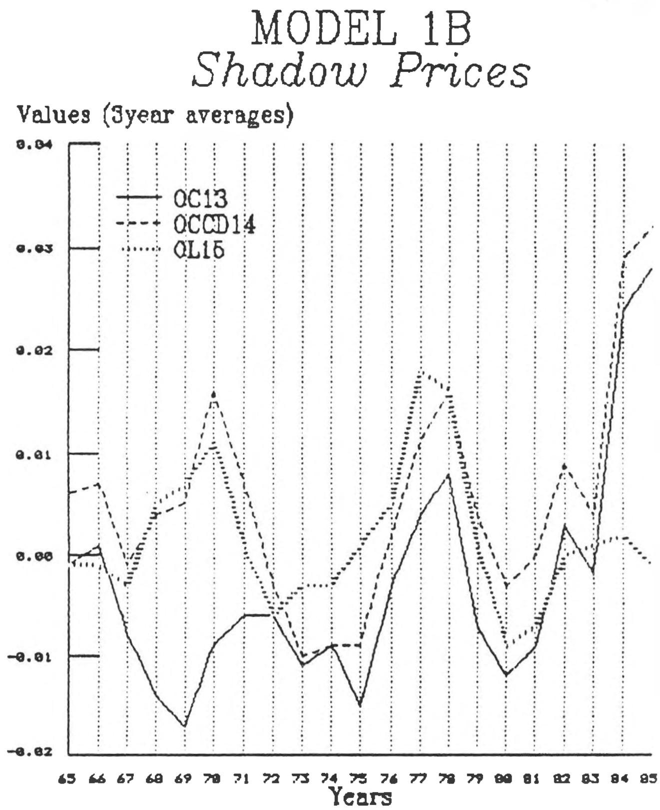
The exact values of these parameters as used in Model 1B are:

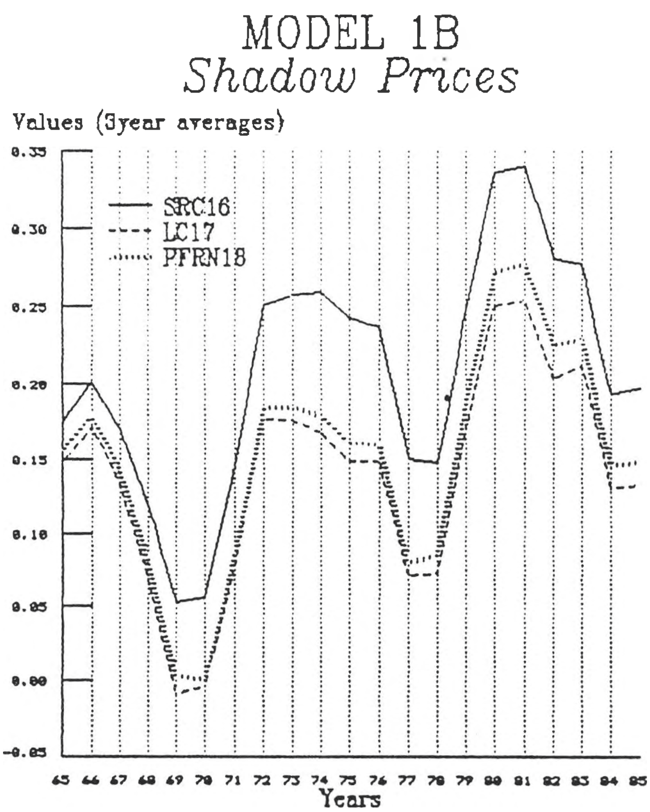
	Parameter values	
Time period	μ_1	μ_2
(1965-1971)	12.266	7.817
(1972-1980)	8.876	6.360
(1981-1985	10.107	8.218

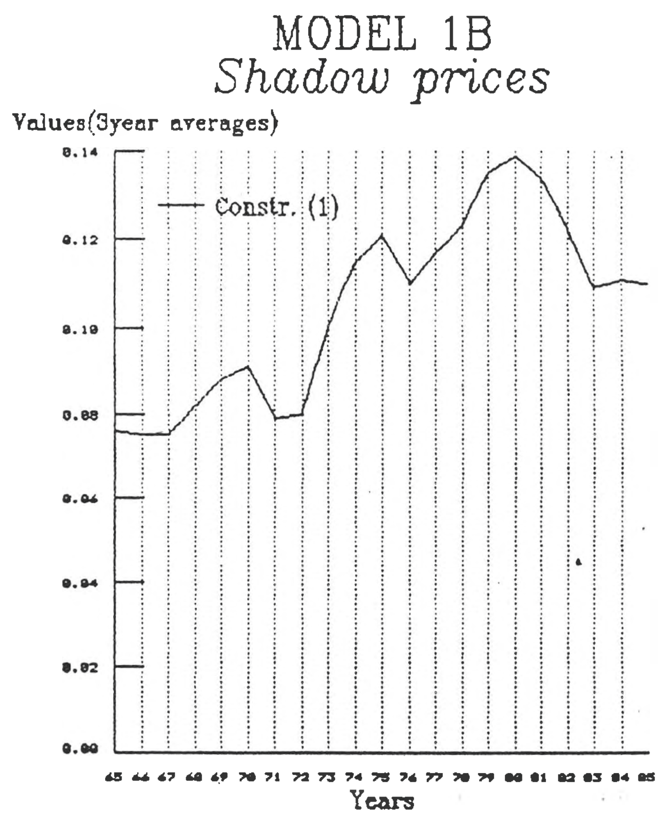
data are calculated from aggregate data.

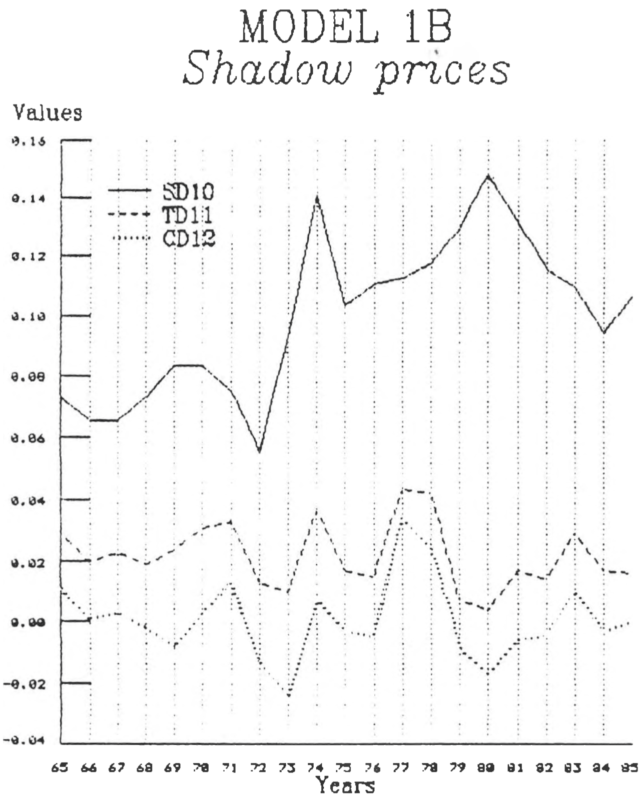
Table 10 shows available funds allowed for allocation after the satisfaction of the liquidity constraints, as well as the maximum funds that can be allocated to loans and other risky assets without violating the market and capital adequacy constraints. Before proceeding with the discussion of the results, Table 10 as well as a graphical representation of the shadow prices of Model 1B will be presented in the following pages.

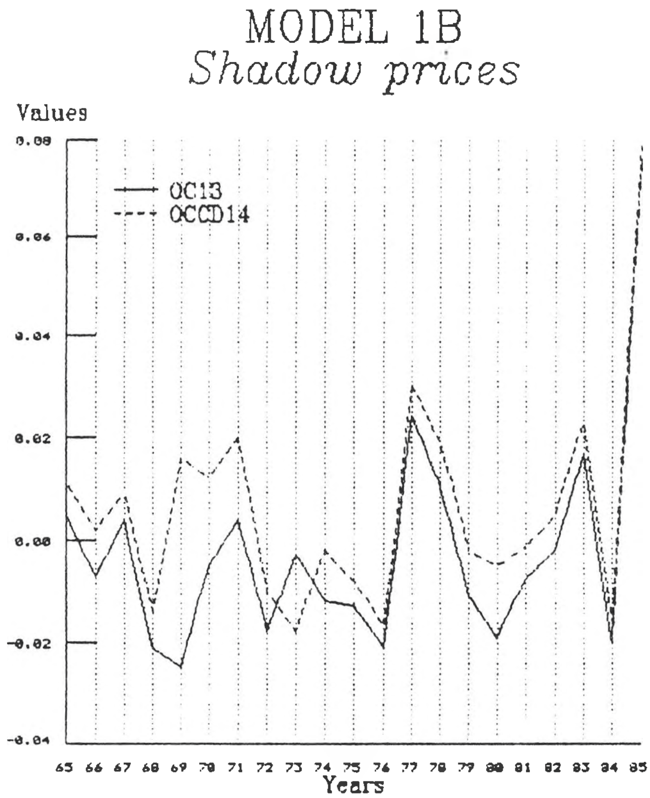

MODEL 1B
Shadow Prices
Values (3year averages)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
SD10
TD11
CD12
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
Years

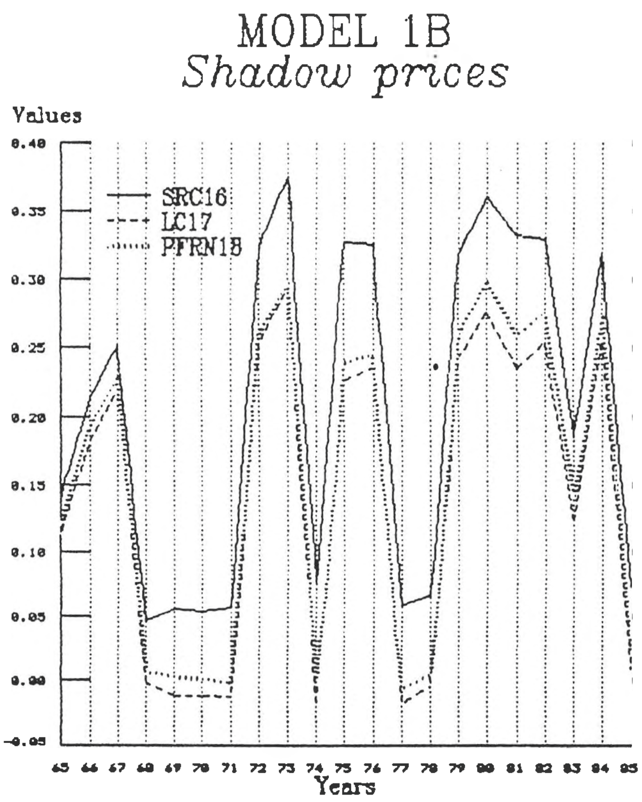

MODEL 1B
Shadow Prices
Values (3year averages)
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
OC13
OCCD14
OL15
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
Years

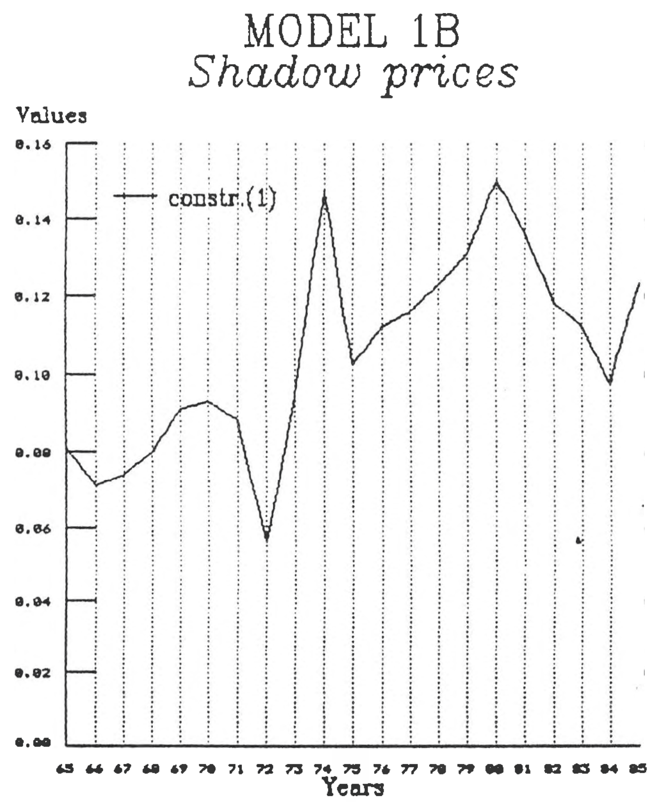

MODEL 1B
Shadow Prices
Values (3year averages)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
SRC16
LC17
PFRN18
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
Years


MODEL 1B
Shadow prices
Values(3year averages)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Constr. (1)
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
Years


MODEL 1B
Shadow prices
Values
SD10
TD11
CD12
Years


MODEL 1B
Shadow prices
Values
OC13
OCCD14
Years


MODEL 1B
Shadow prices
Values
SRC16
LC17
PFRN18
Years


MODEL 1B
Shadow prices
Values
constr.(1)
Years

By looking at table 10 we observe that capital adequacy constraints are effective in the period 1965-1967, in 1973 and during the period 1975-84. In the remaining years the constraint that is effectively restricting the allocation of funds to the highest yielding asset is the market demand for loans (constraint 10).

(a) As far as the shadow prices of sterling liabilities are concerned, Model 1B says almost the same story as Model 1A; in Model 1B we observe the same main peak periods for sterling deposit shadow prices; these peaks occur in 1969, in 1975-76 and in 1980-81. The shadow prices of £ CDs and time deposits are also showing a peak in 1971 and 1977-78 as well as in 1982-84 giving an indication of increased pressures before the introduction of sterling CDs in 1971 and interest bearing sight deposits in 1984.

(b)The shadow prices of Other Currency Deposits are showing major peaks in 1970-72, 1978, 1982 and 1985. The introduction of foreign currency deposits and certificates of deposit in 1972 are explained by the rising shadow prices during that period. In 1982 and 1985 the size of foreign currency deposits rose significantly; the peaks in shadow prices in these two years explain quite reasonably the rising innovative pressures and the resulting innovations.

(c) As far as the shadow prices of capital are concerned, Model 1B does not predict the 1968 innovation adequately since the peak in shadow prices occurs earlier in 1966. However, the rising capital adequacy pressures in the mid 1970s are depicted quite adequately by rising shadow prices from 1971 up to 1974 followed by a fall afterwards.

(d) By looking at the overall balance sheet pressures as depicted by constraint (1) we can identify three major peaks, similar to those observed in Model 1A, in 1969, 1975 and 1980.

In general we can see that the results derived from constraint (1) are almost identical to those of Model 1A.

Model 1C.

In this version of the model the values of the capital adequacy parameters are set equal to the average value for the whole period. In particular the values used in the simulation are:

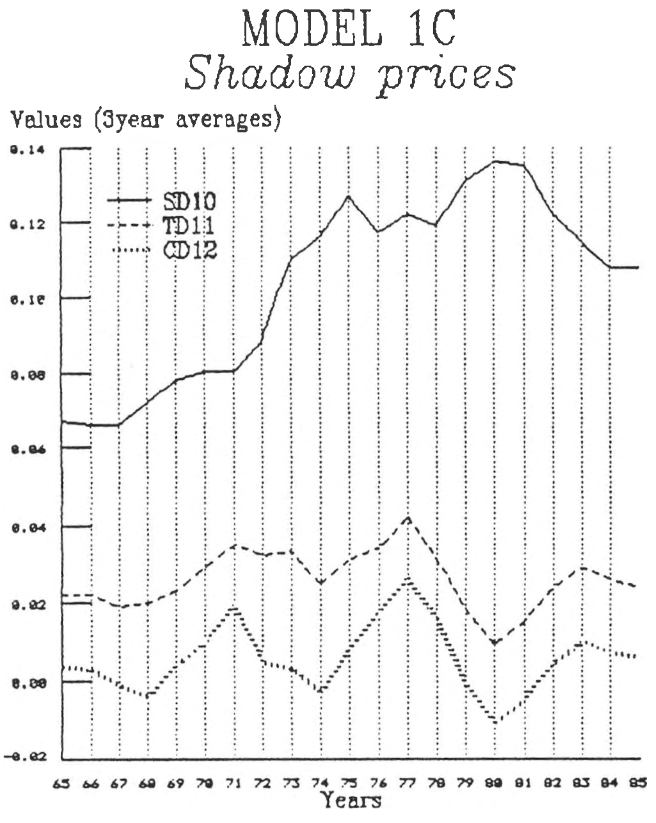
$$\mu_1 = 10.299$$
$$\mu_2 = 7.288$$

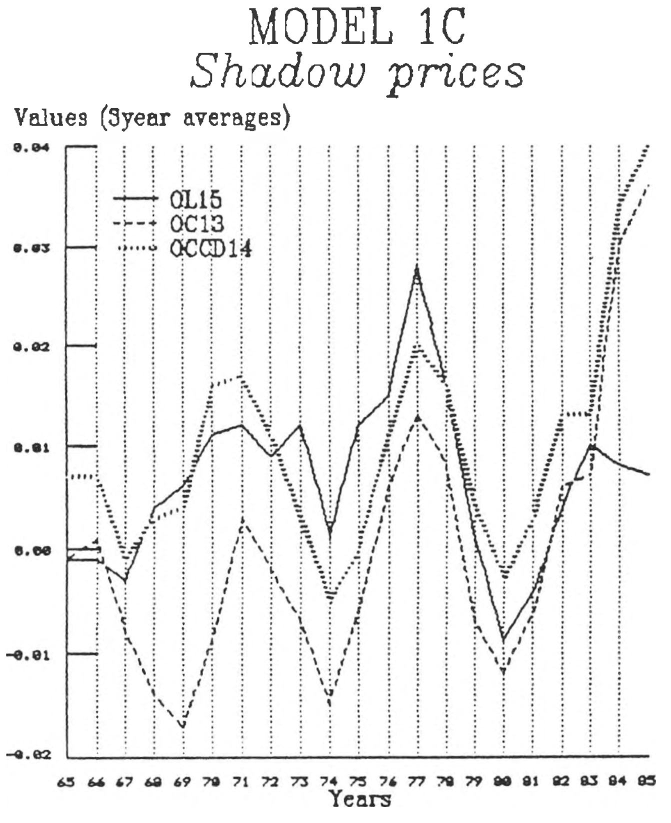
In table 11 we can observe which constraint is effectively restricting the allocation of funds to the highest yielding asset in each year. Before discussing the results of the simulation, Table 11 as well as a graphical representation of the shadow prices of Model 1C will be shown in the following pages.

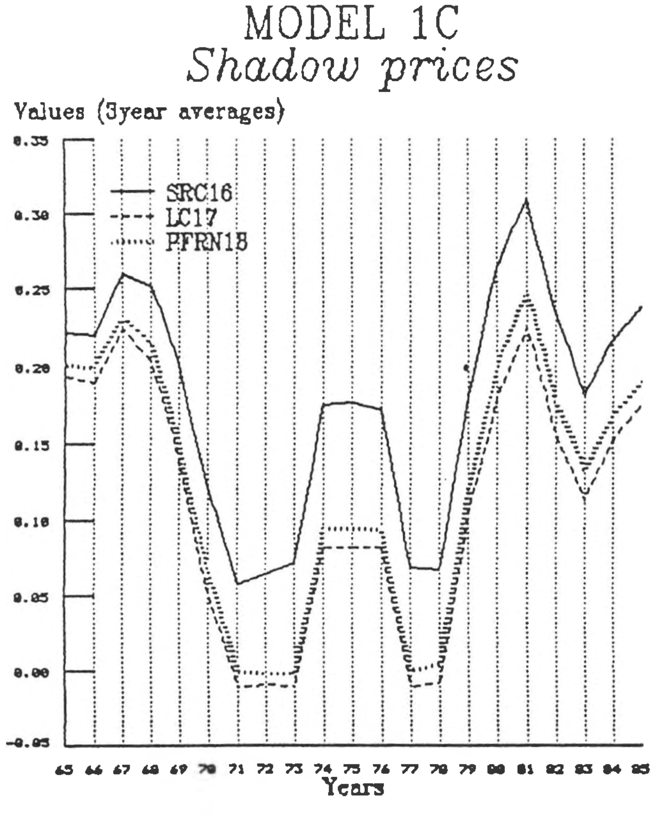
TABLE 11

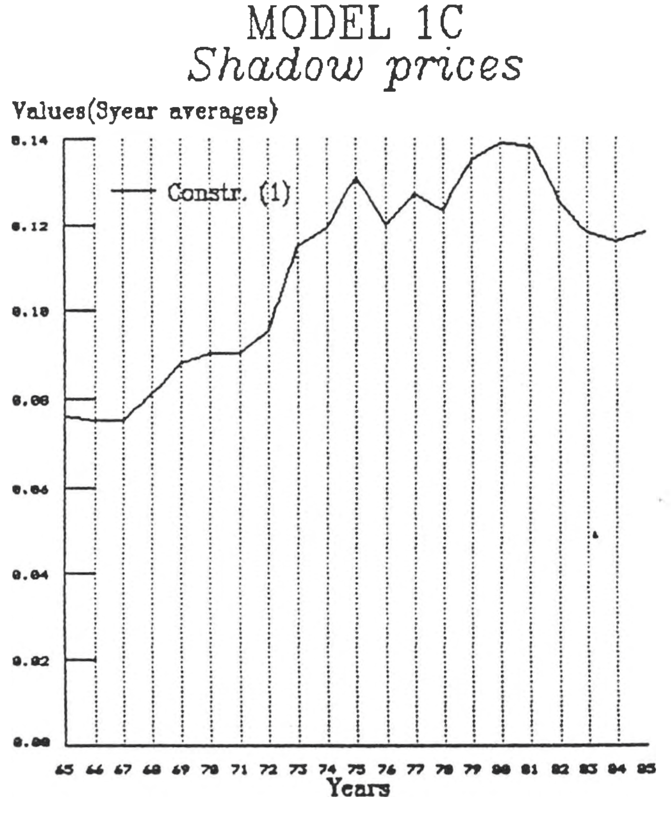
Available funds after satisfaction of liquidity requirements (2)-(5),($H^{liq.}$); Maximum loans permitted by the market constraint (10),(H^{mar}) and the capital adequacy constraints (7),(8), ($H^{risk/cap}$, $H^{loan/cap}$ respectively).

	Model 1C			
Years	$H^{liq.}$	H^{mar}	$H^{loan/cap}$	$H^{risk/cap}$ £millions
1965	5265	4653	3738	**3058**
1966	5406	4732	3964	**3201**
1967	5382	4725	4147	**3053**
1968	5751	5075	4817	**3827**
1969	6001	5328	5488	**4722**
1970	6264	**5623**	9263	10112
1971	6730	**5991**	10298	10929
1972	10280	**9081**	11406	12049
1973	13156	**12460**	14911	15146
1974	16050	**15586**	20057	20316
1975	23423	22738	**19430**	**21359**
1976	23022	**22537**	23744	26997
1977	24461	**24078**	26565	30586
1978	29318	**28718**	31586	36528
1979	35218	**34976**	37701	44507
1980	43171	43381	**40806**	**48179**
1981	56283	54356	**47306**	**55284**
1982	71517	69181	**61052**	**72908**
1983	82645	79962	**70373**	**85429**
1984	93295	90381	**78186**	**94864**
1985	112564	110648	**105006**	**127198**

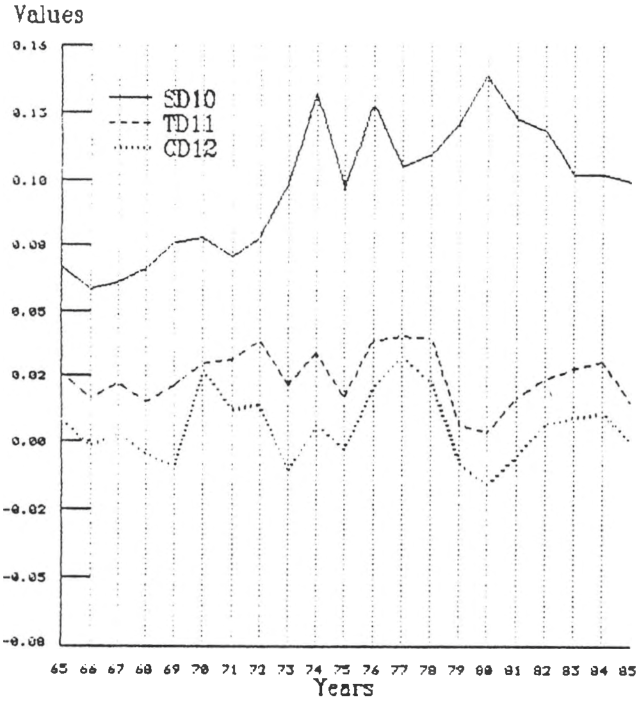

MODEL 1C
Shadow prices
Values (3year averages)
SD10
TD11
CD12
Years


MODEL 1C
Shadow prices
Values (3year averages)
OL15
OC13
OCCD14
Years

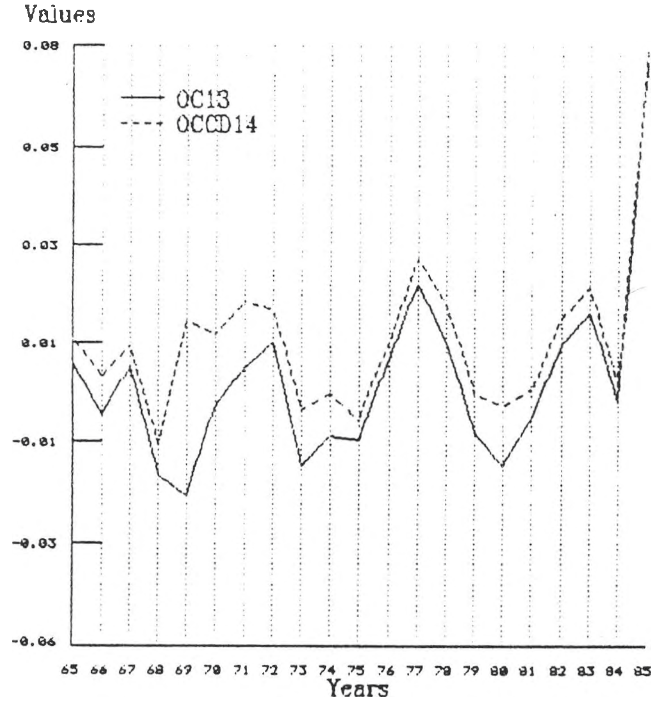

MODEL 1C
Shadow prices
Values (3year averages)
SRC16
LC17
PFRN18
Years


MODEL 1C
Shadow prices
Values(3year averages)
Constr. (1)
Years

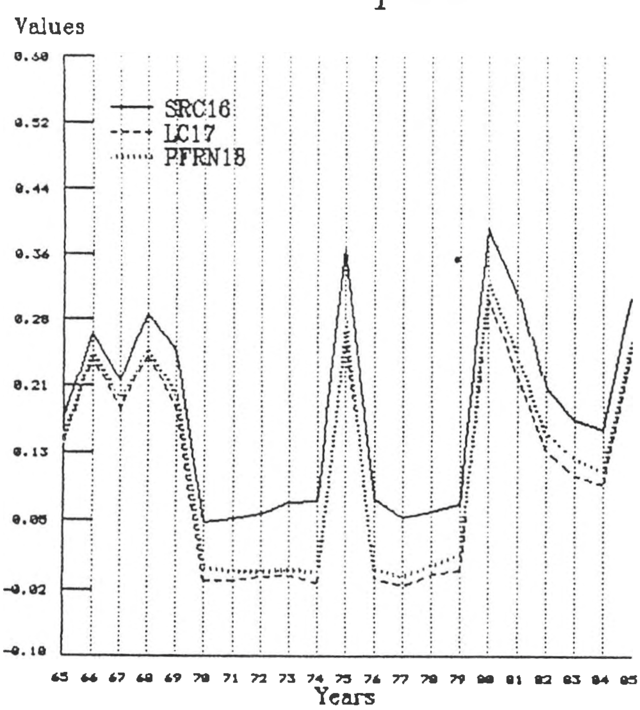
MODEL 1C
Shadow prices



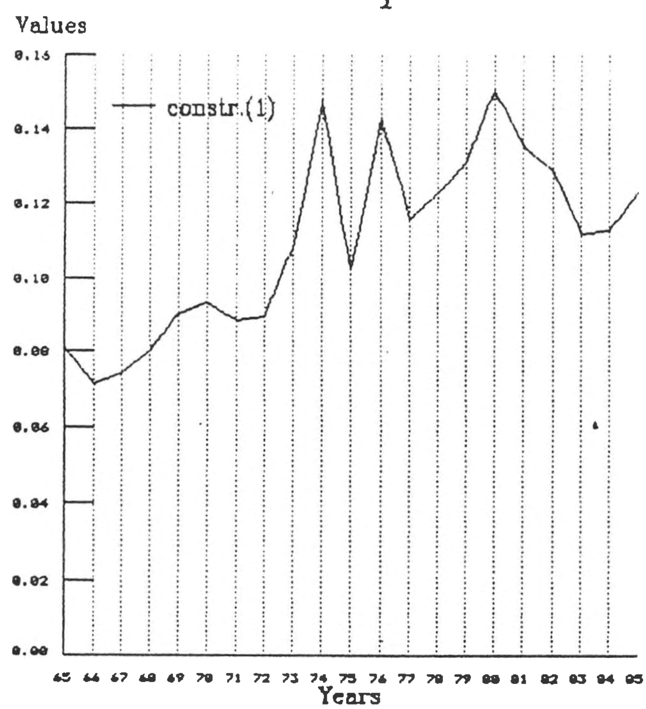
MODEL 1C
Shadow prices



MODEL 1C
Shadow prices



MODEL 1C
Shadow prices



In Model 1C, capital adequacy constraints are binding in 1965-1969, 1975 and in 1980-1985. The market demand for loans has been binding during the remaining years.

(a) As far as the shadow prices of £ and $ liabilities are concerned, Model 1C tells the same story as Model 1B. In fact, it shows a bit sharper rise in the shadow prices of sterling CDs prior to their introduction in 1971. The shadow prices of foreign currency liabilities show a pattern very similar to that observed in Model 1B.

(b) If we turn to the shadow prices of capital we see similar results with Model 1B and even a bit better; there is a peak in shadow prices in 1967 which explains the 1968 innovation; the peak in 1974-76 seems to explain the innovation of floating rate notes. There are two more peaks in 1981 and 1985 reflecting the capital adequacy problems that the banks were facing in the 1980s. The introduction of perpetual floating rate notes in 1984 is explained relatively well by the increase in the shadow price of PFRN18, in 1984.

(c)Finally the shadow prices of constraint (1) behave in almost the same way as in Model 1B.

Model 1D

In this version of the model the values of μ_1 and μ_2 are set each year equal to the previous year's highest observed ratio among the big four clearing banks.

New parameter values for μ_1 and μ_3

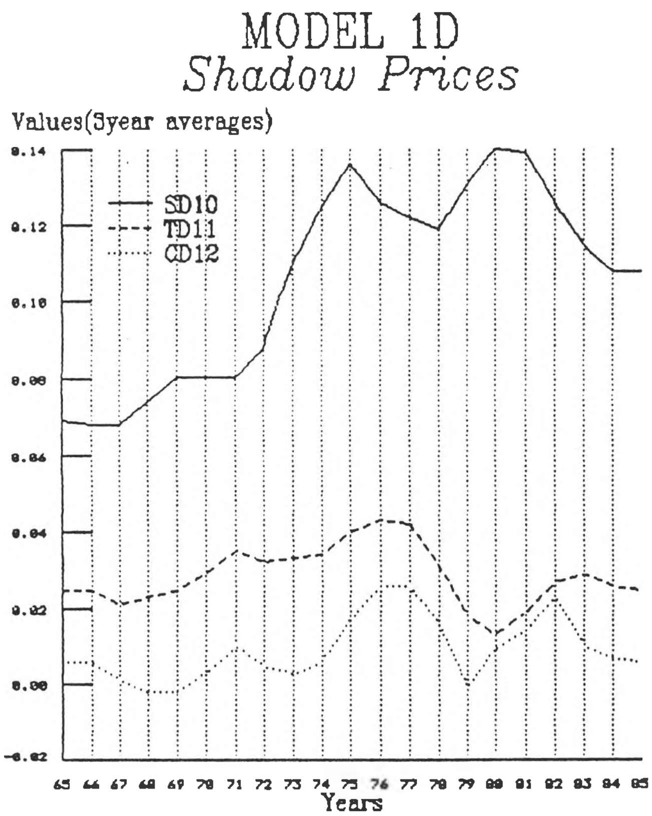
	μ_1	μ_3
1965	14.65	9.47
1966	14.62	10.86
1967	14.98	10.93
1968	16.34	11.94
1969	15.46	10.66
1970	9.10	7.05
1971	7.45	5.75
1972	9.98	6.90
1973	13.56	10.84
1974	11.65	9.57
1975	11.20	8.97
1976	10.07	7.98
1977	10.15	8.14
1978	10.79	8.89
1979	10.85	8.92
1980	10.94	9.01
1981	13.39	11.17
1982	16.56	13.68
1983	11.62	9.38
1984	11.23	9.16
1985	13.83	11.27

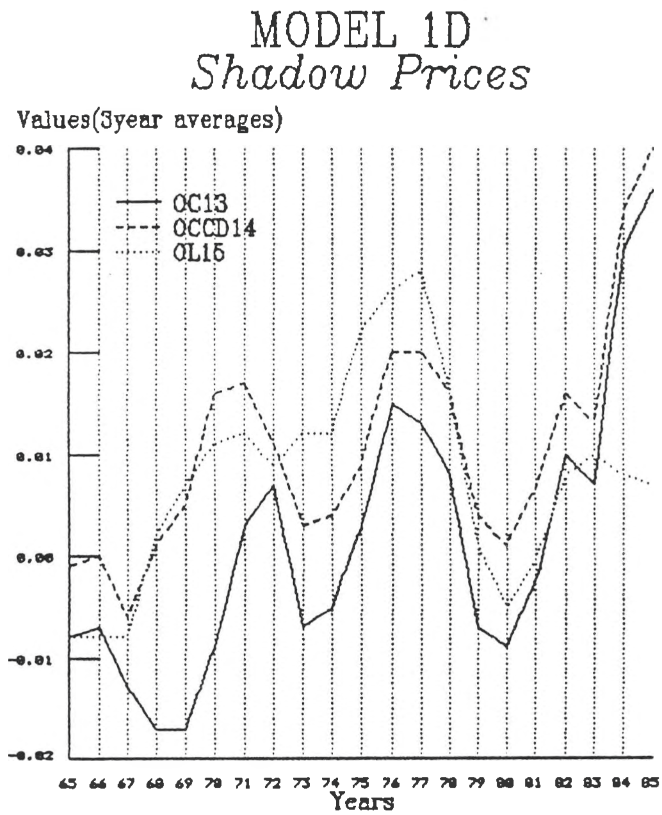
In Table 12 we can observe which constraint is binding each year in Model 1D. In the following two pages Table 12 as well as the graphical representation of Model's 1D shadow prices are given.

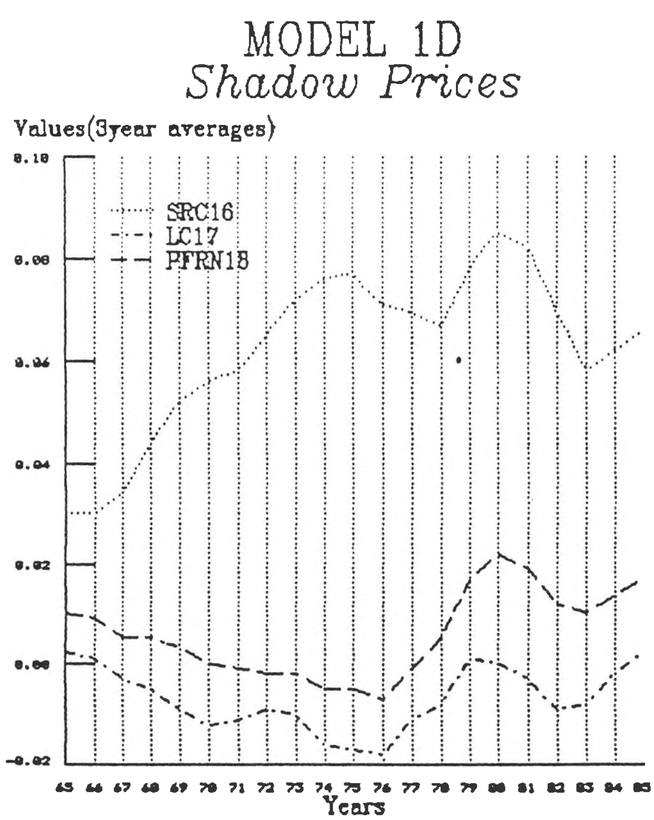
TABLE 12

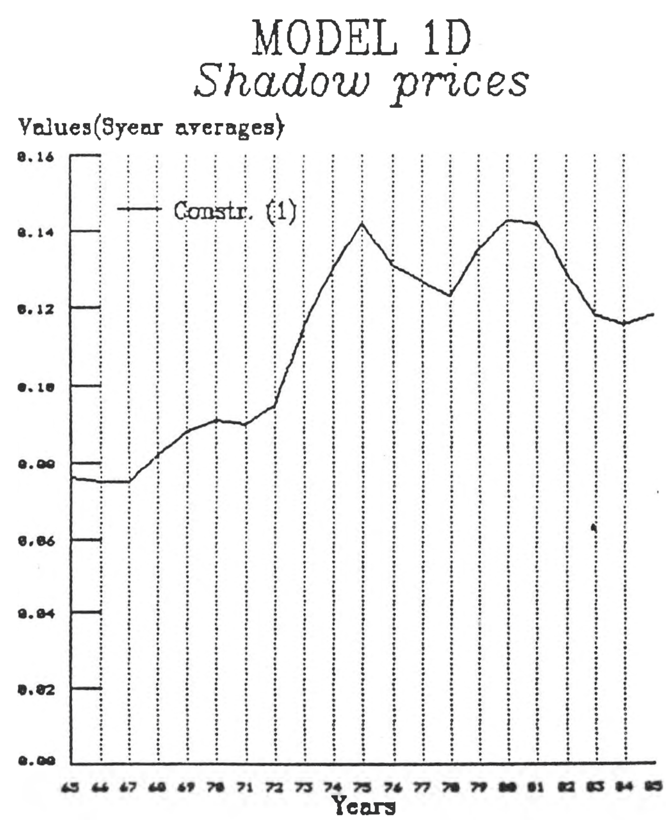
Available funds after satisfaction of liquidity requirements (2)-(5),($H^{liq.}$);
Maximum loans permitted by the market constraint (10),(H^{mar}) and the capital
adequacy constraints (7),(8), ($H^{risk/cap}$, $H^{loan/cap}$ respectively).

Years	Model 1D			
	$H^{liq.}$	H^{mar}	$H^{loan/cap}$	$H^{risk/cap}$ £millions
1965	5265	**4653**	4858	5290
1966	5406	**4732**	5908	5552
1967	5382	**4725**	6219	5717
1968	5751	**5075**	7892	7821
1969	6001	**5328**	8027	8608
1970	6264	**5623**	8961	8588
1971	6730	**5991**	8125	6903
1972	10280	**9081**	10799	11236
1973	13156	**12460**	22179	21558
1974	16050	**15586**	26337	23758
1975	23423	**22738**	23914	23425
1976	23022	**22537**	25999	25853
1977	24461	**24078**	28726	28424
1978	29318	**28718**	38529	38339
1979	35218	**34976**	46143	47005
1980	**43171**	43381	50447	51471
1981	56283	**54356**	72505	75347
1982	71517	**69181**	114597	125356
1983	82645	**79962**	90573	98185
1984	93295	**90381**	98268	104852
1985	112564	**110648**	162378	178073

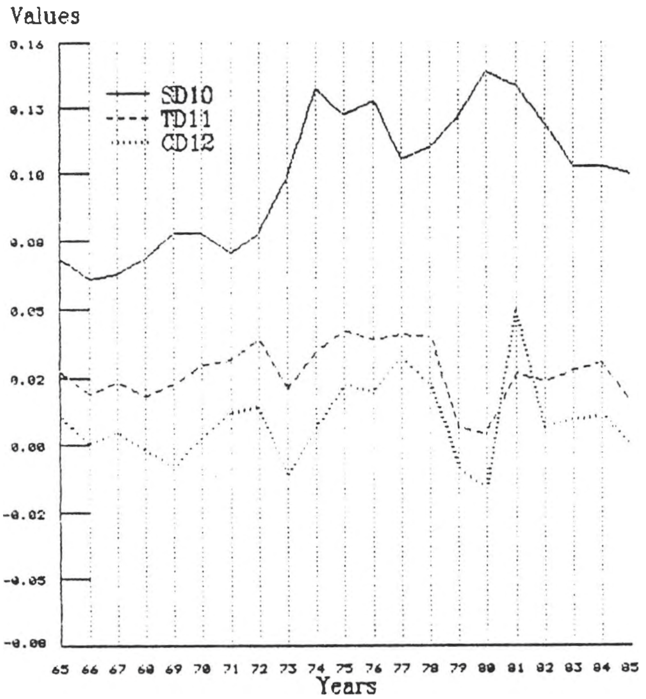

MODEL 1D
Shadow Prices
Values(3year averages)
SD10
TD11
CD12
Years


MODEL 1D
Shadow Prices
Values(3year averages)
OC13
OCCD14
OL15
Years

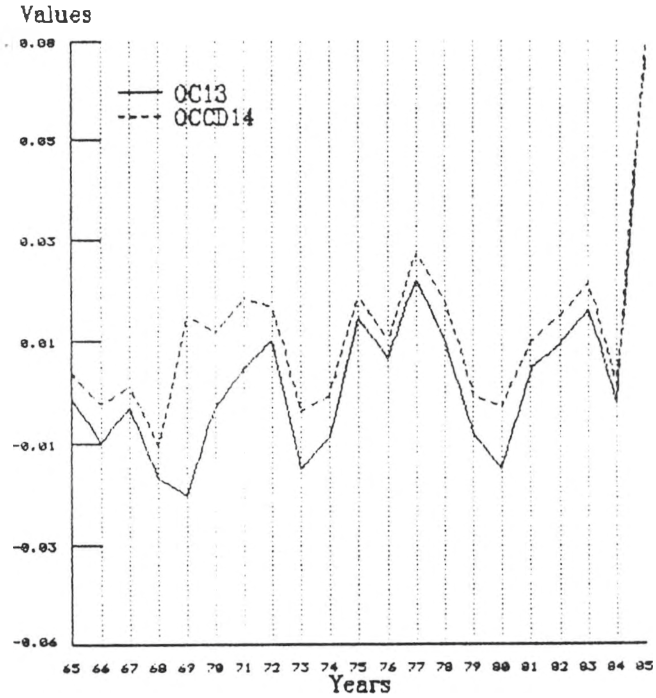

MODEL 1D
Shadow Prices
Values(3year averages)
SRC16
LC17
PFRN18
Years


MODEL 1D
Shadow prices
Values(3year averages)
Constr. (1)
Years

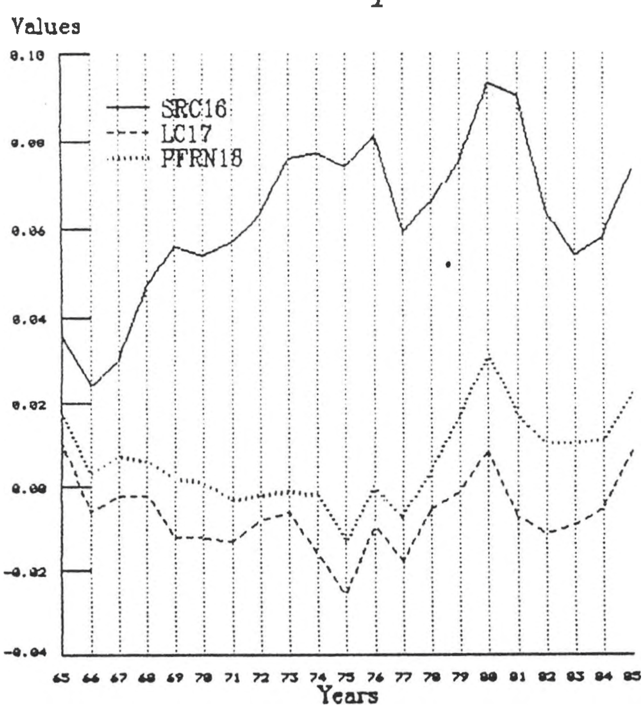
MODEL 1D
Shadow prices



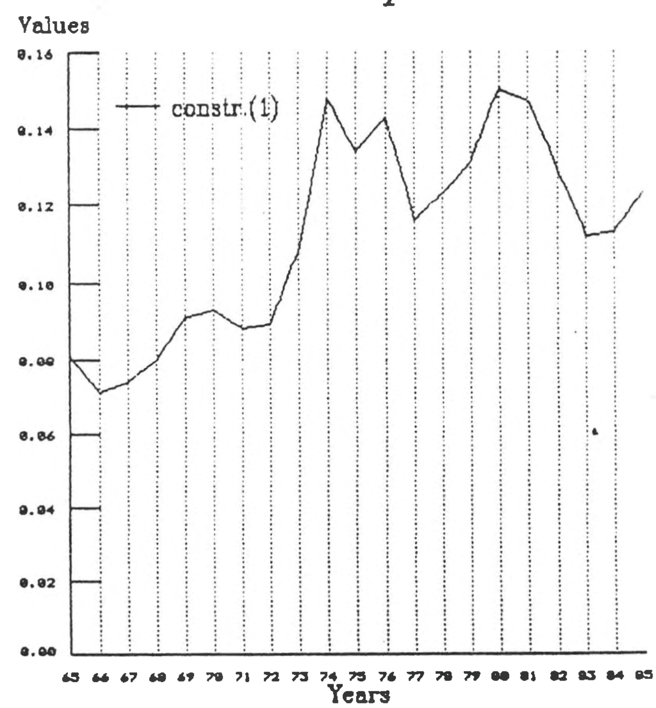
MODEL 1D
Shadow prices



MODEL 1D
Shadow prices



MODEL 1D
Shadow prices



In this version of the model the binding constraint every year (except in 1980, when the binding constraint is the liquidity constraint) is the market demand for loans. The capital adequacy pressures are not clearly shown because the values of the required capital adequacy ratios imposed are much higher (i.e. capital adequacy requirements are less severe) than in the other versions of the model.

(a) The shadow prices of £ and $ liabilities show the same pattern as in Model 1C. The innovations of sterling CDs, foreign currency liabilities, interest bearing sight deposits and process innovations of mid 70s and 80s (liability management and growth in the international part of the banks' operations) are depicted quite accurately by rising shadow prices.

(b)As far as the shadow prices of capital are concerned it seems that there are no significant pressures in the capital side of banks balance sheets leading to major innovations. This is the result of the specification of the capital adequacy ratios employed in this version of the model. However, there are two major peaks in the shadow price line of SRC16 (share capital and reserves) in 1975 and 1980. The peak in 1975 explains up to a point the pressures felt by banks before the introduction of floating rate notes in 1975. The shadow price lines for loan capital and perpetual floating rate notes are showing a peak in 1980 and are rising from 1984 to 1985.

(c) Finally, the shadow prices of the balance sheet constraint (1) show a continuous rise from 1968 up to 1975 reflecting, up to a certain point, the process innovations of that period (liability management and variable rate instruments). Another peak occurs in 1980 coinciding with the new deregulatory measures introduced by the monetary authorities in that year as well as with the clearing banks' entry into the mortgage lending market on a significant scale. Overall, the shadow prices in Model 1D are influenced relatively more by changes in the level of interst rates and the spread between revenues and costs for each particular fund category.

VII.2. Model 2.

As part of the sensitivity analysis five versions (labeled Model 2A, Model 2B, Model 2C, Model 2D, Model 2E) of the model were estimated. As we have already pointed out we do not know the exact value of the banks' degree of risk aversion (as depicted in the value of b in the objective function). We will therefore test four different values ranging from 0.001 up to 1 and derive the optimal solution for the model for the 1965-85 period. Shadow prices in model 2 represent an interaction of various factors; in addition to the interaction of the various constraints and the rates of each balance sheet item, shadow prices depend very much on the degree of risk of each particular asset. In Table 13 we can observe which constraint is effectively restricting the allocation of funds to the highest yielding asset each year. This table is the same for all the versions of Model 2 since funds availability is not affected by the changes in the specification of the risk aversion parameter in the various versions of Model 2.

Observing Table 13 it is clear that the binding constraint in every year is the market demand for loans. This is the result of the adoption of the same values for the capital ratios as those that were used in Model 1D i.e. we assume that the banks observe the highest ratio that existed in the previous year among the four large clearing banks and they consider this as their limit. Therefore the shadow prices depend heavily on the level and variability of interest rates and on the attitudes towards risk of the banks' management.

Specification of various versions of Model 2.

Model 2A is the linear version of Model 2; i.e. the objective function does not include the component representing risk aversion behaviour. In particular, the objective function maximised in this version is:

$$\text{Max } \Pi = \Sigma r_i x_i - \Sigma r_j x_j, \quad i=1,2,..,7 \text{ and } j=8,9,...,12$$

Models 2B, 2C, 2D and 2E differ in the values given to the risk aversion parameter b. In particular the values of b for the various versions of Model 2 are: 1, 0.1, 0.01, and 0.001 respectively

Finally the specification of the variance-covariance matrix Σ is the same in all the versions (2B,2C,2D,2E) of Model 2; it is calculated by using 10year moving averages of interest rates for each variable of the model.

Table 13 as well as graphical representations of the shadow prices of the five versions of the model are following in the next pages.

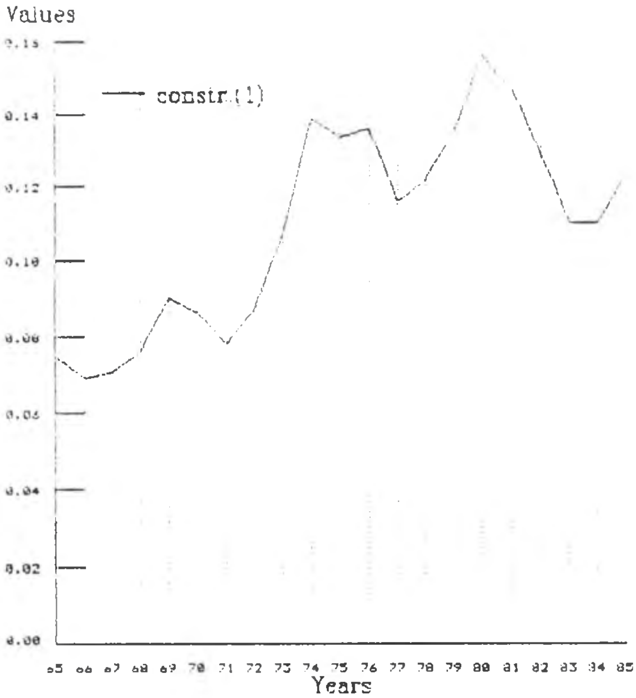
TABLE 13

Available funds after satisfaction of liquidity requirements (2)-(3), ($H^{liq.}$); Maximum loans permitted by the market constraint (6), (H^{mar}) and the capital adequacy constraints (4), (5), ($H^{risk/cap}$, $H^{loan/cap}$ respectively).

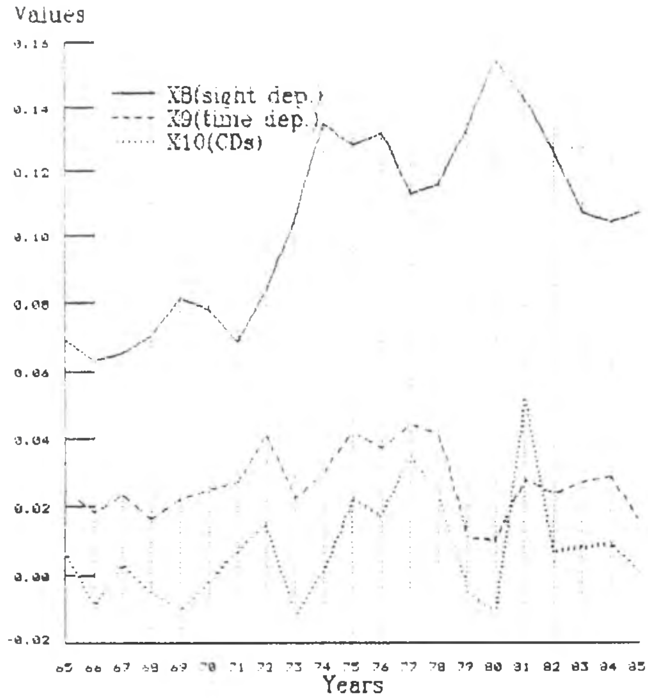
	Model 2			
Years	$H^{liq.}$	H^{mar}	$H^{loan/cap}$	$H^{risk/cap}$ £millions
1965	6219	**4653**	4858	6246
1966	6400	**4732**	5908	6545
1967	6577	**4725**	6219	6912
1968	6968	**5075**	7892	9038
1969	7030	**5328**	8027	9636
1970	7190	**5623**	8961	9514
1971	7973	**5991**	8125	8146
1972	10827	**9081**	10799	12705
1973	13482	**12460**	22179	22773
1974	16456	**15586**	26337	25039
1975	23982	**22738**	23914	24956
1976	23646	**22537**	25999	27490
1977	25102	**24078**	28726	26734
1978	30363	**28718**	38529	40336
1979	35942	**34976**	46143	48738
1980	43779	**43381**	50447	52622
1981	58592	**54356**	72505	77656
1982	73834	**69181**	114597	127673
1983	85208	**79962**	90573	100748
1984	95679	**90381**	98268	107235
1985	114854	**110648**	162378	180363

Unsmoothed results

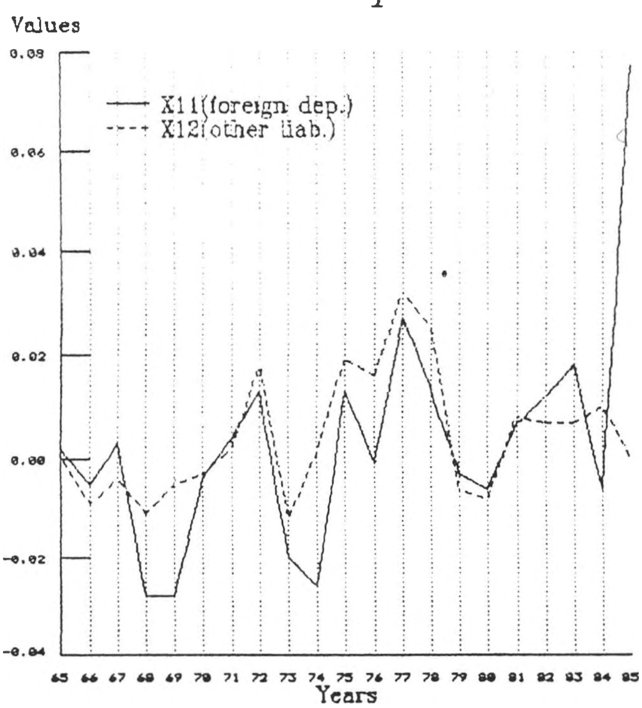
MODEL 2A
Shadow prices



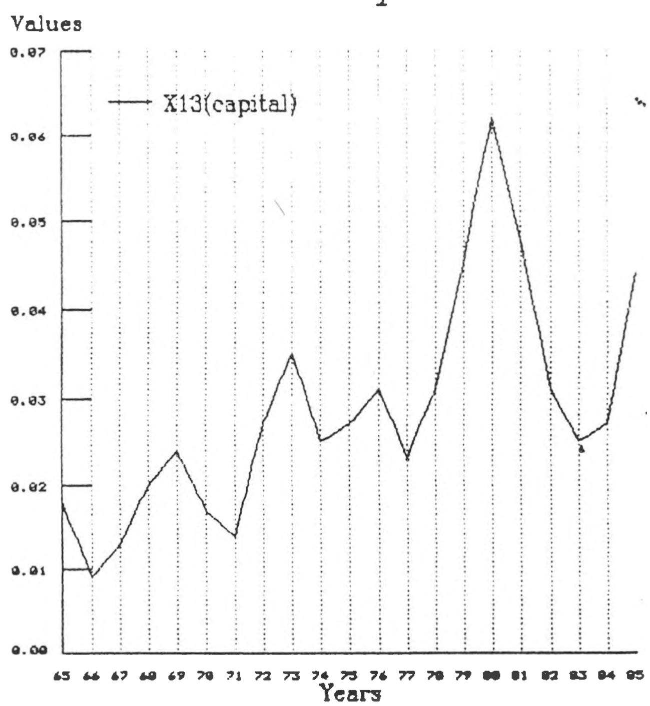
MODEL 2A
Shadow prices

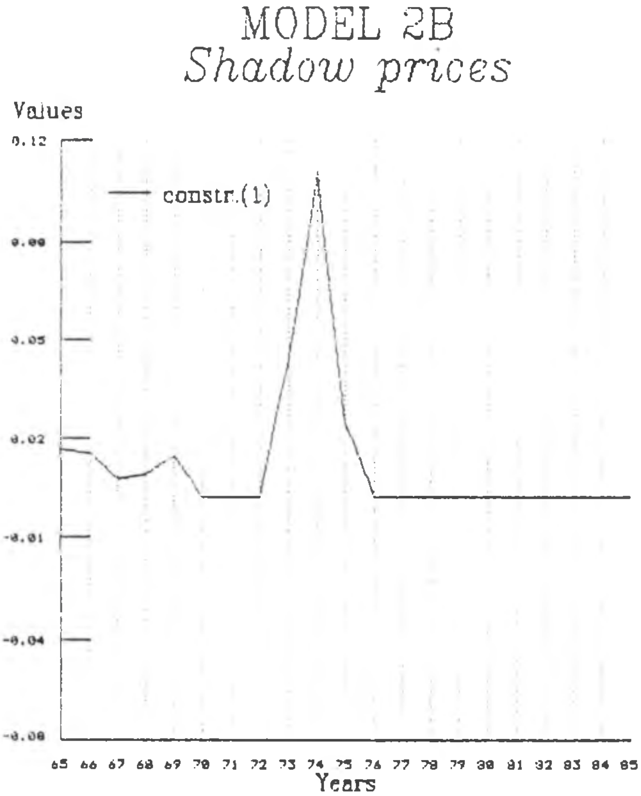


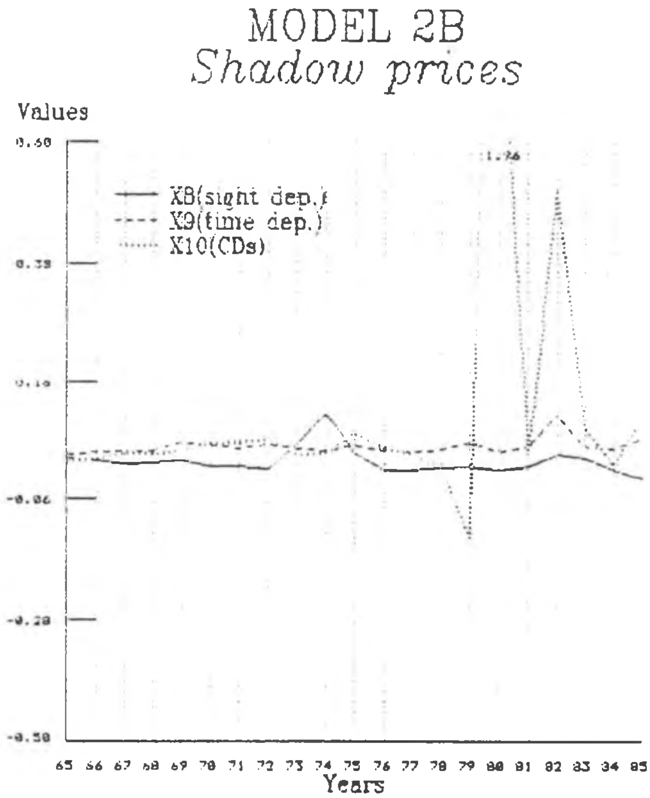
MODEL 2A
Shadow prices

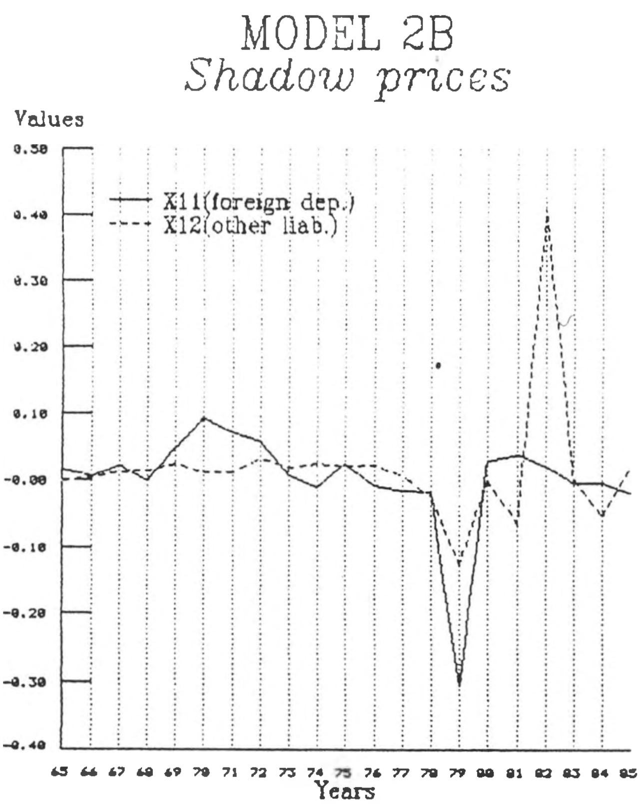


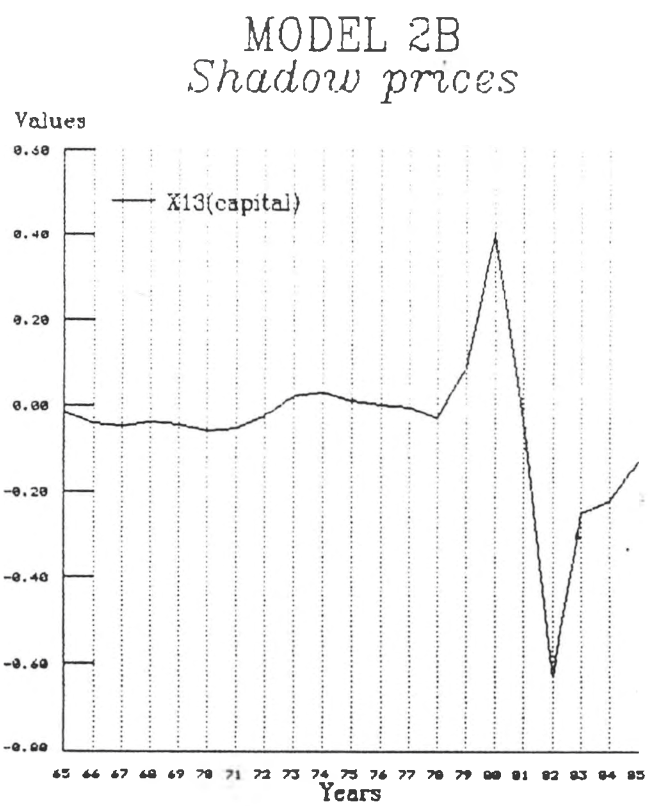
MODEL 2A
Shadow prices

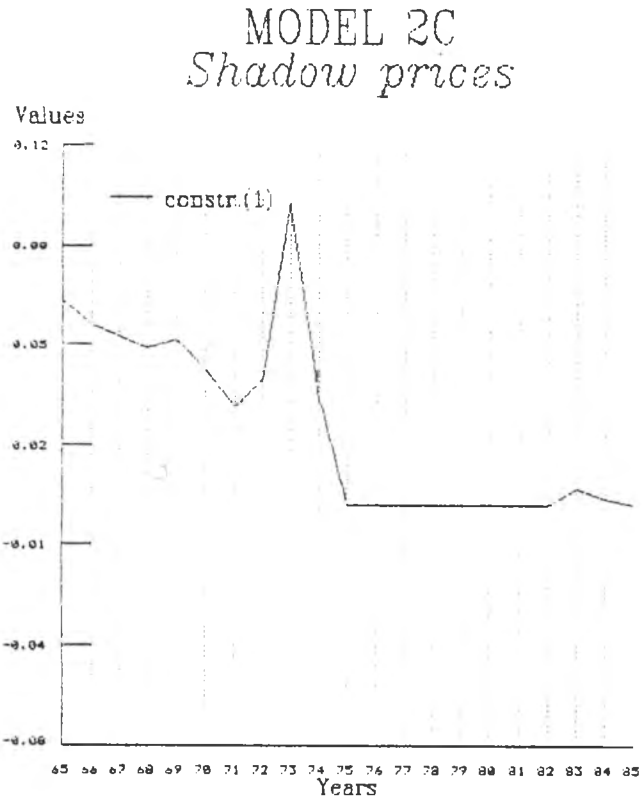


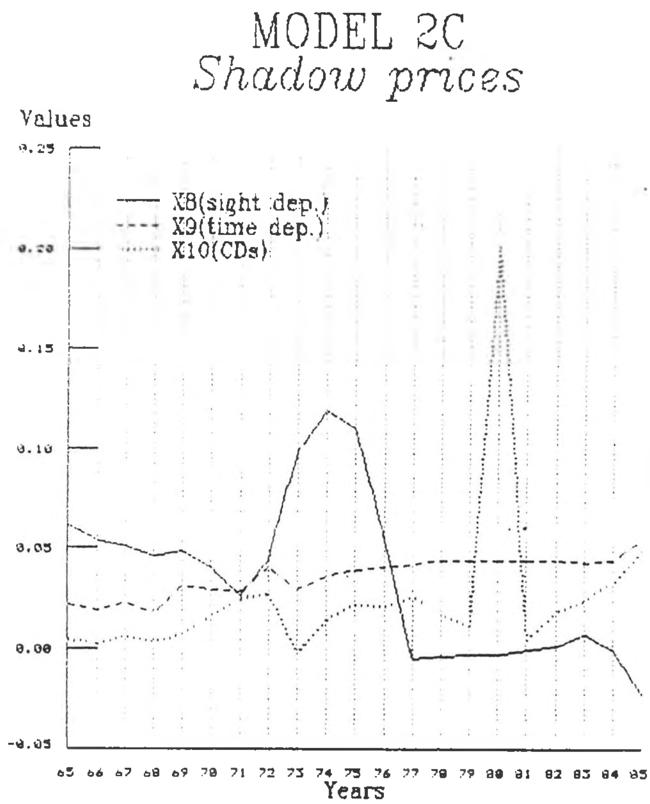

MODEL 2B
Shadow prices
Values
constr.(1)
Years

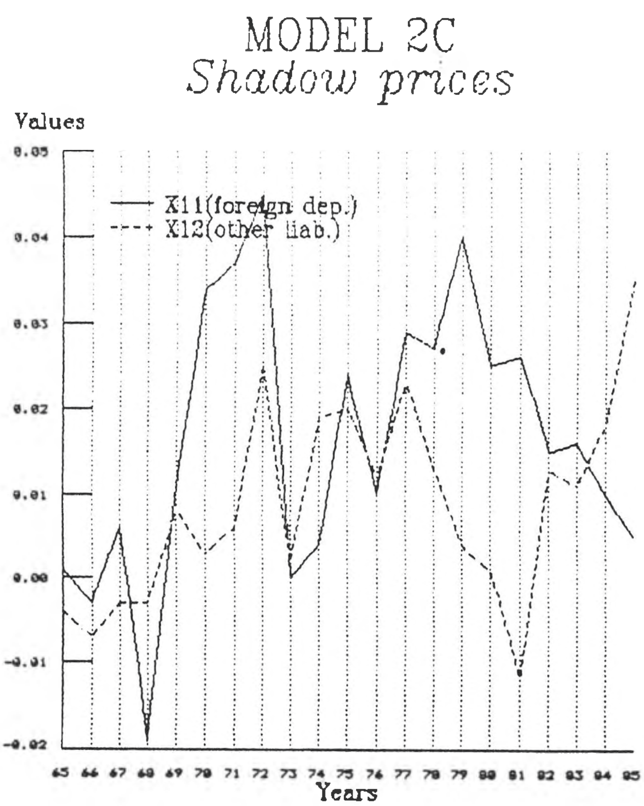

MODEL 2B
Shadow prices
Values
X8(sight dep.
X9(time dep.)
X10(CDs)
Years

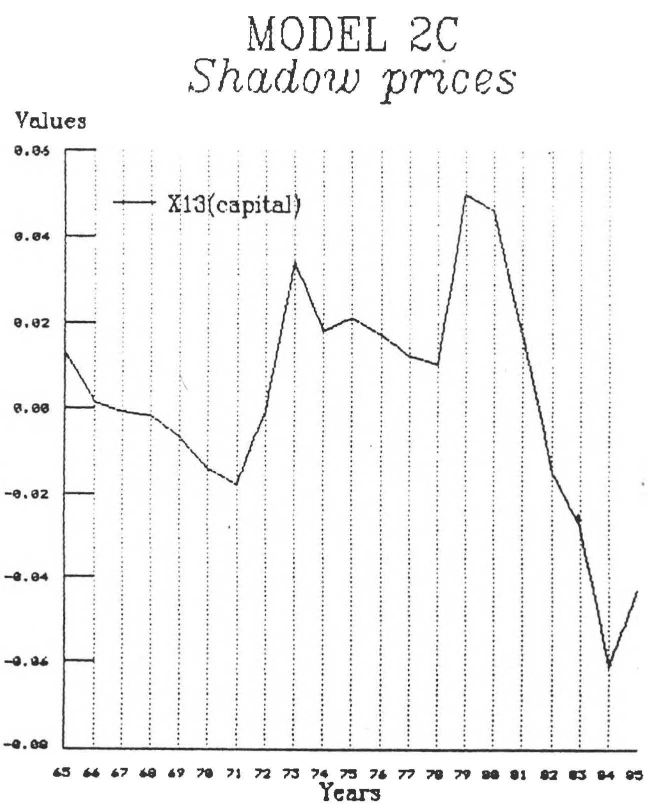

MODEL 2B
Shadow prices
Values
X11(foreign dep.)
X12(other liab.)
Years

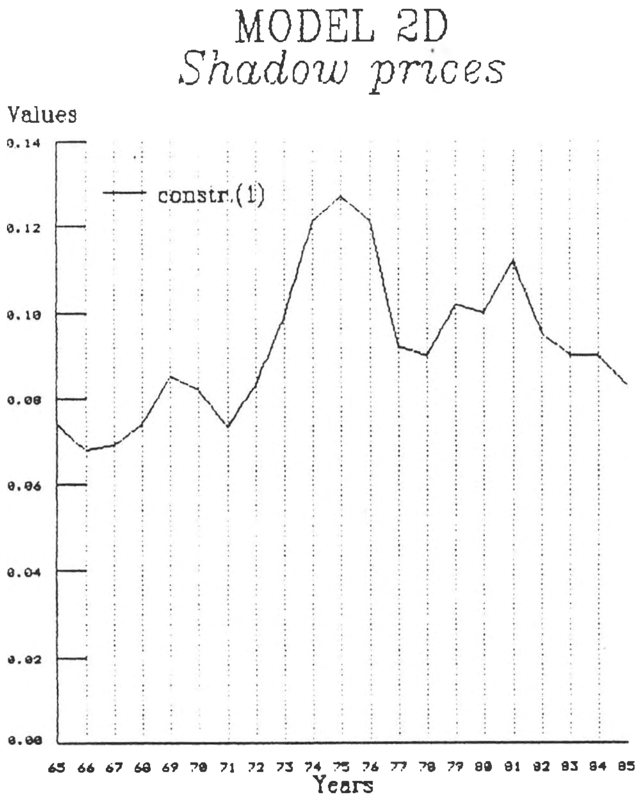

MODEL 2B
Shadow prices
Values
X13(capital)
Years

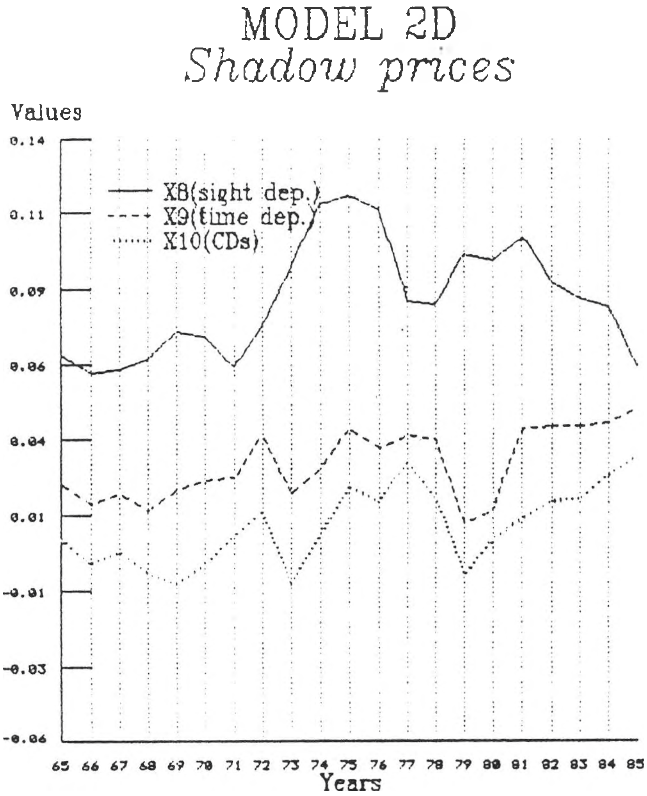

MODEL 2C
Shadow prices
Values
constr.(1)
Years

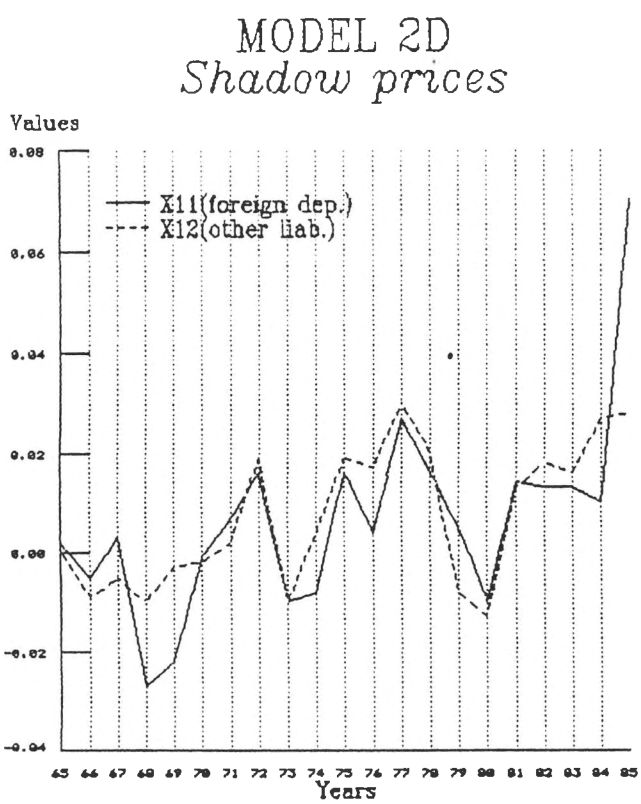

MODEL 2C
Shadow prices
Values
X8(sight dep.)
X9(time dep.)
X10(CDs)
Years

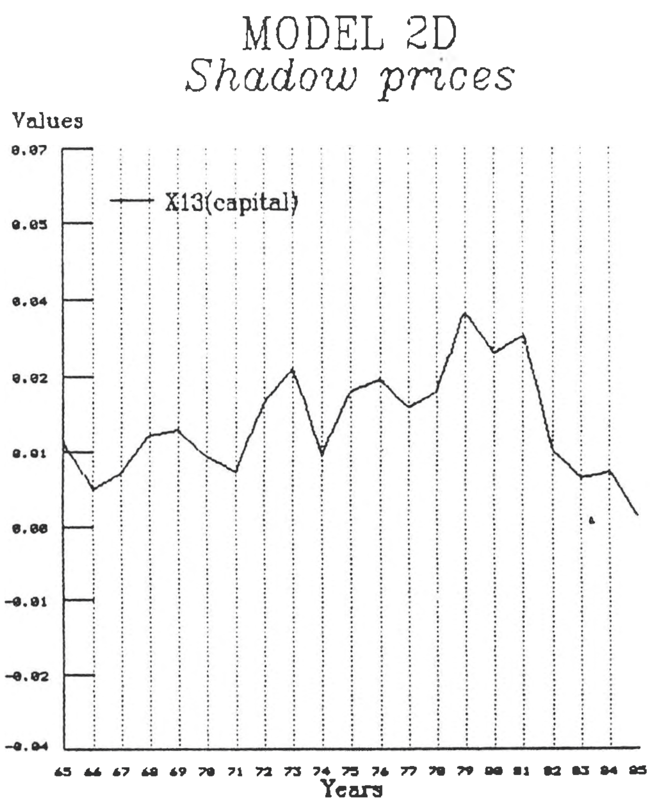

MODEL 2C
Shadow prices
Values
X11(foreign dep.)
X12(other liab.)
Years

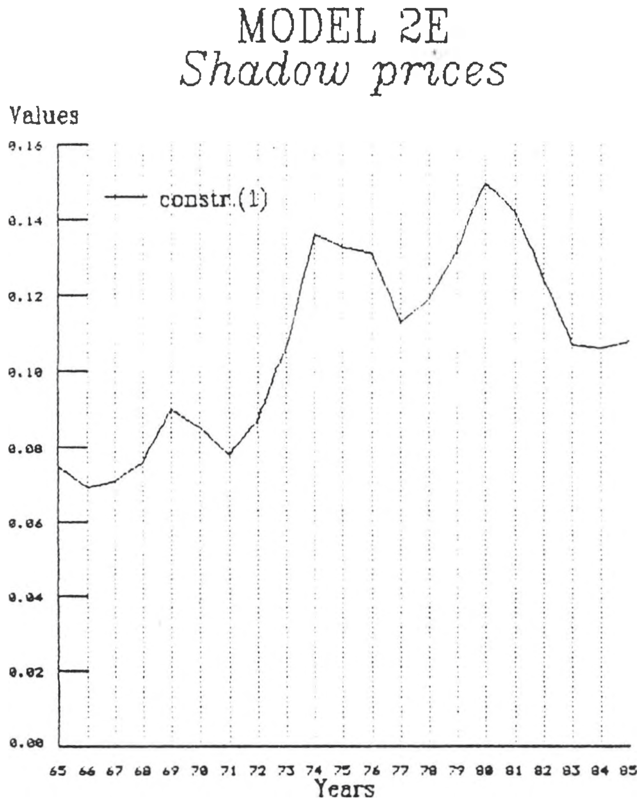

MODEL 2C
Shadow prices
Values
X13(capital)
Years

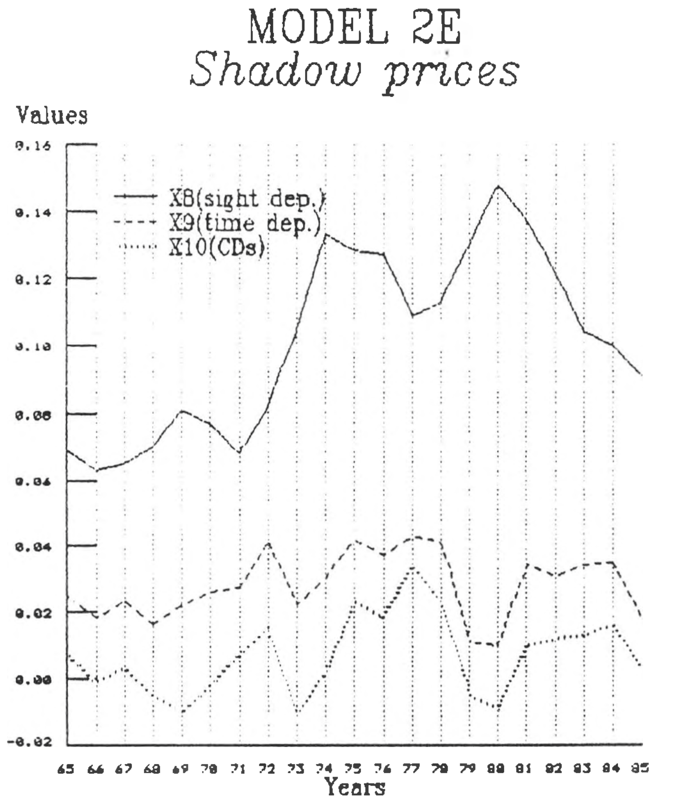

MODEL 2D
Shadow prices
Values
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
constr.(1)
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
Years

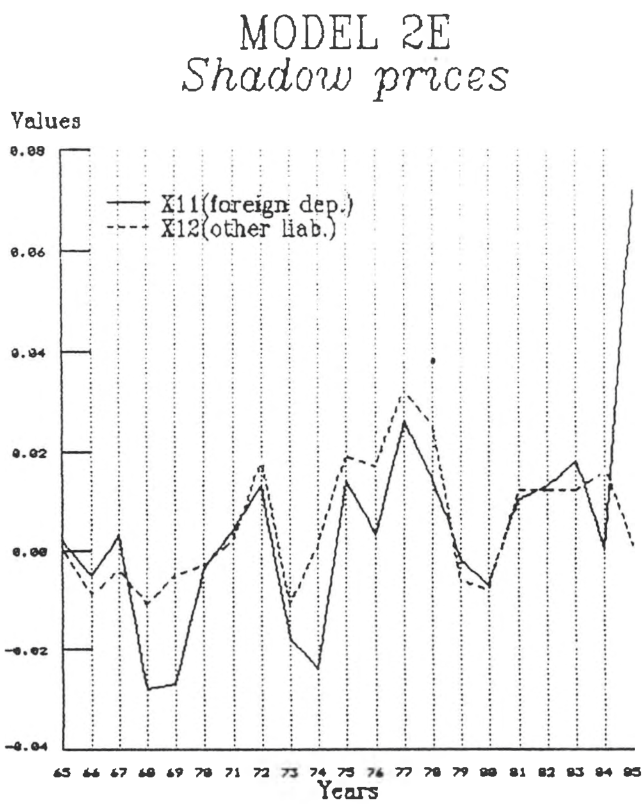

MODEL 2D
Shadow prices
Values
0.14
0.11
0.09
0.06
0.04
0.01
-0.01
-0.03
-0.06
X8(sight dep.)
X9(time dep.)
X10(CDs)
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
Years

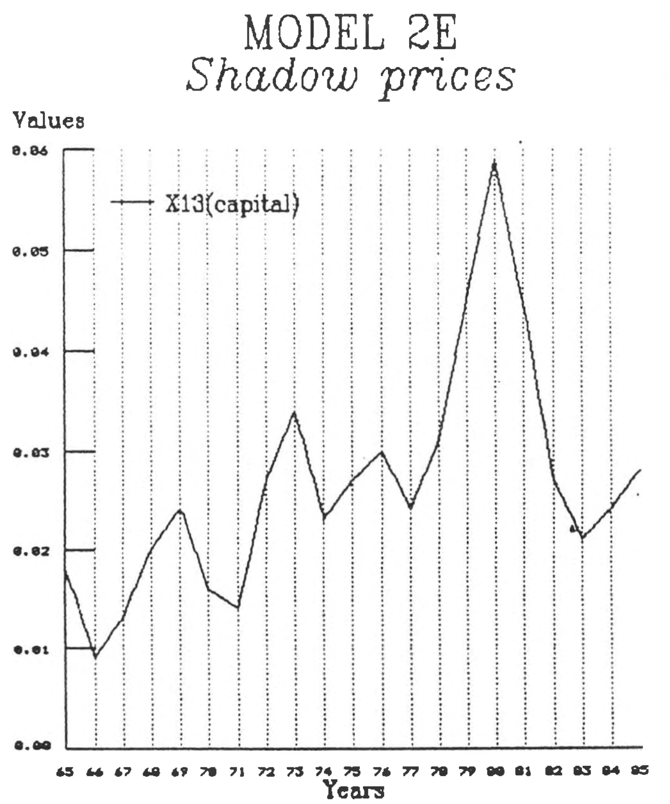

MODEL 2D
Shadow prices
Values
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
X11(foreign dep.)
X12(other liab.)
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
Years


MODEL 2D
Shadow prices
Values
0.07
0.05
0.04
0.02
0.01
0.00
-0.01
-0.02
-0.04
X13(capital)
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
Years

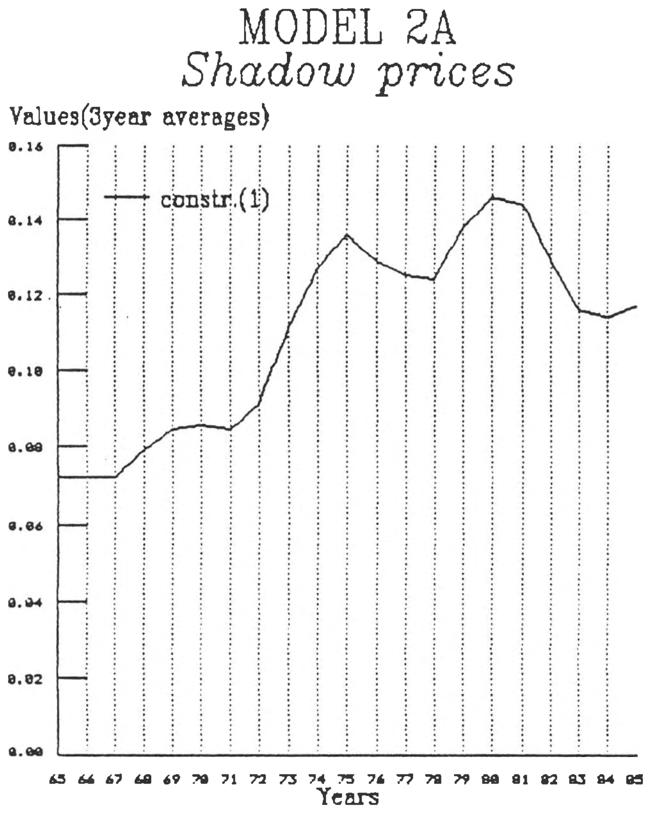

MODEL 2E
Shadow prices
Values
constr.(1)
Years

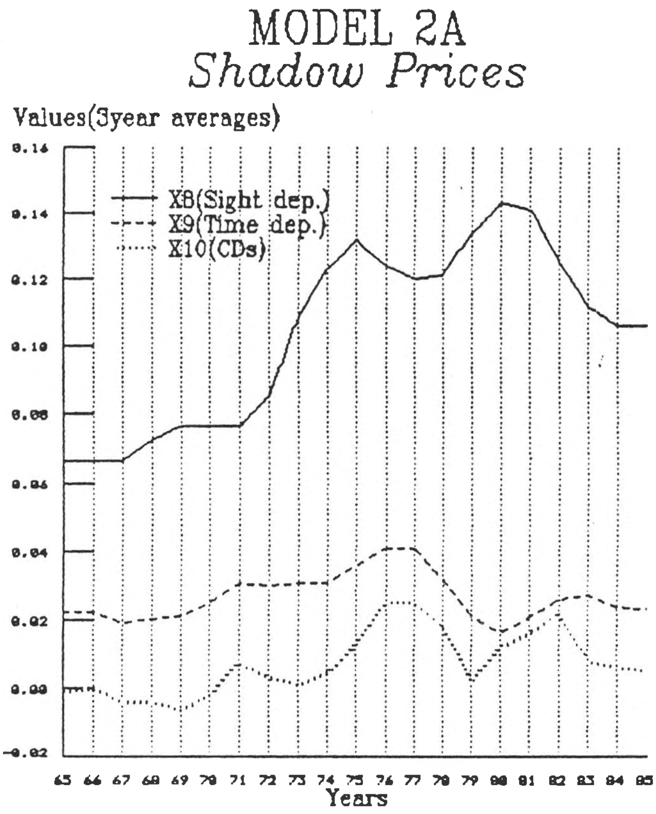

MODEL 2E
Shadow prices
Values
X8(sight dep.)
X9(time dep.)
X10(CDs)
Years

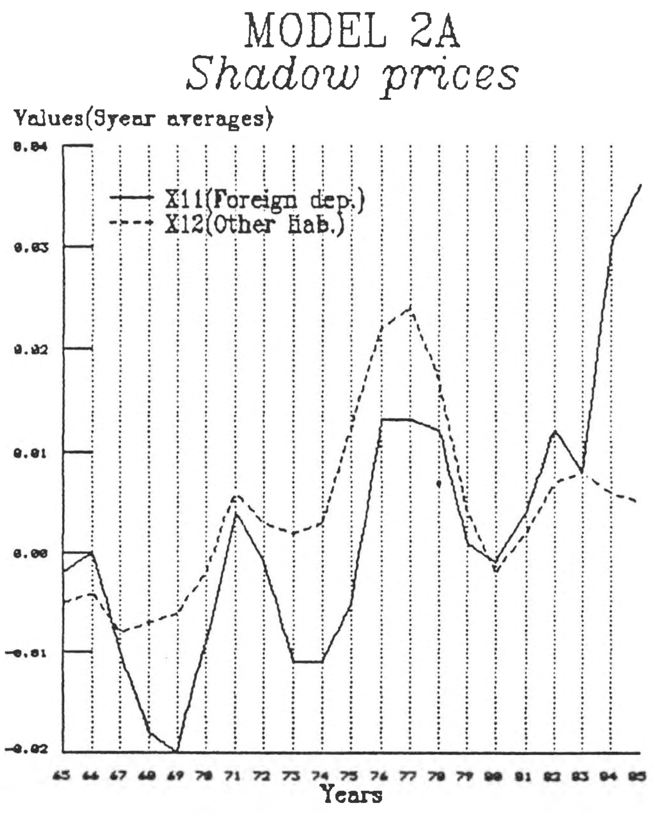

MODEL 2E
Shadow prices
Values
X11(foreign dep.)
X12(other liab.)
Years

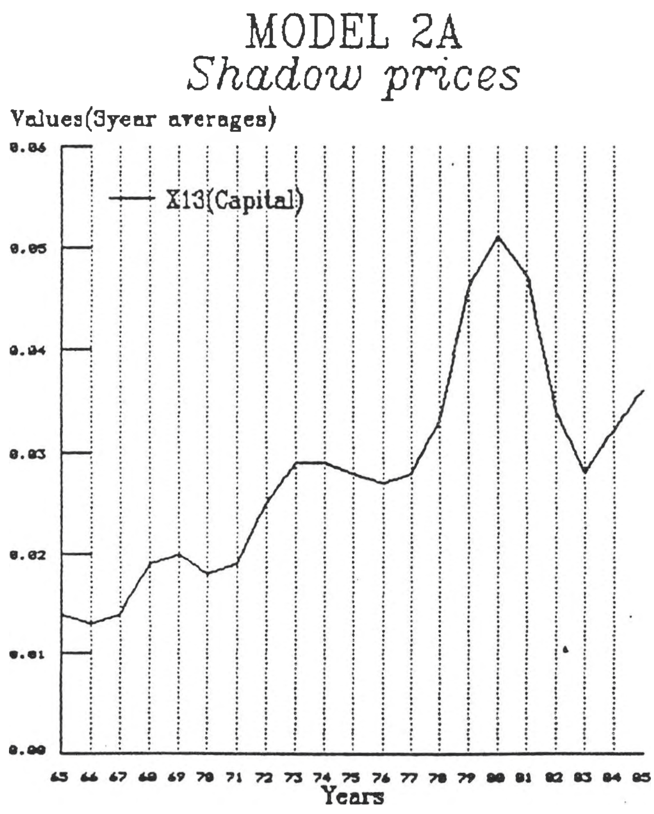

MODEL 2E
Shadow prices
Values
X13(capital)
Years

Results after smoothing

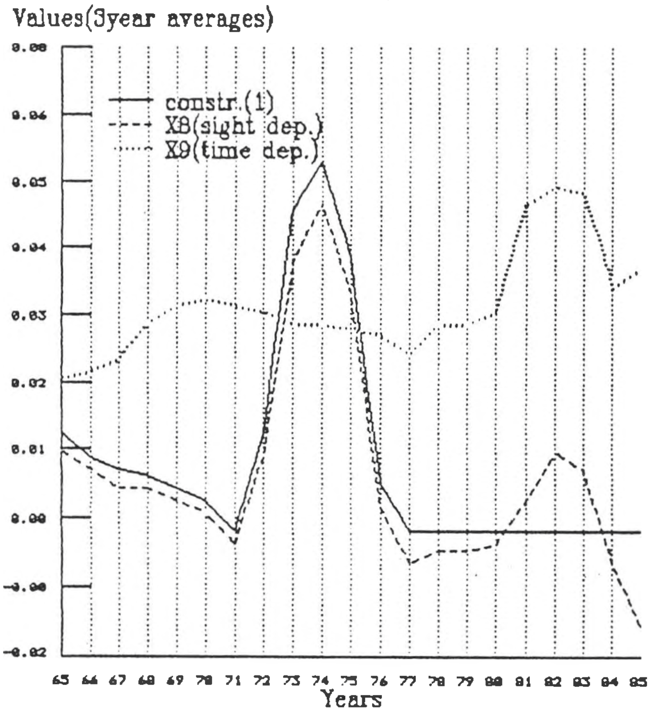

MODEL 2A
Shadow prices
Values(3year averages)
constr.(1)
Years


MODEL 2A
Shadow Prices
Values(3year averages)
X8(Sight dep.)
X9(Time dep.)
X10(CDs)
Years

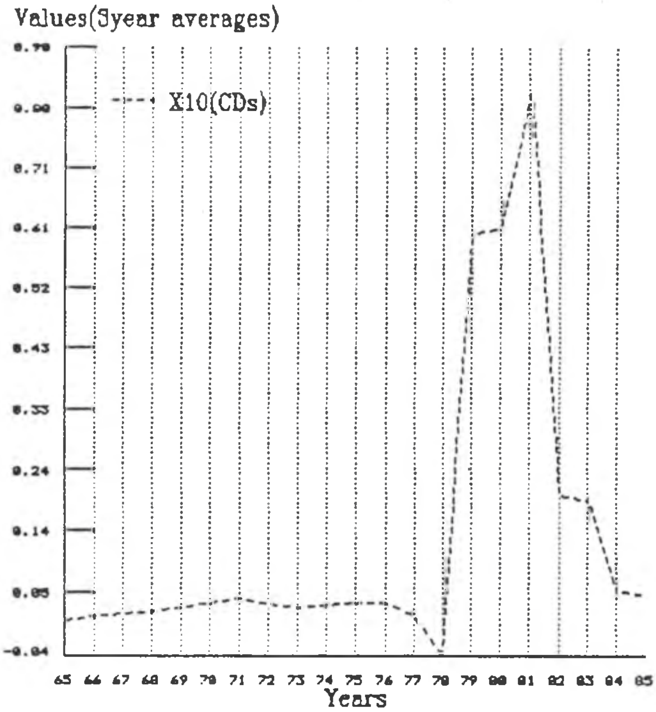

MODEL 2A
Shadow prices
Values(3year averages)
X11(Foreign dep.)
X12(Other liab.)
Years


MODEL 2A
Shadow prices
Values(3year averages)
X13(Capital)
Years

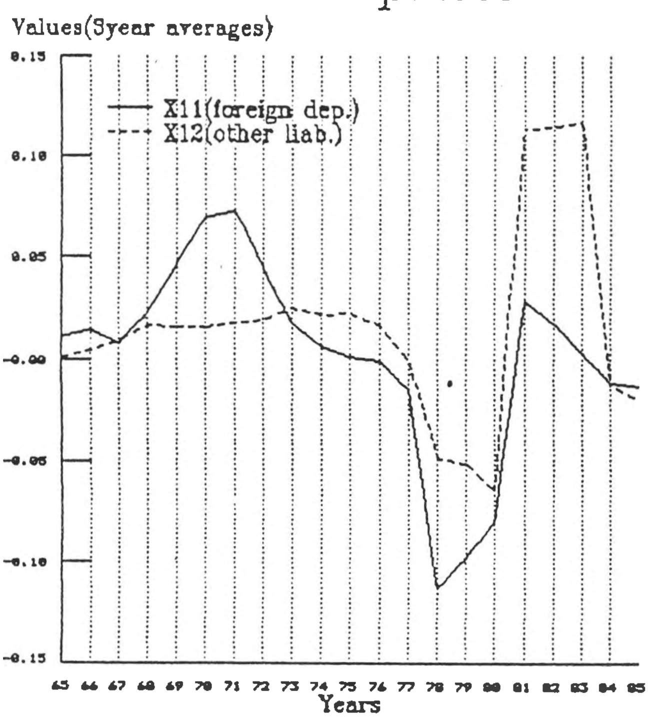
MODEL 2B
Shadow prices



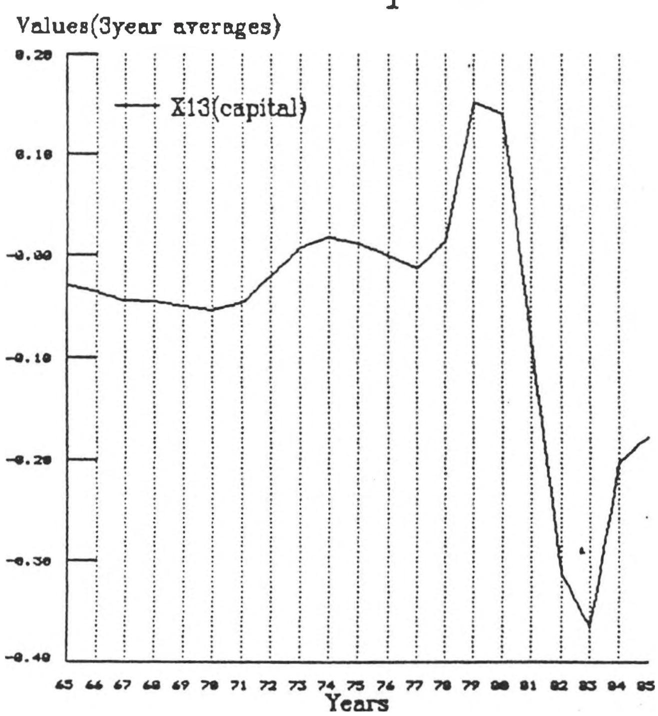
MODEL 2B
Shadow prices



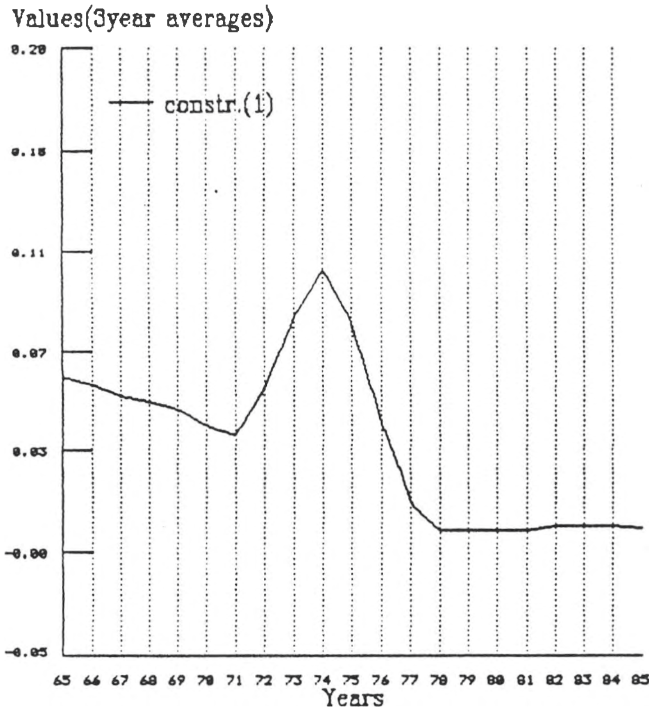
MODEL 2B
Shadow prices



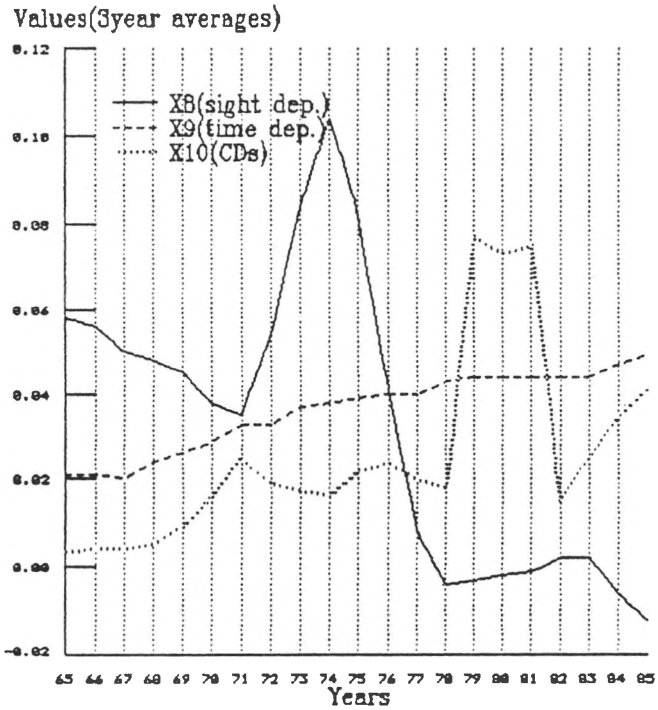
MODEL 2B
Shadow prices



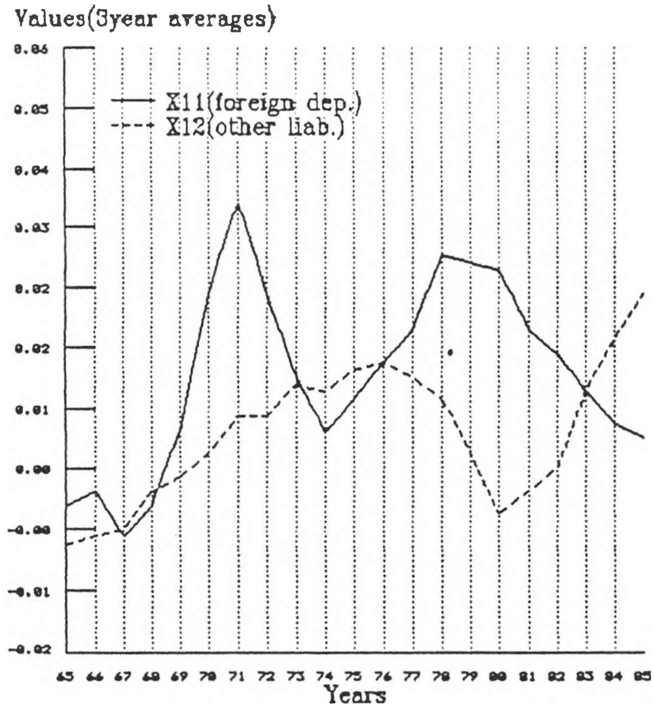
MODEL 2C
Shadow prices



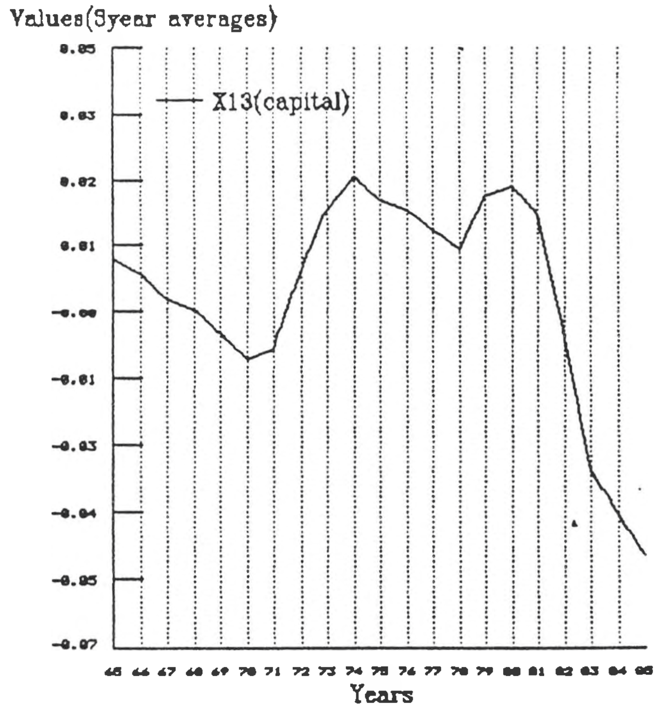
MODEL 2C
Shadow prices

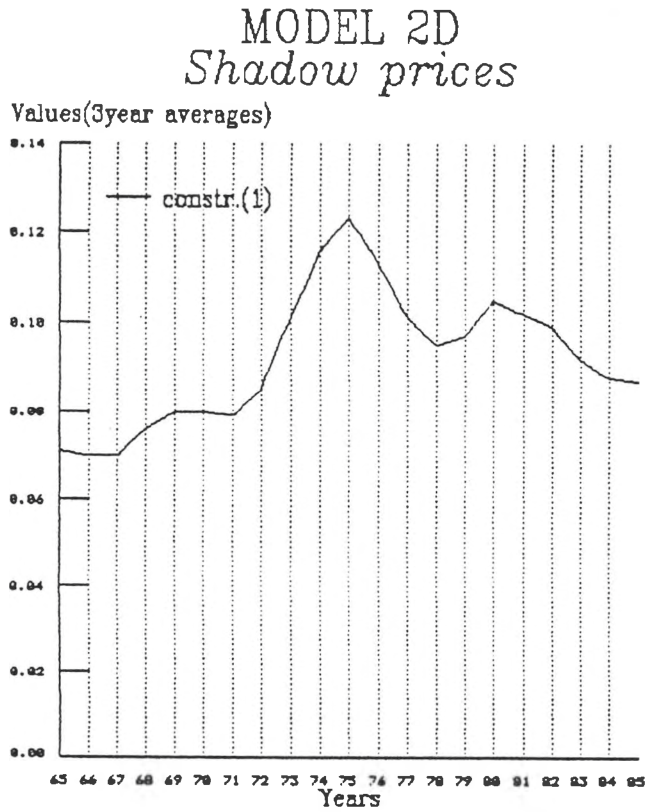


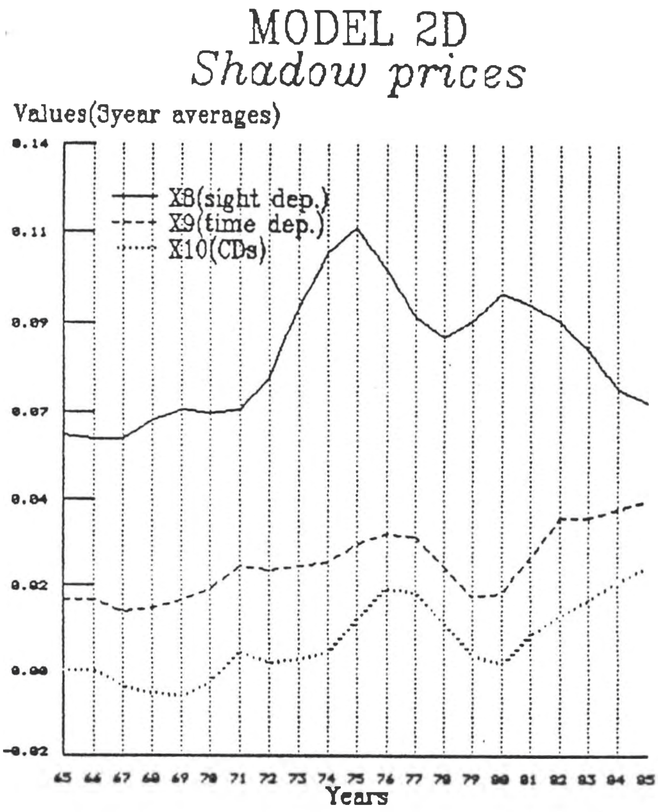
MODEL 2C
Shadow prices

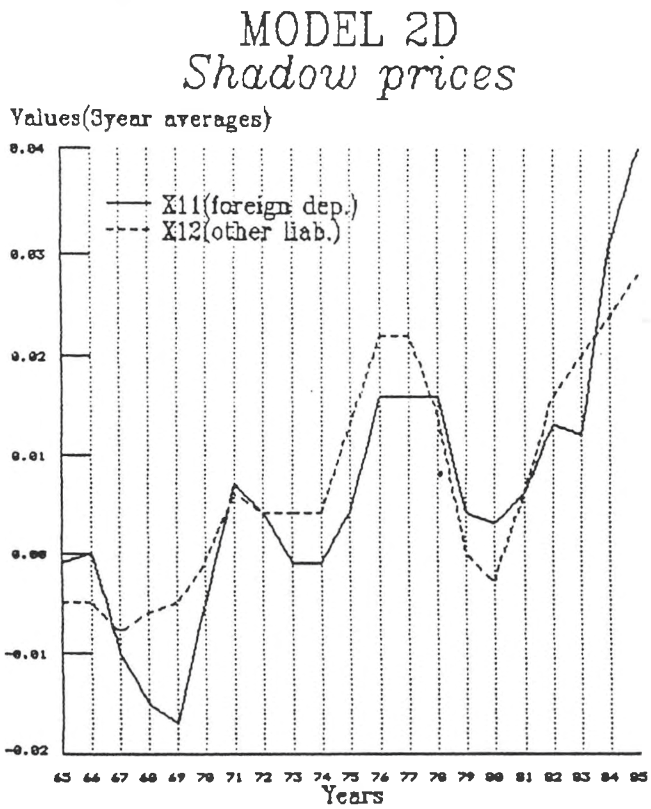


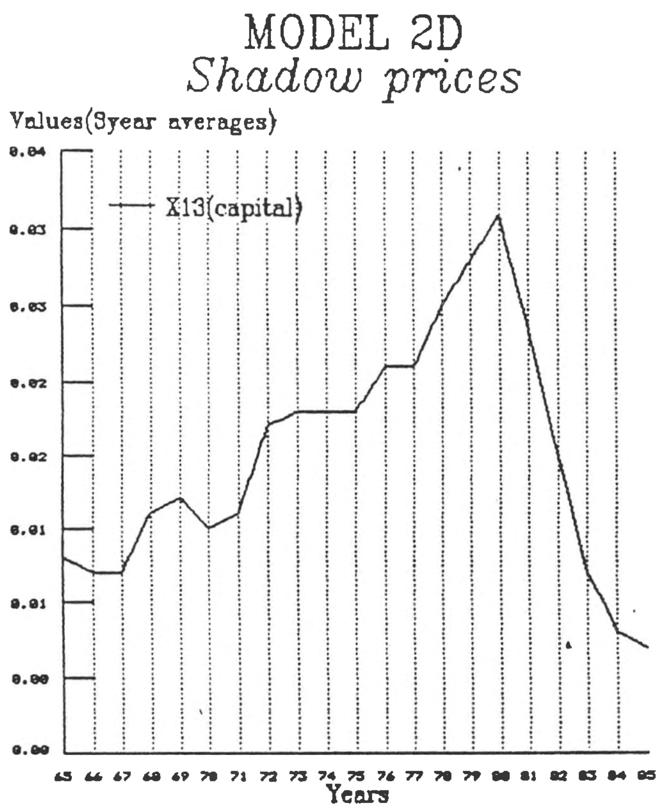
MODEL 2C
Shadow prices

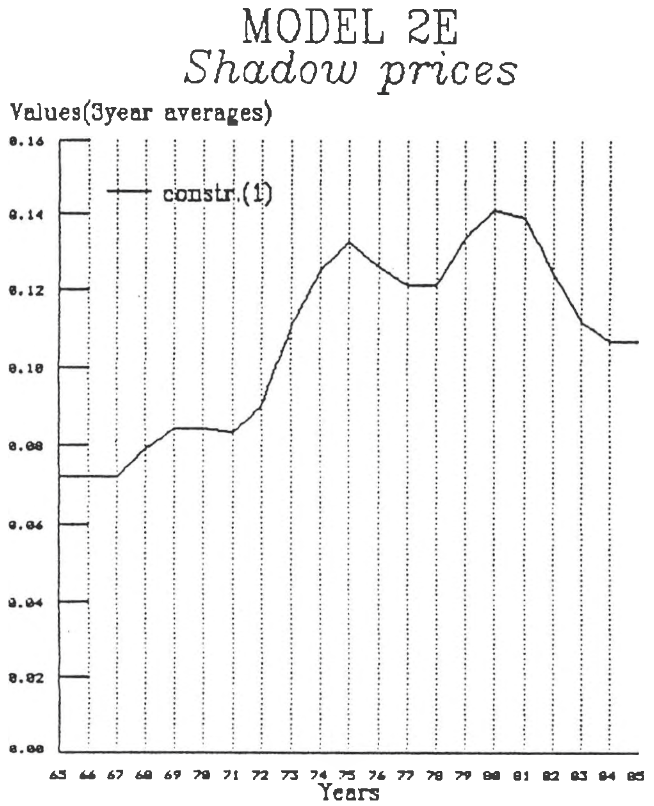


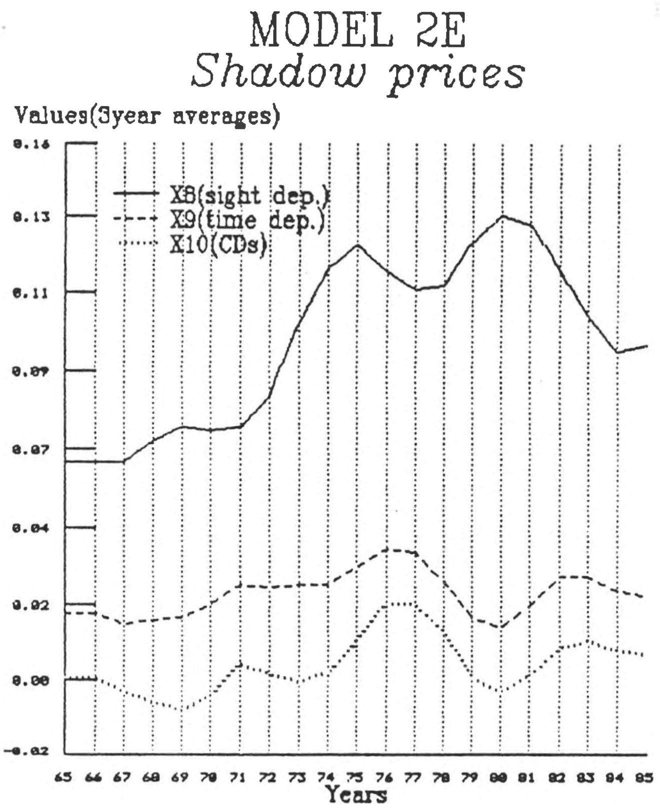

MODEL 2D
Shadow prices
Values(3year averages)
constr.(1)
Years

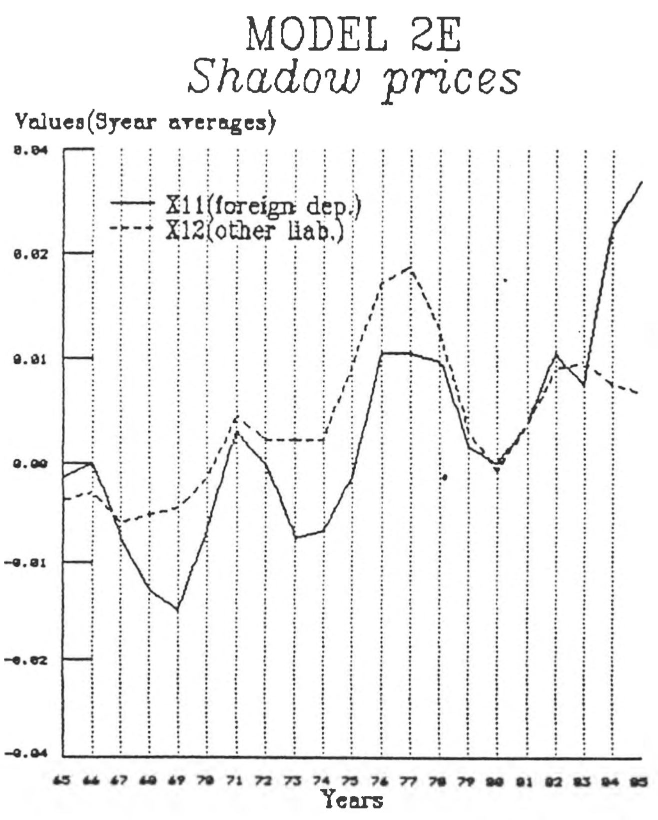

MODEL 2D
Shadow prices
Values(3year averages)
X8(sight dep.)
X9(time dep.)
X10(CDs)
Years

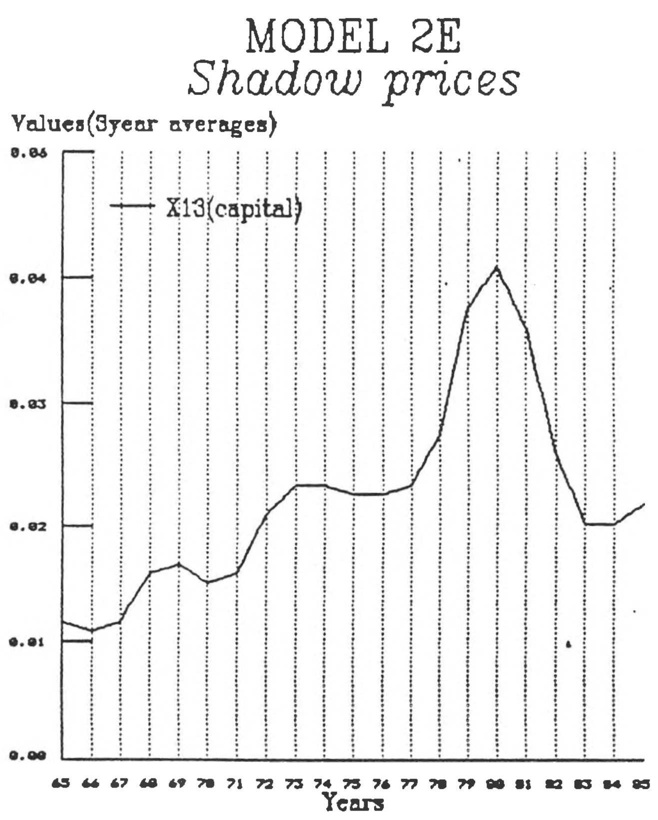

MODEL 2D
Shadow prices
Values(3year averages)
X11(foreign dep.)
X12(other liab.)
Years


MODEL 2D
Shadow prices
Values(3year averages)
X13(capital)
Years


MODEL 2E
Shadow prices
Values(3year averages)
constr.(1)
Years


MODEL 2E
Shadow prices
Values(3year averages)
X8(sight dep.)
X9(time dep.)
X10(CDs)
Years


MODEL 2E
Shadow prices
Values(3year averages)
X11(foreign dep.)
X12(other liab.)
Years


MODEL 2E
Shadow prices
Values(3year averages)
X13(capital)
Years

Discussion of Model's 2 results

In the previous diagrams the results from five simulations of the quadratic programming model were shown. In Model 2A the shadow prices of the linear programming version of Model 2 are presented, while in Models 2B, 2C, 2D and 2E we can see the shadow prices of the quadratic model for the different values of the risk aversion parameter b that were specified; the value of b ranging from b=1 (extremely risk averse behaviour assumed) and b=1/1000 (low risk aversion) respectively.

The results of the optimisation for the various versions of model 2 have shown that the assumption that b=1 is implausible while b=0.1 is unlikely since under both assumptions the results of the optimisation show an abnormally high proportion of funds being allocated to cash; this being a reflection of the highly restrictive risk aversion behaviour assumed. The other two specifications of b give more plausible results in terms of optimal allocation of funds and therefore the resulting shadow prices are more relevant for our study. In the following tables the asset allocation derived from the various simulations of Model 2 is given so that it can be compared with the data of the actual bank portfolios (presented in Appendix 3).

TABLE 14

MODEL 2A

ASSET ALLOCATION

	X1 CASH	X2 M. at Call	X3 BILLS	X4 INVEST.	X5 LOANS	X6 $LOANS
1965	652.9	0	3198.1	0	4653	0
1966	679.3	0	1698.2	1667.5	4732	0
1967	708.2	0	3622.8	0	4725	0
1968	760.9	0	3795.1	0	0	5075
1969	769	0	1922.4	1701.6	0	5328
1970	788.5	0	1971.2	1567.3	0	5623
1971	878.6	0	2196.4	1982	5991	0
1972	820	0	1520.1	1992.9	9081	0
1973	915.9	0	2240.6	1166.5	0	12460
1974	962	0	2883	993.1	0	15586
1975	1032.6	0	3110.2	1444.2	22738	0
1976	1035.5	0	3291.8	1314.7	0	22537
1977	1064.1	0	0	22487.4	6414.5	0
1978	1163.9	0	4232	1822.1	28718	0
1979	1273	0	6099	0	34976	0
1980	1391.7	0	6212.9	0	43379.4	0
1981	1285.7	0	3122.4	4235.9	54356	0
1982	1070	0	3362.7	4643.3	69191	0
1983	1231.7	0	4134.9	5246.5	79962	0
1984	1364.1	0	4287.3	5297.6	0	90381
1985	1396.6	8551.4	0	0	110648	0

TABLE 15

MODEL 2B

ASSET ALLOCATION

	X1 CASH	X2 M. at Call	X3 BILLS	X4 INVEST.	X5 LOANS	X6 $LOANS
1965	652.9	0	2034.5	1163.7	4653	0
1966	1984.1	0	393.4	1667.5	4732	0
1967	2198.3	0	280.6	1852.2	4725	0
1968	2520.6	0	142.4	1892.9	5075	0
1969	2553.3	0	138.1	1701.6	5328	0
1970	3418.5	0	0	908.5	5623	0
1971	3467.1	0	0	1589.9	5991	0
1972	2862.9	979.2	459.4	2650.4	6462	0
1973	915.9	726.5	1260.3	3213.5	10096.3	570.5
1974	962	83.8	2438.5	3901.2	11764.7	1273.7
1975	1032.6	2839.6	0	5039	19060.5	353.3
1976	3836.5	0	2972.5	3348.8	15685.7	2335.6
1977	5251.4	0	3162.1	3776.8	14793.4	2982.3
1978	7093.8	0	4066.6	3527.5	17832.1	3416
1979	7348.5	0	6036.2	0	28883.1	56.3
1980	8272.3	0	5447.6	7152.3	19900.5	10211.2
1981	9373.5	0	0	8778.8	27454.1	17393.6
1982	9115.5	0	44413.7	9922.7	0	14815.1
1983	12185	152.8	0	12336.9	40215	25685.3
1984	17976.7	0	10930.7	8098.3	34804.9	29519.4
1985	15643.9	13837.9	0	17342.2	35378.9	38393

TABLE 16

MODEL 2C

ASSET ALLOCATION

	X1 CASH	X2 M.at Call	X3 BILLS	X4 INVEST.	X5 LOANS	X6 $LOANS
1965	652.9	0	3198.1	0	4653	0
1966	679.3	0	1698.2	1667.5	4732	0
1967	708.2	0	1770.6	1852.2	4725	0
1968	760.9	0	1902.2	1892.2	523.5	4551.5
1969	769	0	1922.4	1701.6	2805.3	2522.7
1970	788.5	0	1971.2	1567.3	5623	0
1971	878.6	0	2196.4	1982	5991	0
1972	820	0	1442.4	2620.1	8531.5	0
1973	915.9	0	2240.6	1166.5	11096.5	1363.5
1974	962	0	2784.7	1785.9	12519.4	2372.1
1975	1032.6	1969.1	621.3	5211.2	19467.9	23.1
1976	1035.5	2146.8	1145	1314.7	21847	689.9
1977	2395.1	0	3475.7	1921.4	22173.8	0
1978	4186.2	0	4408.8	0	26964.3	376.8
1979	4168.1	0	5132.9	0	33047	0
1980	5706.5	0	5446.5	7162.8	24005.5	8662.8
1981	5924.1	0	0	13669.9	27496	15909.9
1982	6231.1	0	0	15325.1	34269.5	22441.4
1983	5366.5	0	0	20015.8	40237.1	24955.5
1984	5651.4	0	0	24350.3	45591.9	25736.4
1985	6060.1	16442.1	0	30489.4	43284.5	24319.9

TABLE 17

MODEL 2D

ASSET ALLOCATION

	X1 CASH	X2 M.at Call	X3 BILLS	X4 INVEST.	X5 LOANS	X6 $LOANS
1965	652.9	0	3198.1	0	4653	0
1966	679.3	0	1698.2	1667.5	4732	0
1967	708.2	0	3622.8	0	4725	0
1968	760.9	0	1902.2	1892.2	0	5075
1969	769	0	1922.4	1701.6	0	5328
1970	788.5	0	1971.2	1567.3	5623	0
1971	878.6	0	2196.4	1982	5991	0
1972	820	0	1520.1	1992.9	9081	0
1973	916	0	2240.6	1166.5	5611.1	6848.9
1974	962	0	2883	993.1	3536.1	12049.9
1975	1032.6	0	2608	5083.4	19601	0
1976	1035.5	0	3291.8	1314.7	20557.8	1979.2
1977	1064.1	0	2583.9	7198.2	19119.9	0
1978	1163.9	0	4232	1822.1	28718	0
1979	1273	0	6099	0	34976	0
1980	1391.7	0	6212.9	0	43379.4	0
1981	1285.7	0	3122.4	16903.2	31750.3	9938.3
1982	1070	0	3362.7	17792.7	42286.2	13755.5
1983	1231.7	0	4134.9	20796.2	48596	15816.3
1984	1364.1	4287.3	0	23493.3	43605.4	28579.9
1985	1396.6	4771.6	0	26755.8	87672.1	0

TABLE 18

MODEL 2E

ASSET ALLOCATION

	X1 CASH	X2 M. at Call	X3 BILLS	X4 INVEST.	X5 LOANS	X6 $LOANS
1965	652.9	0	3198.1	0	4653	0
1966	679.3	0	1698.2	1667.5	4732	0
1967	708.2	0	3622.8	0	4725	0
1968	760.9	0	1902.2	1892.9	0	5075
1969	769	0	1922.4	1701.6	0	5328
1970	788.5	0	1971.2	1567.3	3692.5	1930.5
1971	878.6	0	2196.4	1982	5991	0
1972	820	0	1520.1	1992.9	9081	0
1973	915.9	0	2240.6	1166.4	0	12460
1974	962	0	2883	993	0	15586
1975	1032.6	0	2882.2	3096.1	21314	0
1976	1035.5	0	3291.8	1314.7	2324.5	20212.6
1977	1064.1	0	0	22487.4	6414.5	0
1978	1163.9	0	4232	1822.1	28718	0
1979	1273	0	6099	0	34976	0
1980	1391.7	0	6212.9	0	43379	0
1981	1285.7	0	3122.4	4235.9	54356	0
1982	1070	0	3362.7	4643.3	69191	0
1983	1231.7	0	4134.9	5246.5	79962	0
1984	1364.1	4287.3	0	5297.6	51819.6	38561.4
1985	1396.6	8551.4	0	0	110648	0

Model 2A.

The shadow prices of the linear version of Model 2 are very similar to the results from Model 1D.

(a) Looking at the shadow prices of sterling deposits we want to examine the innovations of £ CDs in 1971 and interest bearing sight deposits in 1981 and 1984. The modest peak in the shadow prices of time deposits and CDs in 1971 seems to explain the pressure to introduce Certificates of Deposit. Other major peaks in shadow prices occur in 1976-77 and in 1982. The later reflects the pressures leading to the innovation of interest rate sight deposits.

(b) Let us now turn to the shadow prices of foreign currency ($) deposits. We observe peaks in 1966, 1971, 1977, 1982 and 1985. This seems to explain the 1971 and 1972 innovations and reflect the increased internationalisation of banks' liabilities during the 80s. The amount of $CDs has increased in 1982 by 72% over the previous year, while in 1985 the increase was 93%.

(c) The shadow prices of capital show a modest peak in 1968-69 and two major peaks in 1974 and 1980. These peaks show quite accurately the problems of capital adequacy faced by the clearing banks that led to the adoption of loan capital instruments in 1968, floating rate notes and perpetual floating rate notes in 1975 and 1984-85 respectively.

(d) Finally the shadow prices of the balance sheet constraint show a continuous upward trend during that period with two major peaks in 1975 and 1980. As we have seen already, similar trends were demonstrated by various versions of Model 1 and reflect quite well the innovations of liability management in the 1970s and the adoption of variable rate lending instruments in mid 1970s as well as mortgage lending and off-balance sheet activities and securitisation in the 1980s.

Model 2B

In general, under the (unlikely) assumption of extreme risk aversion by banks Model 2B (b=1) gives rather disappointing results. The shadow prices of sight and time deposits show major peaks in 1974 and 1982 while the shadow prices of sterling CDs are jumping to a significant peak in 1981. Innovations in foreighn liabilities are better explained. There is a peak in 1971 prior to the introduction of dollar liabilities and CDs that reflects the innovative pressures felt by the banks during that year. Another peak in the shadow prices of foreign currency libilities occurs in 1981 reflecting the spectacular growth in the eurodollar businness of the London clearing banks that we have mentioned before. The shadow prices of capital seem to explain only the 1975 innovation (floating rate notes) while the earlier innovation of subordinated loan capital is not reflected in the shadow prices. However, the capital adequacy problems of the 1980s are reflected in rising shadow prices in the period 1978-1981 and from 1984 to 1985. Finally the overall pressures generated by the balance sheet constraint are not particularly succesful in explaining the off-balance sheet innovations of the 1980s. However there is a peak in 1974 that seems to reflect the increasing involvement of banks in liability management and the switch to variable rate instruments.

Model 2C.

The results from this simulation are better in explaining major innovations. In particular, the shadow prices of sterling CDs are showing a peak in 1971 that seems to explain the innovation of CDs introduced in 1971 by the London clearing banks. Shadow prices of dollar liabilities show major peaks in 1971 and 1978 reflecting the innovative pressures felt by the clearing banks prior to the introduction of dollar deposits and CDs in 1971-72. The shadow prices of capital are similar to the values calculated for Model 2B.

Models 2D and 2E.

The shadow prices derived from the simulations of both these versions of Model 2 are almost identical and quite similar to those obtained from the linear version of the model (Model 2A). This is the result of the lower values attached to the risk aversion parameter b in both these versions of Model 2. As $b \to 0$ the results of the optimisation tend to be equal to those of the linear version of the model.

The innovative pressures are depicted relatively well in these versions of the model. There is a rise in the shadow prices of £ CDs and time deposits prior to their introduction in 1971 with another peak in 1976 while shadow prices of foreign deposits show a peak also in 1971 and again in 1977 and 1985..The shadow price of capital shows three major peaks in 1969, 1974 and 1980. Finally the shadow prices of the balance sheet constraint show two major peaks in 1975 and 1980 and a modest peak in 1969.

VII.3 Formal test of the constraint-induced innovations hypothesis.

Having examined the results from the simulations of both models we will now offer a more formal test of the constraint induced innovations hypothesis by applying a χ^2 test. It is well known that Chi-squared is used for testing the null hypothesis that two criteria of classification, when applied to sample populations, are independent. Two criteria of classification are defined to be independent if the distribution of one criterion in no way depends on the distibution of the other criterion. If two criteria of classification are not independent then there is a degree of association between the two criteria.

In our case the sample population has 21 observations (years 1965-85); the first criterion of classification running down the rows is the existence of a peak in the shadow price line of a particular fund category or constraint and the second criterion of classification running across the columns is the introduction or not of an innovation.

A χ^2 test with one degree of freedom at 0.10 level of significance will be performed for the hypothesis:

Ho: Peaks and troughs in shadow prices are independent of the introduction or not of an innovation.

A rejection of the null hypothesis supports our theory.

The χ^2 test was selected because of its simplicity and adequacy for the specific purposes of this study.

Number of years

		YEAR t shadow prices	
		Peak	Normal/trough
year t,t+1 /	Innovation		
	No Innovation		

The definition of financial innovations has to be expanded in order to be able to carry out the test more accurately; so we will count as additional innovations changes in liabilities or capital above 60% over the previous year that represent a considerable shift in the banks operations and can be considered as process innovations. A detailed account of the dates of introduction of various innovations as used in the tests as well as of the major peaks in shadow prices derived from the simulations of the two models is given in Appendix 6.

In the following tables the results of the χ^2 tests for the various versions of the models of this study are presented.

Results of χ^2 tests

$\chi^2_{0.010} = 2.706$

MODEL 1A
(3year averages)

	χ^2 value	Ho
SD10	2.302	ACCEPT
CD12	0.52	ACCEPT
OC13	0.835	ACCEPT
OCCD14	1.211	ACCEPT
SRC15	0.463	ACCEPT
LC17	0.463	ACCEPT
PFRN18	**13.263**	**REJECT**
(1)	**13.263**	**REJECT**

MODEL 1B
(3year averages)

	χ^2 value	Ho
SD10	0.368	ACCEPT
CD12	0.463	ACCEPT
OC13	0.175	ACCEPT
OCCD14	0.010	ACCEPT
SRC16	0.463	ACCEPT
LC17	0.463	ACCEPT
PFRN18	0.368	ACCEPT
(1)	**13.263**	**REJECT**

MODEL 1C

(3year averages)

	χ^2 value	Ho
SD10	0.232	ACCEPT
CD12	**5.147**	**REJECT**
OC13	0.463	ACCEPT
OCCD14	0.296	ACCEPT
SRC16	0.113	ACCEPT
LC17	**3.070**	**REJECT**
PFRN18	**9.394**	**REJECT**
(1)	**21**	**REJECT**

MODEL 1D

(3year averages)

	χ^2 value	Ho
SD10	**4.202**	**REJECT**
CD12	**5.147**	**REJECT**
OC13	**5.147**	**REJECT**
OCCD14	0.296	ACCEPT
SRC16	0.463	ACCEPT
LC17	0.463	ACCEPT
PFRN18	**4.202**	**REJECT**
(1)	**21**	**REJECT**

MODEL 2A

(3year averages)

	χ^2 value	Ho
X8	4.202	REJECT
X10	14.875	REJECT
X11	3.696	REJECT
X13	5.219	REJECT
(1)	21	REJECT

MODEL 2B

(3year averages)

	χ^2 value	Ho
X8	0.232	ACCEPT
X10	**14.875**	**REJECT**
X11	2.009	ACCEPT
X13	2.488	ACCEPT
(1)	**9.975**	**REJECT**

MODEL 2C

(3year averages)

	χ^2 value	Ho
X8	**4.202**	**REJECT**
X10	**10.032**	**REJECT**
X11	0.810	ACCEPT
X13	0.497	ACCEPT
(1)	**9.975**	**REJECT**

MODEL 2D
(3year averages)

	χ^2 value	Ho
X8	4.202	REJECT
X10	9.394	REJECT
X11	3.696	REJECT
X13	0.884	ACCEPT
(1)	21	REJECT

MODEL 2E
(3year averages)

	χ^2 value	Ho
X8	4.202	REJECT
X10	5.147	REJECT
X11	3.696	REJECT
X13	2.488	ACCEPT
(1)	4.202	REJECT

The above tests show that out of the nine versions of the models tested, the shadow prices of sight deposits support the constraint induced innovations hypothesis in five models, the shadow prices of certificates of deposit support the hypothesis in seven models, the shadow prices of dollar deposits support the hypothesis in four models, the shadow prices of capital support the hypothesis in four models, while the shadow prices of the balance sheet constraint (1) support the constraint induced innovations hypothesis in all nine versions of the models. Model 2A in particular explains accurately the majority of the innovations under consideration.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The empirical results of the two models presented in this thesis seem to support, up to a certain degree, the constraint-induced innovations hypothesis. The statistical (χ^2) tests conducted in Chapter VII seem to suggest that rising shadow prices can predict innovative behaviour in 37.5% of cases (on average) in the various versions of Model 1 and 72% of cases in the various versions of Model 2.

However, the above results should be viewed with caution, taking into account the limitations of the research.

VIII.1. Limitations of the research.

1) A major problem in the formulation of the models was the estimation of the values of the various self-imposed constraints. This problem was aggravated by the flexibility of the rules for capital adequacy in the UK which makes it difficult to estimate the exact values imposed by the regulatory authorities. The approach adopted in the present study was to use observed ratios and to allow them to vary over a significant range in order to test the effect of these changes on the models' results. An alternative method would be to use questionaires hoping to extract the necessary information from the Clearing banks' management themselves.

A related problem is the definition of the banks' objective function. What do banks maximise? The present study assumes profit maximisation. An alternative approach would be utility maximisation. However, in the second approach we could get a much more complicated situation in terms of data requirements as well as computational requirements.

2) In the linear model (Model 1) the objective function is risk-neutral and in the absense of any constraints, all available funds would be allocated to the highest yielding asset. The imposition of linear constraints allows a degree of diversification to the optimal asset allocation derived from the model. However, this problem is eliminated in the second model, where risk averse behaviour is embodied in the objective function.

3) Estimating cost and revenue data imposes another set of serious problems. First of all it is difficult to estimate operational costs for each liability category separately. On the other hand there is the problem of valuation of capital. By accounting convention assets and liabilities are measured in the balance sheets on the basis of historical cost, which may be grossly inaccurate and thus give rise to a false picture if there is a marked divergence between historical cost and current cost, particularly in periods of high inflation. Thus, capital as stated in published balance sheets may be unrealistic. This point was stressed by B. Wesson (1985) who emphasised the importance of current cost adjustment to historical cost figures. However, it is very difficult to find a satisfactory solution to the problem of valuation of capital. It seems that, so far, the most satisfactory approach to evaluate bank capital is book value. When measuring the cost of capital it is however preferable to use market values. One popular way of defininig the cost of equity capital is by applying the formula: $k = D/P + g$, where k is the rate of return on equity, D is the annual cash dividend, P is the observed market price and g is the annual growth rate of earnings.

Related with this is the problem of discontinuity in the capital data series concerning the London Clearing Banks since before 1969 they were allowed to keep hidden reserves and they were not obliged to publish their true profits. As a result, there appears to be an undercapitalisation of the Clearing banks before 1970. However, we might argue that as long as decision makers were basing their decisions on publicly available data this discontinuity will not affect significantly our results.

4) Our conclusions were based on the results of the models' simulations after allowing for smoothing of the shadow prices by using 3-year moving averages. If we look at the unadjusted values we observe a greater level of fluctuations in shadow prices which may alter our conclusions up to a certain extent. In the following tables the test results for the unsmoothed shadow price series are given:

Results of χ^2 tests

$\chi^2_{0.010} = 2.706$

MODEL 1A

	χ^2 value	Ho
SD10	1.373	ACCEPT
CD12	1.868	ACCEPT
OC13	0.038	ACCEPT
OCCD14	4.947	**REJECT**
SRC16	1.111	ACCEPT
LC17	5.219	**REJECT**
PFRN18	5.526	**REJECT**
(1)	7.073	**REJECT**

MODEL 1B

	χ^2 value	Ho
SD10	1.373	ACCEPT
CD12	0.113	ACCEPT
OC13	2.488	ACCEPT
OCCD14	0.100	ACCEPT
SRC16	1.544	ACCEPT
LC17	1.868	ACCEPT
PFRN18	0.835	ACCEPT
(1)	9.394	**REJECT**

MODEL 1C

	χ^2 value	Ho
SD10	2.302	ACCEPT
CD12	0.113	ACCEPT
OC13	0.175	ACCEPT
OCCD14	0.010	ACCEPT
SRC16	0.003	ACCEPT
LC17	1.868	ACCEPT
PFRN18	7.073	**REJECT**
(1)	7.073	**REJECT**

MODEL 1D

	χ^2 value	Ho
SD10	2.302	ACCEPT
CD12	3.070	**REJECT**
OC13	0.038	ACCEPT
OCCD14	0.504	ACCEPT
SRC16	0.003	ACCEPT
LC17	1.868	ACCEPT
PFRN18	2.302	ACCEPT
(1)	7.073	**REJECT**

MODEL 2A

	χ^2 value	Ho
X8	2.302	ACCEPT
X10	3.070	ACCEPT
X11	0.175	ACCEPT
X13	0.420	ACCEPT
(1)	9.394	**REJECT**

MODEL 2B

	χ^2 value	Ho
X8	0.232	ACCEPT
X10	0.113	ACCEPT
X11	0.102	ACCEPT
X13	2.488	ACCEPT
(1)	4.202	**REJECT**

MODEL 2C

	χ^2 value	Ho
X8	4.202	**REJECT**
X10	0.113	ACCEPT
X11	2.084	ACCEPT
X13	0.038	ACCEPT
(1)	0.232	ACCEPT

MODEL 2D

	χ^2 value	Ho
X8	2.302	ACCEPT
X10	0.003	ACCEPT
X11	0.787	ACCEPT
X13	0.030	ACCEPT
(1)	13.263	**REJECT**

MODEL 2E

	χ^2 value	Ho
X8	2.302	ACCEPT
X10	0.003	ACCEPT
X11	0.175	ACCEPT
X13	0.420	ACCEPT
(1)	13.263	REJECT

The above tests show that out of the nine versions of the models tested, the unsmoothed shadow prices of sight deposits support the constraint induced innovations hypothesis in one model, the shadow prices of certificates of deposit support the hypothesis in two models, the shadow prices of dollar deposits support the hypothesis in one model, the shadow prices of capital support the hypothesis in two models, while the shadow prices of the balance sheet constraint (1) support the constraint induced innovations hypothesis in all but one (Model 2C) versions of the models.

The use of the unsmoothed shadow prices leads to a significant reduction in the explanatory power of the constraint-induced innovations model since rising shadow prices can predict innovative behaviour in 28.1% of cases (on average) in the various versions of Model 1 and 24% of cases in the various versions of Model 2. However, by using 3year moving averages for smoothing shadow price values we get a better picture of the overall trend by eliminating the variability created by normal cyclical changes in loan demand. Presumably bank management considers the introduction of new instruments by observing longer term trends rather than cyclical movements which are dealt within the existing policy instruments framework. It should be stressed however that the issue of whether management decision making is short-term or long-term oriented in the issue of introducing new financial instruments has not been empirically verified in this thesis and therefore the smoothed results should be viewed with caution

VIII.2. <u>An alternative approach.</u>

The models were used to test the profit opportunities aspect of the constraint-induced innovations theory. However, constraints can lead to pressures for innovations by reducing a financial firm's utility as well. This is a complementary approach of adversity-induced innovations (Ben-Horim, M. & Silber, W.L., 1977). If we assume that a bank is goal maximising rather than profit maximising only, then deviations between goals and actual results each year will impose pressures for innovations. If these deviations persist over a period of time and they increase, then the pressures to innovate increase as well. Various goals of a financial firm include, among others, rate of growth of profits and total assets, market share and relative asset growth (compared with the growth of competitive financial institutions), and maximisation of shareholders' wealth.

In the case of the London clearing banks four main indicators will be examined as approximations of alternative goals of the banks' managements. Although the values set each year for these goals by the banks' managements are not known and consequently the deviation between goals and outcomes is also unknown, we can assume that these deviations are likely to be larger the larger the decline over time of the actual results. The indicators used are: growth of total assets, growth of profits, relative asset growth between the clearing banks and all banks and relative asset growth between the clearing banks and building societies. A decrease over time in these indicators can lead to reductions in utility and hence lead to the introduction of innovations. The data for total assets for the London clearing banks, building societies as well as for the whole banking sector are presented in Table 19; while in Table 20 the data for annual consolidated after-tax profits for three major clearing banks (Barclays, Lloyds and Midland) are given. In figures 5 and 6 a graphical presentation of the above mentioned data is given.

TABLE 19

Total assets of London clearing banks, monetary sector and of building societies. Their growth and relationship. (£million).

end-year	Total Assets L.C.B.	(1) Growth in assets	Total Assets monetary sector	(2) Growth in assets	Total Assets building societies	(3) Growth in assets	Relative Growth (1)/(2)	Relative Growth (1)/(3)
1965	9773	100	15926	100	5531	100	1	1
1966	10185	104	17783	111	6305	113	0.94	0.92
1967	10668	109	20540	128	7445	134	0.85	0.81
1968	11394	116	24287	152	8298	150	0.76	0.77
1969	11726	119	28388	178	9289	167	0.67	0.71
1970	12002	122	33727	211	10818	195	0.58	0.63
1971	13429	137	39623	248	12919	233	0.55	0.59
1972	16328	167	53234	334	15246	275	0.50	0.61
1973	21754	222	74693	469	17545	317	0.47	0.70
1974	27446	280	88153	553	20093	363	0.51	0.77
1975	33228	339	107682	676	24203	437	0.50	0.78
1976	33497	342	136274	855	28202	509	0.40	0.67
1977	35671	364	144849	909	34288	619	0.40	0.59
1978	42364	433	167407	1051	39538	714	0.41	0.61
1979	49737	508	199590	1253	45789	827	0.41	0.61
1980	59615	609	233392	1465	53792	972	0.42	0.63
1981	72258	739	333705	2095	61814	1117	0.35	0.66
1982	89317	913	410628	2578	73032	1320	0.35	0.69
1983	102030	1043	479442	3011	85868	1552	0.35	0.67
1984	114570	1172	602994	3786	102688	1856	0.31	0.63
1985	139946	1431	587692	3690	120763	2183	0.39	0.66

TABLE 20

After tax profits
(Barclays, Lloyds, Midland)
(consolidated figures)

(£million)

end-year	Total profits	Growth in profits
1965	36.6	100
1966	37.3	101
1967	38.5	105
1968	47.8	130
1969	77.6	212
1970	90.5	247
1971	118.3	323
1972	157.9	431
1973	231.9	633
1974	151	412
1975	141.9	387
1976	243.5	665
1977	359.6	982
1978	505.1	1380
1979	743.1	2030
1980	743.2	2030
1981	917	2505
1982	776.6	2121
1983	746	2038
1984	525	1434
1985	914	2497

By looking at figures 5 and 6 we observe developments through time in the clearing banks' rate of growth of total assets and changes in their market share as well as the relative growth of profits compared to their assets.

In particular, in Figure 5 the clearing banks' decreasing market share is reflected in the downward sloping lines that

Figure 5

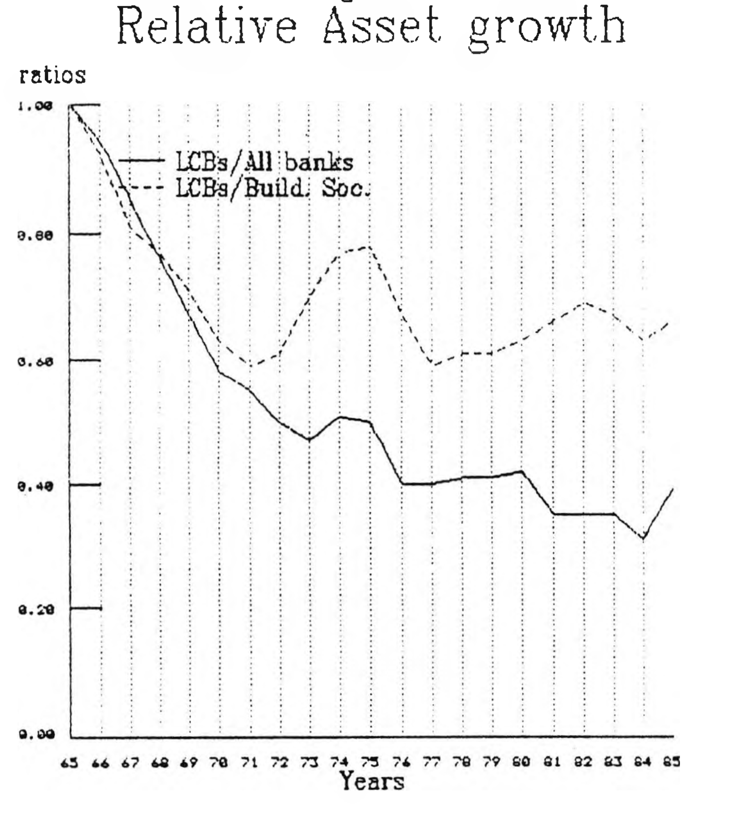
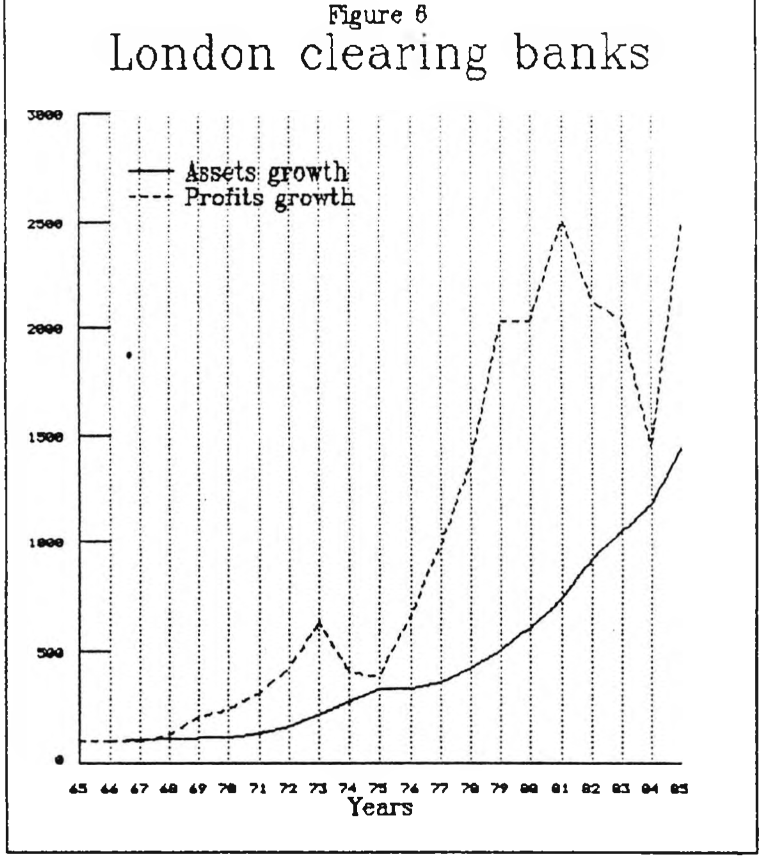


Figure 6



compare the rate of growth of assets of the clearing banks to the rate of growth of the whole banking sector as well as to the building societies. Major troughs in these lines should lead to increased innovative pressures. The major troughs occur in 1971 (lowest market share in relation to building societies), 1977 and 1984. The clearing banks' performance in relation to the whole banking system shows modest troughs in 1973, 1976 and 1984. If we attempt to predict the innovations of the period by looking at these troughs (which imply reduction in utility), it is difficult to predict the timing of the innovations. The trough in 1971 could be seen as an explanation of the £CDs innovation in that year and the adoption of foreign currency instruments; however the entry of the clearing banks to the mortgage lending business in 1981 and the increased internationalisation of the banks' activities in the 1980s are not predicted successfully.

If we look at profit growth and compare it with the growth of total assets for the clearing banks during the 1965-85 period (figure 6) there are two major troughs: in 1974-75 and in 1984. The reduction in profits in 1974-75 coincides with the clearing banks' increased engagement in liability management and the introduction of variable rate instruments and can be seen as explaining these innovations relatively well. The trough in 1984 can explain the introduction of interest bearing retail deposits and up to a certain extent the introduction of perpetual floating rate notes.

The above results show that the adversity-induced innovations hypothesis can explain a limited number of innovations during the 1965-85. Of course the above results are best viewed heuristically since a more formal specification of the banks' utility function is needed that would incorporate various objectives in order to be able to conduct more rigorous empirical tests.

Summing up we can say that the theory of constraint induced innovations is a useful tool of analysing the process of financial innovations given the limitations mentioned above. The empirical study of the theory presented here explained accurately more than half of the innovations in the 1965-85 period. An alternative test of adversity-induced innovations showed less satisfactory results. However, reaction to profit opportunities as well as reaction to decreases in utility are complementary aspects of the constraint-induced innovations theory.

A number of extentions can be made to the models presented in this study in order to apply the same technique to another set of institutions or to another time period or even to another financial system.

END NOTES

[1] Home banking offers the possibility to either collect information or send instructions regarding the customer's account(s).

[2] The building societies' share of retail deposits increased spectacularly in the 1980s. Furthermore, they begun to offer cheque accounts and ATM facilities to customers.

[3] During that period the Supplementary Special Deposits Scheme (commonly known as the "corset") was in operation imposing quantitative ceilings on the expansion of clearing banks' credit.

[4] A Note Issuance Facility (NIF) is a revolving facility which enables a borrower to issue a stream of short-term notes, generally known as "Euro-notes" over a medium-term period. (BIS, April 1986)

[5] A swap is a financial transaction in which two counterparties agree to exchange streams of payments over time. The two main types are Currency Swaps and Interest Rate Swaps.

[6] A Forward Rate Agreement (FRA) is an agreement between two counterparties, one wishing to protect itself against a future rise in interest rates and the other against a future fall. Without any commitment to lend or borrow the principal amount, the parties agree to an interest rate for, say, a three-month period beginning six months hence. At maturity, they settle by paying (receiving) only the difference between the interest rate agreed earlier and the then current interest rate. (BIS, April 1986).

[7] An Option is a contract conveying the right, but not the obligation, to buy or sell a specified financial instrument at a fixed price before or at a certain future date.

[8] The main goal is usually to eliminate market imperfections (due to natural monopoly, incomplete information and restricted entry to the market) and encourage the competitive market. However, perfect competition in banking may not be completely desirable since (J.Grady & M.Weale, 1986, p.35):

> *It has gradually been recognised that, while competition and the operation of a free market generally may be desirable objectives, banking is somehow or other different...It is believed that the social costs of failure outweigh any advantages that untramelled competition might bring.*

[9] Exchange Control Act 1947, the Companies Act of 1948 (Schedule 8) and 1967 (Section 123) and the Protection of Depositors Act.

[10] The first of the fringe banks to face liquidity problems was London and County Securities.

[11] Infrastructure includes: premises, equipment (other than leased equipment), trade investments, goodwill, and, if considering unconsolidated acccounts, investments in subsidiaries.

[12] A detailed description of the weights attached to each asset category can be found in BEQB, (1980, p.329).

[13] The dates of introduction of these new instruments are the dates that they were first introduced in the London Clearing Banks' balance sheets, since our reference framework is the group of the London Clearing Banks.

[14] Changes (through time) in operational costs and revenues may have an influence on one kind of innovations in banks; namely: technological innovations such as Point Of Sale EFTs and ATMs.

[15] From 1971, the cash and liquid assets ratios were replaced by the reserve assets ratio. In this new ratio government securities of one year or less to maturity were considered as reserve assets.

[16] Implying the imposition of direct credit ceilings.

[17] Freund, R.M. (1956), Courakis, A.S. (1974 and 1980), Parkin, M. (1970) and Parkin, M., Gray, M. & Barratt, R.J. (1970).

APPENDIX 1

Results of simulations of Model 1

SHADOW PRICES
(Model 1A)

	(1)	SD10	TD11	CD12	OC13	OCCD14	OL15	SRC16	LC17	PFRN18
1965	0.081	0.073	0.029	0.011	0.005	0.011	0.006	0.036	0.010	0.017
1966	0.071	0.065	0.020	0.001	-0.007	0.002	-0.007	0.024	-0.006	0.003
1967	0.074	0.065	0.023	0.003	-0.005	0.000	-0.010	0.265	0.233	0.242
1968	0.080	0.073	0.019	-0.002	-0.021	-0.014	-0.001	0.047	-0.002	0.006
1969	0.091	0.083	0.024	-0.008	-0.025	0.016	0.016	0.056	-0.012	0.002
1970	0.086	0.078	0.026	-0.002	-0.010	0.007	-0.002	0.096	0.029	0.043
1971	0.069	0.061	0.019	0.000	-0.010	0.006	-0.007	0.165	0.095	0.105
1972	0.056	0.055	0.013	-0.013	-0.018	-0.010	-0.013	0.279	0.208	0.214
1973	0.108	0.105	0.022	-0.012	-0.019	-0.006	-0.005	0.076	-0.006	-0.001
1974	0.113	0.111	0.006	-0.023	-0.042	-0.032	-0.013	0.370	0.277	0.291
1975	0.102	0.103	0.017	-0.003	-0.013	-0.008	-0.013	0.326	0.226	0.239
1976	0.112	0.110	0.015	-0.005	-0.021	-0.017	-0.005	0.313	0.223	0.232
1977	0.075	0.078	0.009	0.000	-0.011	-0.005	-0.009	0.337	0.260	0.271
1978	0.086	0.085	0.010	-0.008	-0.021	-0.012	-0.011	0.327	0.256	0.265
1979	0.131	0.129	0.007	-0.009	-0.011	-0.002	-0.010	0.304	0.228	0.246
1980	0.150	0.148	0.004	-0.017	-0.019	-0.005	-0.014	0.357	0.272	0.295
1981	0.135	0.131	0.017	-0.006	-0.007	-0.001	-0.004	0.304	0.207	0.231
1982	0.129	0.126	0.025	0.007	0.009	0.016	0.007	0.220	0.146	0.167
1983	0.100	0.098	0.018	-0.001	0.006	0.012	-0.003	0.274	0.211	0.230
1984	0.097	0.094	0.017	-0.003	-0.020	-0.016	-0.002	0.293	0.230	0.246
1985	0.123	0.106	0.016	0.000	0.076	0.079	0.000	0.309	0.244	0.258

SHADOW PRICES
(Model 1A)
(3year averages)

	(1)	SD10	TD11	CD12	OC13	OCCD14	OL15	SRC16	LC17	PFRN18
1965	0.076	0.069	0.025	0.006	-0.001	0.007	-0.001	0.03	0.002	0.01
1966	0.075	0.068	0.024	0.005	-0.002	0.004	-0.004	0.108	0.079	0.087
1967	0.075	0.068	0.021	0.001	-0.004	-0.004	-0.006	0.112	0.075	0.084
1968	0.082	0.074	0.022	-0.002	-0.017	0.001	0.002	0.123	0.073	0.083
1969	0.086	0.078	0.023	-0.004	-0.019	0.003	0.004	0.066	0.005	0.05
1970	0.082	0.074	0.023	-0.003	-0.015	0.010	0.002	0.106	0.037	0.05
1971	0.07	0.065	0.019	-0.005	-0.013	0.001	-0.007	0.18	0.111	0.121
1972	0.078	0.074	0.018	-0.008	-0.016	-0.005	-0.008	0.173	0.099	0.106
1973	0.092	0.090	0.014	-0.016	-0.026	-0.016	-0.01	0.242	0.16	0.168
1974	0.108	0.106	0.015	-0.013	-0.025	-0.015	-0.01	0.257	0.166	0.176
1975	0.109	0.108	0.013	-0.010	-0.025	-0.019	-0.01	0.336	0.242	0.254
1976	0.096	0.097	0.014	-0.003	-0.015	-0.010	-0.009	0.325	0.236	0.247
1977	0.091	0.091	0.011	-0.004	-0.018	-0.011	-0.008	0.325	0.246	0.256
1978	0.097	0.097	0.009	-0.006	-0.014	-0.006	-0.010	0.323	0.248	0.261
1979	0.122	0.121	0.007	-0.011	-0.017	-0.006	-0.012	0.329	0.252	0.269
1980	0.139	0.136	0.009	-0.011	-0.012	-0.003	-0.009	0.322	0.236	0.257
1981	0.138	0.135	0.015	-0.005	-0.006	0.003	-0.004	0.294	0.208	0.231
1982	0.121	0.118	0.02	0	0.003	0.009	0	0.266	0.188	0.209
1983	0.109	0.106	0.02	0.001	-0.002	0.004	0.001	0.262	0.196	0.214
1984	0.107	0.099	0.017	-0.001	0.021	0.025	-0.002	0.292	0.228	0.245
1985	0.11	0.1	0.017	-0.002	0.028	0.032	-0.001	0.301	0.237	0.252

SHADOW PRICES

(Model 1B)

(we use calculated averages for $\mu1,\mu2$ for the periods:65-71,72-80,81-85)

	(1)	SD10	TD11	CD12	OC13	OCCD14	OL15	SRC16	LC17	PFRN18
1965	0.081	0.073	0.029	0.011	0.005	0.011	0.006	0.138	0.112	0.119
1966	0.071	0.065	0.02	0.001	-0.007	0.002	-0.007	0.212	0.182	0.191
1967	0.074	0.065	0.023	0.003	0.004	0.009	-0.001	0.251	0.219	0.228
1968	0.080	0.073	0.019	-0.002	-0.021	-0.014	-0.001	0.047	-0.002	0.006
1969	0.091	0.083	0.024	-0.008	-0.025	0.016	0.016	0.056	-0.012	0.002
1970	0.093	0.083	0.031	0.003	-0.005	0.012	0.005	0.054	-0.012	0.001
1971	0.088	0.075	0.033	0.013	0.004	0.020	0.012	0.057	-0.013	-0.003
1972	0.056	0.055	0.013	-0.013	-0.018	-0.010	-0.013	0.323	0.252	0.258
1973	0.095	0.093	0.010	-0.024	-0.003	-0.018	-0.018	0.374	0.292	0.297
1974	0.148	0.141	0.036	0.007	-0.012	-0.002	0.022	0.077	-0.016	-0.002
1975	0.102	0.103	0.017	-0.003	-0.013	-0.008	-0.013	0.326	0.226	0.239
1976	0.112	0.110	0.015	-0.005	-0.021	-0.017	-0.005	0.325	0.235	0.244
1977	0.116	0.112	0.043	0.034	0.024	0.030	0.032	0.059	-0.018	-0.007
1978	0.123	0.117	0.042	0.024	0.010	0.019	0.026	0.066	-0.005	0.004
1979	0.131	0.129	0.007	-0.009	-0.011	-0.002	-0.010	0.317	0.241	0.259
1980	0.150	0.148	0.004	-0.017	-0.019	-0.005	-0.014	0.36	0.275	0.298
1981	0.135	0.131	0.017	-0.006	-0.007	-0.001	-0.004	0.331	0.234	0.258
1982	0.118	0.115	0.014	-0.004	-0.002	0.005	-0.004	0.328	0.254	0.275
1983	0.112	0.109	0.029	0.010	0.017	0.023	0.009	0.185	0.122	0.141
1984	0.097	0.094	0.017	-0.003	-0.02	-0.016	-0.002	0.319	0.256	0.272
1985	0.123	0.106	0.016	0.000	0.076	0.079	0.000	0.073	0.008	0.022

SHADOW PRICES

(Model 1B)

(we use calculated averages for $\mu 1, \mu 2$ for the periods:65-71,72-80,81-85)

(3year averages)

	(1)	SD10	TD11	CD12	OC13	OCCD14	OL15	SRC16	LC17	PFRN18
1965	0.076	0.069	0.025	0.006	-0.001	0.006	-0.001	0.175	0.147	0.155
1966	0.075	0.068	0.024	0.005	0.001	0.007	-0.001	0.200	0.171	0.179
1967	0.075	0.068	0.021	0.001	-0.008	-0.001	-0.003	0.170	0.133	0.142
1968	0.082	0.074	0.022	-0.002	-0.014	0.004	0.005	0.118	0.068	0.079
1969	0.088	0.080	0.025	-0.002	-0.017	0.005	0.007	0.052	-0.009	0.003
1970	0.091	0.080	0.029	0.003	-0.009	0.016	0.011	0.056	-0.004	0.000
1971	0.079	0.071	0.026	0.001	-0.006	0.007	0.001	0.145	0.076	0.085
1972	0.080	0.074	0.019	-0.008	-0.006	-0.003	-0.006	0.251	0.177	0.184
1973	0.100	0.096	0.020	-0.010	-0.011	-0.010	-0.003	0.258	0.176	0.184
1974	0.115	0.112	0.021	-0.007	-0.009	-0.009	-0.003	0.259	0.167	0.178
1975	0.121	0.118	0.023	0.000	-0.015	-0.009	0.001	0.243	0.148	0.160
1976	0.110	0.108	0.025	0.009	-0.003	0.002	0.005	0.237	0.148	0.159
1977	0.117	0.113	0.033	0.018	0.004	0.011	0.018	0.150	0.071	0.080
1978	0.123	0.119	0.031	0.016	0.008	0.016	0.016	0.147	0.073	0.085
1979	0.135	0.131	0.018	-0.001	-0.007	0.004	0.001	0.248	0.170	0.187
1980	0.139	0.136	0.009	-0.005	-0.012	-0.003	-0.009	0.336	0.243	0.272
1981	0.134	0.131	0.012	-0.009	-0.009	0.000	-0.007	0.340	0.254	0.277
1982	0.122	0.118	0.020	0.000	0.003	0.009	0.000	0.281	0.203	0.225
1983	0.109	0.106	0.020	0.001	-0.002	0.004	0.001	0.277	0.211	0.229
1984	0.111	0.103	0.021	0.002	0.024	0.029	0.002	0.192	0.129	0.145
1985	0.110	0.100	0.017	-0.002	0.028	0.032	-0.001	0.196	0.132	0.147

SHADOW PRICES

(Model 1C)

(we use calculated averages for $\mu 1, \mu 2$ for the period: 1965-1985)

	(1)	SD10	TD11	CD12	OC13	OCCD14	OL15	SRC16	LC17	PFRN18
1965	0.081	0.071	0.027	0.009	0.005	0.011	0.006	0.17	0.144	0.151
1966	0.071	0.062	0.017	-0.002	-0.007	0.002	-0.007	0.271	0.241	0.25
1967	0.074	0.065	0.023	0.003	0.004	0.009	-0.001	0.215	0.183	0.192
1968	0.080	0.07	0.016	-0.005	-0.021	-0.014	-0.001	0.294	0.245	0.253
1969	0.090	0.081	0.022	-0.01	-0.026	0.015	0.015	0.251	0.183	0.197
1970	0.093	0.083	0.031	0.028	-0.005	0.012	0.005	0.054	-0.012	0.001
1971	0.088	0.075	0.033	0.013	0.004	0.020	0.012	0.057	-0.013	-0.003
1972	0.089	0.083	0.041	0.015	0.010	0.018	0.020	0.063	-0.008	-0.002
1973	0.108	0.105	0.022	-0.012	-0.019	-0.006	-0.005	0.076	-0.006	-0.001
1974	0.148	0.141	0.036	0.007	-0.012	-0.002	0.022	0.077	-0.016	-0.002
1975	0.102	0.103	0.017	-0.003	-0.013	-0.008	-0.013	0.372	0.272	0.285
1976	0.143	0.136	0.041	0.021	0.006	0.010	0.026	0.081	-0.009	0.000
1977	0.116	0.112	0.043	0.034	0.024	0.030	0.032	0.059	-0.018	-0.007
1978	0.123	0.117	0.042	0.024	0.010	0.019	0.026	0.066	-0.005	0.004
1979	0.131	0.129	0.007	-0.009	-0.011	-0.002	-0.010	0.075	-0.001	0.017
1980	0.150	0.148	0.004	-0.017	-0.019	-0.005	-0.014	0.399	0.314	0.337
1981	0.135	0.131	0.017	-0.006	-0.007	-0.001	-0.004	0.318	0.221	0.245
1982	0.129	0.126	0.025	0.007	0.009	0.016	0.007	0.209	0.135	0.156
1983	0.112	0.109	0.029	0.01	0.017	0.023	0.009	0.171	0.108	0.127
1984	0.113	0.109	0.032	0.012	-0.004	0.000	0.014	0.16	0.097	0.113
1985	0.123	0.106	0.016	0.000	0.076	0.079	0.000	0.314	0.249	0.263

SHADOW PRICES

(Model 1C)

(we use calculated averages for $\mu 1, \mu 2$ for the period: 1965-1985)

(3year averages)

	(1)	SD10	TD11	CD12	OC13	OCCD14	OL15	SRC16	LC17	PFRN18
1965	0.076	0.067	0.022	0.004	-0.001	0.007	-0.001	0.221	0.193	0.201
1966	0.075	0.066	0.022	0.003	0.001	0.007	-0.001	0.219	0.189	0.198
1967	0.075	0.066	0.019	-0.001	-0.008	-0.001	-0.003	0.260	0.223	0.232
1968	0.081	0.072	0.02	-0.004	-0.014	0.003	0.004	0.253	0.204	0.214
1969	0.088	0.078	0.023	0.004	-0.017	0.004	0.006	0.200	0.139	0.150
1970	0.090	0.080	0.029	0.010	-0.009	0.016	0.011	0.121	0.053	0.065
1971	0.090	0.080	0.035	0.019	0.003	0.017	0.012	0.058	-0.011	-0.001
1972	0.095	0.088	0.032	0.005	-0.002	0.011	0.009	0.065	-0.009	-0.002
1973	0.115	0.110	0.033	0.003	-0.007	0.003	0.012	0.072	-0.010	-0.002
1974	0.119	0.116	0.025	-0.003	-0.015	-0.005	0.001	0.175	0.083	0.094
1975	0.131	0.127	0.031	0.008	-0.006	0.000	0.012	0.177	0.082	0.094
1976	0.120	0.117	0.034	0.017	0.006	0.011	0.015	0.171	0.082	0.093
1977	0.127	0.122	0.042	0.026	0.013	0.020	0.028	0.069	-0.011	-0.001
1978	0.123	0.119	0.031	0.016	0.008	0.016	0.016	0.067	-0.008	0.005
1979	0.135	0.131	0.018	-0.001	-0.007	0.004	0.001	0.180	0.103	0.119
1980	0.139	0.136	0.009	-0.011	-0.012	-0.003	-0.009	0.264	0.178	0.200
1981	0.138	0.135	0.015	-0.005	-0.006	0.003	-0.004	0.309	0.223	0.246
1982	0.125	0.122	0.024	0.004	0.006	0.013	0.004	0.233	0.155	0.176
1983	0.118	0.115	0.029	0.01	0.007	0.013	0.01	0.180	0.113	0.132
1984	0.116	0.108	0.026	0.007	0.030	0.034	0.008	0.215	0.151	0.168
1985	0.118	0.108	0.024	0.006	0.036	0.040	0.007	0.237	0.173	0.188

SHADOW PRICES
(Model 1D)

	(1)	SD10	TD11	CD12	OC13	OCCD14	OL15	SRC16	LC17	PFRN18
1965	0.081	0.073	0.029	0.011	-0.003	0.003	-0.001	0.036	0.010	0.017
1966	0.071	0.065	0.020	0.001	-0.013	-0.004	-0.014	0.024	-0.006	0.003
1967	0.074	0.067	0.025	0.005	-0.005	0.000	-0.010	0.030	-0.002	0.007
1968	0.080	0.073	0.019	-0.002	-0.021	-0.014	0.000	0.047	-0.002	0.006
1969	0.091	0.083	0.024	-0.008	-0.025	0.016	0.016	0.056	-0.012	0.002
1970	0.093	0.083	0.031	0.003	-0.005	0.012	0.005	0.054	-0.012	0.001
1971	0.088	0.075	0.033	0.013	0.004	0.020	0.012	0.057	-0.013	-0.003
1972	0.089	0.083	0.041	0.015	0.010	0.018	0.020	0.063	-0.008	-0.002
1973	0.108	0.105	0.022	-0.012	-0.019	-0.006	-0.005	0.076	-0.006	-0.001
1974	0.148	0.141	0.036	0.007	-0.012	-0.002	0.022	0.077	-0.016	-0.002
1975	0.134	0.130	0.044	0.024	0.015	0.020	0.019	0.074	-0.026	-0.013
1976	0.143	0.136	0.041	0.021	0.006	0.010	0.026	0.081	-0.009	0.000
1977	0.116	0.112	0.043	0.034	0.024	0.030	0.032	0.059	-0.018	-0.007
1978	0.123	0.117	0.042	0.024	0.010	0.019	0.026	0.066	-0.005	0.004
1979	0.131	0.129	0.007	-0.009	-0.011	-0.002	-0.010	0.075	-0.001	0.017
1980	0.150	0.148	0.004	-0.017	-0.019	-0.005	-0.014	0.093	0.008	0.031
1981	0.147	0.142	0.028	0.053	0.004	0.010	0.008	0.090	-0.007	0.017
1982	0.129	0.126	0.025	0.007	0.009	0.016	0.007	0.063	-0.011	0.010
1983	0.112	0.109	0.029	0.010	0.017	0.023	0.009	0.054	-0.009	0.010
1984	0.113	0.109	0.032	0.012	-0.004	0.000	0.014	0.058	-0.005	0.011
1985	0.123	0.106	0.017	0.000	0.076	0.079	0.000	0.073	0.008	0.022

SHADOW PRICES

(Model 1D)

3year averages

	(1)	SD10	TD11	CD12	OC13	OCCD14	OL15	SRC16	LC17	PFRN18
1965	0.076	0.069	0.025	0.006	-0.008	-0.001	-0.008	0.030	0.002	0.010
1966	0.075	0.068	0.025	0.006	-0.007	0.000	-0.008	0.030	0.001	0.009
1967	0.075	0.068	0.021	0.001	-0.013	-0.006	-0.008	0.034	-0.003	0.005
1968	0.082	0.074	0.023	-0.002	-0.017	0.001	0.002	0.044	-0.005	0.005
1969	0.088	0.080	0.025	-0.002	-0.017	0.005	0.007	0.052	-0.009	0.003
1970	0.091	0.080	0.029	0.003	-0.009	0.016	0.011	0.056	-0.012	0.000
1971	0.090	0.080	0.035	0.010	0.003	0.017	0.012	0.058	-0.011	-0.001
1972	0.095	0.088	0.032	0.005	0.007	0.011	0.009	0.065	-0.009	-0.002
1973	0.115	0.110	0.033	0.003	-0.007	0.003	0.012	0.072	-0.010	-0.002
1974	0.130	0.125	0.034	0.006	-0.005	0.004	0.012	0.076	-0.016	-0.005
1975	0.142	0.136	0.040	0.017	0.003	0.009	0.022	0.077	-0.017	-0.005
1976	0.131	0.126	0.043	0.026	0.015	0.020	0.026	0.071	-0.018	-0.007
1977	0.127	0.122	0.042	0.026	0.013	0.020	0.028	0.069	-0.011	-0.001
1978	0.123	0.119	0.031	0.016	0.008	0.016	0.016	0.067	-0.008	0.005
1979	0.135	0.131	0.018	-0.001	-0.007	0.004	0.001	0.078	0.001	0.017
1980	0.143	0.140	0.013	0.009	-0.009	0.001	-0.005	0.085	0.000	0.022
1981	0.142	0.139	0.019	0.014	-0.002	0.007	0.000	0.082	-0.003	0.019
1982	0.129	0.126	0.027	0.023	0.010	0.016	0.008	0.069	-0.009	0.012
1983	0.118	0.115	0.029	0.010	0.007	0.013	0.010	0.058	-0.008	0.010
1984	0.116	0.108	0.026	0.007	0.030	0.034	0.008	0.062	-0.002	0.014
1985	0.118	0.108	0.025	0.006	0.036	0.040	0.007	0.066	0.002	0.017

APPENDIX 2

Results of simulations of Model 2

SHADOW PRICES

Model 2A

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.075	0.069	0.025	0.007	0.002	0.000	0.018
1966	0.069	0.063	0.018	-0.009	-0.005	-0.009	0.009
1967	0.071	0.065	0.023	0.003	0.003	-0.004	0.013
1968	0.076	0.070	0.016	-0.005	-0.028	-0.011	0.020
1969	0.090	0.081	0.022	-0.010	-0.028	-0.005	0.024
1970	0.086	0.078	0.025	-0.002	-0.004	-0.003	0.017
1971	0.078	0.068	0.027	0.007	0.004	0.002	0.014
1972	0.087	0.083	0.041	0.015	0.013	0.018	0.027
1973	0.107	0.105	0.022	-0.012	-0.020	-0.012	0.035
1974	0.139	0.135	0.030	0.001	-0.026	0.001	0.025
1975	0.134	0.128	0.042	0.022	0.013	0.019	0.027
1976	0.136	0.132	0.037	0.017	-0.001	0.016	0.031
1977	0.116	0.113	0.044	0.035	0.027	0.032	0.023
1978	0.122	0.116	0.041	0.023	0.013	0.025	0.031
1979	0.135	0.133	0.011	-0.005	-0.003	-0.006	0.045
1980	0.156	0.154	0.010	-0.011	-0.006	-0.008	0.062
1981	0.147	0.142	0.028	0.052	0.007	0.008	0.047
1982	0.129	0.126	0.024	0.007	0.012	0.007	0.031
1983	0.110	0.107	0.027	0.008	0.018	0.007	0.025
1984	0.110	0.104	0.029	0.009	-0.006	0.010	0.027
1985	0.123	0.107	0.016	0.001	0.077	0.000	0.044

SHADOW PRICES

Model 2A

(3year averages)

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.072	0.066	0.022	-0.001	-0.002	-0.005	0.014
1966	0.072	0.066	0.022	0.000	0.000	-0.004	0.013
1967	0.072	0.066	0.019	-0.004	-0.010	-0.008	0.014
1968	0.079	0.072	0.020	-0.004	-0.018	-0.007	0.019
1969	0.084	0.076	0.021	-0.006	-0.020	-0.006	0.020
1970	0.085	0.076	0.025	-0.002	-0.009	-0.002	0.018
1971	0.084	0.076	0.031	0.007	0.004	0.006	0.019
1972	0.091	0.085	0.030	0.003	-0.001	0.003	0.025
1973	0.111	0.108	0.031	0.001	-0.011	0.002	0.029
1974	0.127	0.123	0.031	0.004	-0.011	0.003	0.029
1975	0.136	0.132	0.036	0.013	-0.005	0.012	0.028
1976	0.129	0.124	0.041	0.025	0.013	0.022	0.027
1977	0.125	0.120	0.041	0.025	0.013	0.024	0.028
1978	0.124	0.121	0.032	0.018	0.012	0.017	0.033
1979	0.138	0.134	0.021	0.002	0.001	0.004	0.046
1980	0.146	0.143	0.016	0.012	-0.001	-0.002	0.051
1981	0.144	0.141	0.021	0.016	0.004	0.002	0.047
1982	0.129	0.125	0.026	0.022	0.012	0.007	0.034
1983	0.116	0.112	0.027	0.008	0.008	0.008	0.028
1984	0.114	0.106	0.024	0.006	0.030	0.006	0.032
1985	0.117	0.106	0.023	0.005	0.036	0.005	0.036

SHADOW PRICES

Model 2B

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.016	0.015	0.023	0.009	0.016	-0.002	-0.017
1966	0.015	0.011	0.026	0.015	0.006	0.003	-0.045
1967	0.006	0.004	0.030	0.026	0.021	0.011	-0.049
1968	0.008	0.006	0.028	0.023	-0.002	0.012	-0.042
1969	0.014	0.010	0.045	0.030	0.048	0.024	-0.048
1970	0.000	0.000	0.037	0.042	0.091	0.010	-0.062
1971	0.000	0.000	0.033	0.044	0.070	0.010	-0.055
1972	0.000	-0.005	0.040	0.049	0.057	0.030	-0.027
1973	0.048	0.040	0.034	0.021	0.006	0.018	0.020
1974	0.110	0.098	0.029	0.024	-0.012	0.024	0.027
1975	0.025	0.025	0.039	0.061	0.023	0.020	0.007
1976	0.000	-0.006	0.030	0.034	-0.009	0.021	0.000
1977	0.000	-0.007	0.027	0.021	-0.017	0.006	-0.008
1978	0.000	-0.003	0.031	-0.003	-0.018	-0.026	-0.032
1979	0.000	0.000	0.045	-0.136	-0.305	-0.125	0.083
1980	0.000	-0.006	0.027	1.960	0.028	-0.003	0.401
1981	0.000	-0.001	0.037	0.025	0.037	-0.065	-0.063
1982	0.000	0.023	0.097	0.514	0.020	0.407	-0.627
1983	0.000	0.016	0.036	0.070	-0.006	0.000	-0.250
1984	0.000	-0.008	0.034	0.001	-0.006	-0.056	-0.223
1985	0.000	-0.022	0.051	0.096	-0.021	0.017	-0.133

SHADOW PRICES

Model 2B

(3year averages)

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.016	0.013	0.025	0.012	0.011	0.001	-0.031
1966	0.012	0.01	0.026	0.017	0.014	0.004	-0.037
1967	0.010	0.007	0.028	0.021	0.008	0.009	-0.045
1968	0.009	0.007	0.034	0.026	0.022	0.016	-0.046
1969	0.007	0.005	0.037	0.032	0.046	0.015	-0.051
1970	0.005	0.003	0.038	0.039	0.070	0.015	-0.055
1971	0.000	-0.002	0.037	0.045	0.073	0.017	-0.048
1972	0.016	0.012	0.036	0.038	0.044	0.019	-0.021
1973	0.053	0.044	0.034	0.031	0.017	0.024	0.007
1974	0.061	0.054	0.034	0.035	0.006	0.021	0.018
1975	0.045	0.039	0.033	0.040	0.001	0.022	0.011
1976	0.008	0.004	0.032	0.039	-0.001	0.016	0.000
1977	0.000	-0.005	0.029	0.017	-0.015	0.000	-0.013
1978	0.000	-0.003	0.034	-0.039	-0.113	-0.048	0.014
1979	0.000	-0.003	0.034	0.607	-0.098	-0.051	0.151
1980	0.000	-0.002	0.036	0.616	-0.080	-0.064	0.140
1981	0.000	0.005	0.054	0.833	0.028	0.113	-0.096
1982	0.000	0.013	0.057	0.203	0.017	0.114	-0.313
1983	0.000	0.010	0.056	0.195	0.003	0.117	-0.367
1984	0.000	-0.005	0.040	0.056	-0.011	-0.013	-0.202
1985	0.000	-0.015	0.043	0.049	-0.014	-0.020	-0.178

SHADOW PRICES

Model 2C

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.068	0.062	0.022	0.004	0.001	-0.004	0.013
1966	0.060	0.054	0.019	0.002	-0.003	-0.007	0.001
1967	0.056	0.051	0.023	0.006	0.006	-0.003	-0.001
1968	0.052	0.046	0.017	0.003	-0.019	-0.003	-0.002
1969	0.055	0.048	0.031	0.007	0.011	0.008	-0.007
1970	0.045	0.040	0.029	0.016	0.034	0.003	-0.014
1971	0.033	0.026	0.028	0.025	0.037	0.006	-0.018
1972	0.042	0.038	0.042	0.033	0.045	0.025	-0.001
1973	0.101	0.097	0.030	0.000	0.000	0.002	0.034
1974	0.124	0.118	0.040	0.019	0.004	0.019	0.018
1975	0.101	0.097	0.043	0.030	0.024	0.020	0.021
1976	0.035	0.032	0.035	0.016	0.010	0.012	0.017
1977	0.000	-0.005	0.042	0.026	0.029	0.023	0.012
1978	0.000	-0.004	0.044	0.017	0.027	0.013	0.010
1979	0.000	-0.003	0.044	0.011	0.040	0.004	0.050
1980	0.000	-0.003	0.044	0.203	0.025	0.001	0.046
1981	0.000	-0.001	0.044	0.004	0.026	-0.012	0.016
1982	0.000	0.001	0.044	0.018	0.015	0.013	-0.015
1983	0.005	0.007	0.043	0.024	0.016	0.011	-0.028
1984	0.002	-0.001	0.044	0.033	0.010	0.018	-0.061
1985	0.000	-0.023	0.054	0.048	0.005	0.035	-0.043

SHADOW PRICES

Model 2C

(3year averages)

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.064	0.058	0.021	0.003	-0.001	-0.006	0.007
1966	0.061	0.056	0.021	0.004	0.001	-0.005	0.004
1967	0.056	0.050	0.020	0.004	-0.005	-0.004	-0.001
1968	0.054	0.048	0.024	0.005	-0.001	0.001	-0.003
1969	0.051	0.045	0.026	0.009	0.009	0.003	-0.008
1970	0.044	0.038	0.029	0.016	0.027	0.006	-0.013
1971	0.040	0.035	0.033	0.025	0.039	0.011	-0.011
1972	0.059	0.054	0.033	0.019	0.027	0.011	0.005
1973	0.089	0.084	0.037	0.017	0.016	0.015	0.017
1974	0.109	0.104	0.038	0.016	0.009	0.014	0.024
1975	0.087	0.082	0.039	0.022	0.013	0.017	0.019
1976	0.045	0.041	0.040	0.024	0.018	0.018	0.017
1977	0.012	0.008	0.040	0.020	0.022	0.016	0.013
1978	0.000	-0.004	0.043	0.018	0.032	0.013	0.009
1979	0.000	-0.003	0.044	0.077	0.031	0.006	0.020
1980	0.000	-0.002	0.044	0.073	0.030	-0.002	0.022
1981	0.000	-0.001	0.044	0.075	0.022	0.001	0.016
1982	0.002	0.002	0.044	0.015	0.019	0.004	-0.009
1983	0.002	0.002	0.044	0.025	0.014	0.014	-0.035
1984	0.002	-0.006	0.047	0.035	0.010	0.021	-0.044
1985	0.001	-0.012	0.049	0.041	0.008	0.027	-0.052

SHADOW PRICES
MODEL 2D

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.074	0.068	0.025	0.007	0.002	0	0.017
1966	0.068	0.062	0.018	-0.001	-0.005	-0.009	0.008
1967	0.069	0.063	0.022	0.003	0.003	-0.005	0.011
1968	0.074	0.067	0.016	-0.004	-0.027	-0.01	0.018
1969	0.085	0.076	0.023	-0.008	-0.022	-0.003	0.019
1970	0.082	0.074	0.026	-0.001	-0.001	-0.002	0.014
1971	0.073	0.064	0.027	0.008	0.007	0.002	0.011
1972	0.083	0.078	0.041	0.016	0.016	0.019	0.024
1973	0.099	0.097	0.022	-0.008	-0.010	-0.010	0.030
1974	0.121	0.118	0.030	0.009	-0.008	0.004	0.014
1975	0.127	0.121	0.043	0.024	0.016	0.019	0.026
1976	0.121	0.116	0.037	0.019	0.004	0.017	0.028
1977	0.092	0.086	0.041	0.032	0.027	0.030	0.023
1978	0.090	0.085	0.040	0.020	0.016	0.020	0.026
1979	0.102	0.101	0.012	-0.005	0.005	-0.008	0.040
1980	0.100	0.099	0.016	0.007	-0.010	-0.013	0.033
1981	0.112	0.107	0.043	0.014	0.014	0.013	0.036
1982	0.095	0.092	0.044	0.019	0.013	0.018	0.015
1983	0.09	0.087	0.044	0.02	0.013	0.016	0.01
1984	0.09	0.084	0.045	0.028	0.01	0.027	0.011
1985	0.083	0.064	0.05	0.034	0.07	0.028	0.003

SHADOW PRICES

MODEL 2D

(3year averages)

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.071	0.065	0.022	0.003	-0.001	-0.005	0.013
1966	0.070	0.064	0.022	0.003	0.000	-0.005	0.012
1967	0.070	0.064	0.019	-0.001	-0.010	-0.008	0.012
1968	0.076	0.069	0.020	-0.003	-0.015	-0.006	0.016
1969	0.080	0.072	0.022	-0.004	-0.017	-0.005	0.017
1970	0.080	0.071	0.025	0.000	-0.005	-0.001	0.015
1971	0.079	0.072	0.031	0.008	0.007	0.006	0.016
1972	0.085	0.080	0.030	0.005	0.004	0.004	0.022
1973	0.101	0.098	0.031	0.006	-0.001	0.004	0.023
1974	0.116	0.112	0.032	0.008	-0.001	0.004	0.023
1975	0.123	0.118	0.037	0.017	0.004	0.013	0.023
1976	0.113	0.108	0.040	0.025	0.016	0.022	0.026
1977	0.101	0.096	0.039	0.024	0.016	0.022	0.026
1978	0.095	0.091	0.031	0.016	0.016	0.014	0.030
1979	0.097	0.095	0.023	0.007	0.004	0.000	0.033
1980	0.105	0.102	0.024	0.005	0.003	-0.003	0.036
1981	0.102	0.099	0.034	0.013	0.006	0.006	0.028
1982	0.099	0.095	0.044	0.018	0.013	0.016	0.020
1983	0.092	0.088	0.044	0.022	0.012	0.020	0.012
1984	0.088	0.078	0.046	0.027	0.031	0.024	0.008
1985	0.087	0.074	0.048	0.031	0.040	0.028	0.007

SHADOW PRICES

MODEL 2E

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.075	0.069	0.025	0.007	0.002	0.000	0.018
1966	0.069	0.063	0.018	-0.001	-0.005	-0.009	0.009
1967	0.071	0.065	0.023	0.003	0.003	-0.004	0.013
1968	0.076	0.070	0.016	-0.005	-0.028	-0.011	0.020
1969	0.090	0.081	0.022	-0.010	-0.027	-0.005	0.024
1970	0.085	0.077	0.026	-0.002	-0.004	-0.003	0.016
1971	0.078	0.068	0.027	0.007	0.004	0.002	0.014
1972	0.087	0.082	0.041	0.015	0.013	0.018	0.027
1973	0.106	0.104	0.022	-0.011	-0.018	-0.011	0.034
1974	0.136	0.133	0.030	0.002	-0.024	0.001	0.023
1975	0.133	0.128	0.042	0.023	0.014	0.019	0.027
1976	0.131	0.127	0.037	0.018	0.003	0.017	0.030
1977	0.113	0.109	0.043	0.034	0.026	0.032	0.024
1978	0.119	0.113	0.041	0.023	0.014	0.025	0.031
1979	0.132	0.130	0.011	-0.005	-0.002	-0.006	0.045
1980	0.150	0.148	0.010	-0.009	-0.007	-0.008	0.059
1981	0.142	0.137	0.034	0.010	0.010	0.012	0.044
1982	0.124	0.121	0.031	0.012	0.013	0.012	0.027
1983	0.107	0.104	0.034	0.013	0.018	0.012	0.021
1984	0.106	0.100	0.035	0.016	0.000	0.016	0.024
1985	0.108	0.091	0.018	0.003	0.072	0.001	0.028

SHADOW PRICES

MODEL 2E

(3year averages)

YEAR	(1)	X8	X9	X10	X11	X12	X13
1965	0.072	0.066	0.022	0.003	-0.002	-0.005	0.014
1966	0.072	0.066	0.022	0.003	0.000	-0.004	0.013
1967	0.072	0.066	0.019	-0.001	-0.010	-0.008	0.014
1968	0.079	0.072	0.020	-0.004	-0.017	-0.007	0.019
1969	0.084	0.076	0.021	-0.006	-0.020	-0.006	0.020
1970	0.084	0.075	0.025	-0.002	-0.009	-0.002	0.018
1971	0.083	0.076	0.031	0.007	0.004	0.006	0.019
1972	0.090	0.085	0.030	0.004	0.000	0.003	0.025
1973	0.110	0.106	0.031	0.002	-0.010	0.003	0.028
1974	0.125	0.122	0.031	0.005	-0.009	0.003	0.028
1975	0.133	0.129	0.036	0.014	-0.002	0.012	0.027
1976	0.126	0.121	0.041	0.025	0.014	0.023	0.027
1977	0.121	0.116	0.040	0.025	0.014	0.025	0.028
1978	0.121	0.117	0.032	0.017	0.013	0.017	0.033
1979	0.134	0.130	0.021	0.003	0.002	0.004	0.045
1980	0.141	0.138	0.018	-0.001	0.000	-0.001	0.049
1981	0.139	0.135	0.025	0.004	0.005	0.005	0.043
1982	0.124	0.121	0.033	0.012	0.014	0.012	0.031
1983	0.112	0.108	0.033	0.014	0.010	0.013	0.024
1984	0.107	0.098	0.029	0.011	0.030	0.010	0.024
1985	0.107	0.100	0.027	0.010	0.036	0.009	0.026

APPENDIX 3

Specification of policy parameters and aggregate balance sheet data

POLICY PARAMETERS

Model 1

YEAR	α_1	k_1	k_2	α_2	k_3	α_3	β_1	β_2	μ_3
1965/	0.08	1	0	0.28	0	0	0.117	0.35	0.614
1966/	0.08	1	0	0.28	0	0	0.117	0.35	0.614
1967/	0.08	1	0	0.28	0	0	0.135	0.35	0.614
1968/	0.08	1	0	0.28	0	0	0.128	0.35	0.614
1969/	0.08	1	0	0.28	0	0	0.107	0.35	0.614
1970/	0.08	1	0	0.28	0	0	0.094	0.35	0.614
1971/	0.08	1	0	0.28	0	0	0.117	0.35	0.133
1972/	0.015	0	0.214	0.125	1	0.02	0.111	0.35	0.353
1973/	0.015	0	0.214	0.125	1	0.02	0.07	0.35	0.46
1974/	0.015	0	0.214	0.125	1	0.02	0.06	0.35	0.466
1975/	0.015	0	0.219	0.125	1	0.02	0.068	0.35	0.489
1976/	0.015	0	0.243	0.125	1	0.02	0.07	0.35	0.675
1977/	0.015	0	0.261	0.125	1	0.02	0.067	0.35	0.77
1978/	0.015	0	0.159	0.125	1	0.02	0.068	0.35	0.697
1979/	0.015	0	0.203	0.125	1	0.02	0.051	0.35	0.671
1980/	0.015	0	0.258	0.125	1	0.02	0.029	0.35	0.649
1981/	0.021	1	0	0.072	0	0	0.051	0.35	0.768
1982/	0.014	1	0	0.058	0	0	0.042	0.35	0.809
1983/	0.014	1	0	0.061	0	0	0.04	0.35	0.84
1984/	0.014	1	0	0.058	0	0	0.034	0.35	0.818
1985/	0.012	1	0	0.053	0	0	0.03	0.35	0.829

POLICY PARAMETERS

Model 2

YEAR	α_1	k_1	k_2	α_2	μ_1	μ_2
1965/	0.08	1	0	0.28	14.65	9.47
1966/	0.08	1	0	0.28	14.62	10.86
1967/	0.08	1	0	0.28	14.98	10.93
1968/	0.08	1	0	0.28	16.34	11.94
1969/	0.08	1	0	0.28	15.46	10.66
1970/	0.08	1	0	0.28	9.10	7.05
1971/	0.08	1	0	0.28	7.45	5.75
1972/	0.015	0	0.124	0.125	9.98	6.90
1973/	0.015	0	0.124	0.125	13.56	10.84
1974/	0.015	0	0.124	0.125	11.65	9.57
1975/	0.015	0	0.138	0.125	11.20	8.97
1976/	0.015	0	0.157	0.125	10.07	7.98
1977/	0.015	0	0.169	0.125	10.15	8.14
1978/	0.015	0	0.097	0.125	10.79	8.89
1979/	0.015	0	0.111	0.125	10.85	8.92
1980/	0.015	0	0.107	0.125	10.94	9.01
1981/	0.021	1	0	0.072	13.39	11.17
1982/	0.014	1	0	0.058	16.56	13.68
1983/	0.014	1	0	0.061	11.62	9.38
1984/	0.014	1	0	0.058	11.23	9.16
1985/	0.012	1	0	0.053	13.83	11.27

A S S E T S

£ millions

YEAR	C1	MC2	TOTAL BILLS	GVS5	OTI6	LA7	OCL8	OTAS9	TOTAL ASSETS
1965/	739	910	1114	956	131	4653	0	1270	9773
1966/	767	1006	1135	997	140	4732	0	1408	10185
1967/	798	1136	1056	1195	146	4725	0	1612	10668
1968/	851	1335	995	1213	162	5075	0	1763	11394
1969/	879	1451	862	1030	171	5328	0	2005	11726
1970/	826	1466	920	928	187	5623	0	2052	12002
1971/	894	1536	1184	1244	199	5805	186	2381	13429
1972/	823	1039	821	1470	180	8542	539	2914	16328
1973/	907	1125	719	1217	355	11380	1080	4971	21754
1974/	974	1127	859	1285	593	14030	1556	7022	27446
1975/	1026	815	1326	1529	891	18805	3933	4903	33228
1976/	1025	828	1241	1653	895	17911	4626	5318	33497
1977/	1077	1060	1141	1687	923	18834	5244	5705	35671
1978/	1151	1724	1093	1996	1254	22685	6033	6428	42364
1979/	1286	1735	1173	1742	1436	27875	7101	7389	49737
1980/	1384	1990	1448	1154	1627	33826	9555	8631	59615
1981/	1312	1899	1201	2321	1911	38621	15735	9258	72258
1982/	1043	2389	1019	2311	2314	48346	20845	11050	89317
1983/	1269	2777	1344	2540	2683	56208	23754	11455	102030
1984/	1363	2901	1357	2403	2925	62779	27602	13240	114570
1985/	1409	2921	1793	2311	1964	69874	40774	18900	139946

LIABILITIES

£ millions

YEAR	SD10	TD11	CD12	OC13	OCCD14	OL15	TOTAL LIABILITIES
1965/	4869	3292	0	0	0	1100	9261
1966/	4955	3536	0	0	0	1150	9641
1967/	5084	3769	0	0	0	1246	10099
1968/	5334	4177	0	0	0	1222	10733
1969/	5249	4363	0	0	0	1361	10973
1970/	5372	4484	0	0	0	875	10731
1971/	5873	4601	147	361	0	1034	12016
1972/	6425	6050	761	884	18	625	14763
1973/	6537	9041	1780	1660	64	626	19708
1974/	8344	11289	1721	2576	119	645	24694
1975/	9325	12415	774	3641	321	4086	30562
1976/	10175	12427	788	4285	311	2253	30239
1977/	11655	12659	903	4897	289	1739	32142
1978/	14167	13769	1434	5612	288	2760	38030
1979/	16306	16406	1266	6794	291	3501	44564
1980/	16731	21663	1303	9498	508	4313	54016
1981/	17748	26192	1332	15106	846	4543	65767
1982/	19598	33158	2417	19804	1449	4514	80940
1983/	22185	38285	3615	22251	1640	4398	92374
1984/	25628	39009	5459	25699	1643	6404	103842
1985/	31034	40544	4766	36872	3164	8708	125538

CAPITAL

£ millions

YEAR	SRC16	LC17	PFRN18	TOTAL CAPITAL	TOT.CAP.+TOT.LIAB
1965/	513	0	0	513	9774
1966/	544	0	0	544	10185
1967/	569	0	0	569	10668
1968/	618	43	0	661	11394
1969/	710	43	0	753	11726
1970/	1180	91	0	1271	12002
1971/	1307	106	0	1413	13429
1972/	1459	106	0	1565	16328
1973/	1778	268	0	2046	21754
1974/	2428	324	0	2752	27446
1975/	2302	364	0	2666	33228
1976/	2818	440	0	3258	33497
1977/	3109	420	0	3529	35671
1978/	3814	520	0	4334	42364
1979/	4624	549	0	5173	49737
1980/	5089	510	0	5599	59615
1981/	5719	772	0	6491	72258
1982/	7235	1142	0	8377	89317
1983/	8071	1585	0	9656	102030
1984/	8080	2218	430	10728	114570
1985/	9335	1951	3122	14408	139946

APPENDIX 4

Derivation of cost and revenue figures.

Data sources and definition of revenue and cost figures

•Revenue figures

r_2 : interest rate on money at call. Data are taken from BEQB (various issues)

r_3 : interest rate on Treasury bills. Data are taken from BEQB.

r4 : is a calculated average of interest rates on: Prime Bank bills and Trade bills. Data are taken from BEQB (various issues).

r_5 : interest rate on government securities. We used figures for short-dated government stock taken from BEQB.

r_6 : interest rate on other investments. It is approximated by the gross redemption yields of long-dated British government securities. Data are taken from CSO Financial Statistics.

r_7 : interest rate on loans and advances. We calculated the base rate (or bank rate) for each year and we added 3% (since the rate on advances varies between 1% above base rate and 5% above base rate)

r_8 : interest rate on foreign currency loans. It is calculated by adding a spread of 1.25% over the rate on Euro-dollar (3-month) deposits. (It is assumed that the spread varies between 0.5% and 2% over the Eurodollar deposits rate) and the figures are adjusted to take into account the forward premiums or discounts on US$. Data are taken from BEQB.

Cost figures

r_{10}: cost of sight deposits. Until 1981 there are no available data with respect to the size of interest bearing retail accounts so we assume that they represent a negligible percentage of sight deposits. Therefore before 1981 $r_{10}=0$. From 1981 data on interest bearing demand deposits for the London Clearing Banks Group are available (in: Abstract of Banking Statistics, issued by the Statistical Unit of the Commitee of London Clearing Bankers.) and we calculated the values of r_{10} as a weighted average of the rate on money at call (as an approximation of the rate on interest bearing demand deposits) and zero.

r_{11}: cost of deposit and time deposit accounts. It is calculated by substracting 2% for the period 1965-1970 and 1.75% for the period 1971-1985 from base rate. Data are taken from BEQB.

r_{12}: cost of sterling CD's. Data for 1971-1985 are taken from BEQB. Before 1971 the values of the rate of (the hypothetical) CD's are approximated by the rate on Prime Bank (3-month) Bills, which can be considered as substitude to CD's before 1971.

r_{13}: cost of foreign currency ($) deposits. It is represented by the rate on 3-month Eurodollar deposits; the values of r_{13} are adjusted to take account of any forward premiums or discounts on US$. Data are taken from BEQB.

r_{14}: cost of other currency ($) CD's. For the period 1972-1985, figures are taken from: Federal Reserve Bulletin. Figures are adjusted to take into account forward premiums or discounts on US$. Before 1972 we use the data used by Ben-Horim and Silber.

r_{15}: cost of other liabilities. It is approximated by the interest rate on 3-month Prime Trade bills. Data are taken from BEQB.

r_{16}: cost of share capital. It is approximated by the dividend yield of ordinary shares (financial group). Data are taken from CSO Financial Statistics.

r_{17}: cost of loan capital. It is approximated by the redemption yield of debenture and loan stocks. Data are taken from CSO Financial Statistics.

r_{18}: cost of perpetual floating rate notes is approximated by the gross flat yield of government consols. Data taken from CSO Financial Statistics.

* All the above rates are calculated 12-month averages.

COSTS

Model 1

YEAR	(SD10) r_{10}	(TD11) r_{11}	(CD12) r_{12}	(OC13) r_{13}	(OCCD14) r_{14}	(OL15) r_{15}	(SRC16) r_{16}	(LC17) r_{17}	(PFRN18) r_{18}
1965/	0	0.044	0.062	0.070	0.064	0.075	0.045	0.071	0.064
1966/	0	0.045	0.064	0.072	0.063	0.078	0.047	0.077	0.068
1967/	0	0.042	0.062	0.064	0.059	0.075	0.044	0.076	0.067
1968/	0	0.054	0.075	0.101	0.094	0.087	0.033	0.082	0.074
1969/	0	0.059	0.091	0.129	0.088	0.095	0.035	0.103	0.089
1970/	0	0.052	0.08	0.090	0.073	0.089	0.039	0.105	0.092
1971/	0	0.042	0.062	0.073	0.057	0.076	0.031	0.101	0.091
1972/	0	0.042	0.068	0.074	0.066	0.069	0.026	0.097	0.091
1973/	0	0.083	0.117	0.131	0.118	0.119	0.032	0.114	0.109
1974/	0	0.105	0.134	0.166	0.156	0.138	0.071	0.164	0.15
1975/	0	0.086	0.106	0.117	0.112	0.115	0.06	0.16	0.147
1976/	0	0.095	0.115	0.135	0.131	0.12	0.062	0.152	0.143
1977/	0	0.069	0.078	0.089	0.083	0.084	0.057	0.134	0.123
1978/	0	0.075	0.093	0.107	0.098	0.097	0.057	0.128	0.119
1979/	0	0.122	0.138	0.140	0.131	0.141	0.056	0.132	0.114
1980/	0	0.144	0.165	0.167	0.153	0.164	0.057	0.142	0.119
1981/	0.001	0.115	0.138	0.139	0.133	0.139	0.057	0.154	0.13
1982/	0.001	0.102	0.12	0.118	0.111	0.122	0.066	0.14	0.119
1983/	0.001	0.081	0.1	0.093	0.087	0.103	0.058	0.121	0.102
1984/	0.004	0.079	0.099	0.116	0.112	0.1	0.055	0.118	0.102
1985/	0.015	0.105	0.121	0.046	0.043	0.123	0.05	0.115	0.101

REVENUES

Model 1

YEAR	(MC2) r_2	(TB3) r_3	(OB4) r_4	(GVS5) r_5	(OTI6) r_6	(LA7) r_7	(OCL8) r_8
1965/	0.053	0.081	0.069	0.066	0.066	0.094	0.082
1966/	0.055	0.062	0.071	0.068	0.069	0.095	0.084
1967/	0.051	0.074	0.068	0.067	0.068	0.092	0.077
1968/	0.064	0.071	0.080	0.076	0.076	0.104	0.114
1969/	0.069	0.072	0.090	0.088	0.091	0.109	0.142
1970/	0.063	0.070	0.086	0.079	0.093	0.102	0.103
1971/	0.048	0.055	0.069	0.067	0.088	0.089	0.085
1972/	0.047	0.056	0.066	0.077	0.090	0.089	0.086
1973/	0.076	0.095	0.113	0.105	0.108	0.13	0.144
1974/	0.084	0.113	0.134	0.125	0.148	0.153	0.179
1975/	0.095	0.102	0.110	0.115	0.144	0.134	0.13
1976/	0.106	0.112	0.117	0.121	0.144	0.143	0.148
1977/	0.069	0.075	0.081	0.101	0.127	0.116	0.101
1978/	0.077	0.086	0.094	0.113	0.125	0.123	0.119
1979/	0.122	0.131	0.138	0.126	0.130	0.169	0.152
1980/	0.148	0.150	0.161	0.138	0.138	0.192	0.179
1981/	0.115	0.131	0.135	0.147	0.147	0.163	0.152
1982/	0.111	0.114	0.118	0.128	0.129	0.149	0.13
1983/	0.097	0.096	0.100	0.112	0.108	0.128	0.105
1984/	0.094	0.093	0.097	0.113	0.107	0.127	0.128
1985/	0.123	0.116	0.120	0.111	0.106	0.156	0.059

COSTS

Model 2

YEAR	(x8) r_8	(x9) r_9	(x10) r_{10}	(x11) r_{11}	(x12) r_{12}	(x13) r_{13}
1955	0	0.024	0.039	0.038	0.047	0.052 *
1956	0	0.034	0.051	0.059	0.062	0.060 *
1957	0	0.037	0.050	0.062	0.065	0.062 *
1958	0	0.033	0.046	0.048	0.058	0.062 *
1959	0	0.020	0.035	0.039	0.046	0.055 *
1960	0	0.034	0.051	0.052	0.061	0.054 *
1961	0	0.038	0.054	0.059	0.067	0.062 *
1962	0	0.028	0.043	0.046	0.060	0.061 *
1963	0	0.020	0.038	0.042	0.053	0.047
1964	0	0.033	0.050	0.052	0.063	0.052
1965	0	0.044	0.062	0.067	0.075	0.057
1966	0	0.045	0.064	0.068	0.078	0.060
1967	0	0.042	0.062	0.062	0.075	0.058
1968	0	0.054	0.075	0.098	0.087	0.056
1969	0	0.059	0.091	0.109	0.095	0.066
1970	0	0.052	0.080	0.082	0.089	0.069
1971	0	0.042	0.062	0.065	0.076	0.064
1972	0	0.042	0.068	0.070	0.069	0.060
1973	0	0.083	0.117	0.125	0.119	0.072
1974	0	0.105	0.134	0.161	0.138	0.114
1975	0	0.086	0.106	0.115	0.115	0.107
1976	0	0.095	0.115	0.133	0.120	0.105
1977	0	0.069	0.078	0.086	0.084	0.093
1978	0	0.075	0.093	0.103	0.097	0.091
1979	0	0.122	0.138	0.136	0.141	0.090
1980	0	0.144	0.165	0.160	0.164	0.094
1981	0.001	0.115	0.138	0.136	0.139	0.100
1982	0.001	0.102	0.120	0.115	0.122	0.098
1983	0.001	0.081	0.100	0.090	0.103	0.085
1984	0.004	0.079	0.099	0.114	0.100	0.083
1985	0.015	0.105	0.121	0.045	0.123	0.079

* Average of: 20-year debenture and loan stocks (redemption yield) and Industrial Ordinary Shares dividend yield.

REVENUES

Model 2

YEAR	(MC2) r_2	(TB3+OB4) r_3	(GVS5+OTI6) r_4	(LA7) r_5	(OCL8) r_6
1955	0.032	0.046	0.041	0.074	0.051
1956	0.042	0.055	0.050	0.084	0.071
1957	0.043	0.054	0.054	0.087	0.073
1958	0.039	0.050	0.052	0.083	0.062
1959	0.028	0.056	0.047	0.070	0.051
1960	0.043	0.061	0.056	0.084	0.066
1961	0.046	0.059	0.060	0.088	0.074
1962	0.041	0.052	0.056	0.078	0.061
1963	0.030	0.051	0.051	0.070	0.057
1964	0.041	0.047	0.058	0.083	0.066
1965	0.053	0.075	0.066	0.094	0.082
1966	0.055	0.067	0.069	0.095	0.084
1967	0.051	0.071	0.068	0.092	0.077
1968	0.064	0.076	0.076	0.104	0.114
1969	0.069	0.081	0.090	0.109	0.142
1970	0.063	0.078	0.086	0.102	0.103
1971	0.048	0.062	0.078	0.089	0.085
1972	0.047	0.061	0.084	0.089	0.086
1973	0.076	0.104	0.107	0.130	0.144
1974	0.084	0.124	0.137	0.153	0.179
1975	0.095	0.106	0.130	0.134	0.130
1976	0.106	0.115	0.133	0.143	0.148
1977	0.069	0.078	0.114	0.116	0.101
1978	0.077	0.090	0.119	0.123	0.119
1979	0.122	0.135	0.128	0.169	0.152
1980	0.148	0.156	0.138	0.192	0.179
1981	0.115	0.133	0.147	0.163	0.152
1982	0.111	0.116	0.129	0.149	0.130
1983	0.097	0.098	0.110	0.128	0.105
1984	0.094	0.095	0.110	0.127	0.128
1985	0.123	0.118	0.109	0.156	0.059

APPENDIX 5

Data sources and definitions of balance sheet figures.

*Liabilities: Each category comprises the following (BEQB) :

SD10:	(1965-1971)	Current accounts.
	(1971-1985)	Sight deposits.
TD11:	(1965-1973)	Deposit accounts.
	(1975-1985)	Time deposits.
CD12:	(1971-1985)	Negotiable certificates of deposit. Sterling.
OC13:	(1971-1985)	Current and deposit accounts. All holders. Other currencies.
OCCD14:	(1971-1985)	Negotiable certificates of deposit. US dollars.

*Assets: Each category comprises the following (BEQB) :

C1:	(1965-1975)	Coin, Notes and Balances with Bank of England. Total.
	(1975-1982)	Notes and coin + (Reserve assets) Balances with Bank of England.
	(1982-1985)	Notes and coin + Balances with Bank of England. (Other).
MC2:	(1965-1971)	Money at call and short notice. Total.
	(1971-1975)	Money at call and short notice; to discount market + to other borrowers.
	(1975-1981)	Reserve assets. Money at call.
	(1981-1985)	Market loans. Secured money with LDMA.
BILLS:	(1965-1974)	Bills discounted. Total.
	(1975-1980)	Reserve assets. UK and N. Ireland Treasury Bills + Other Bills + Bills (Other than reserve assets).
	(1981-1985)	Sterling assets. Treasury Bills + Eligible Bills + Other Bills.
GVS5:	(1965-1971)	Investments. British government guaranteed securities.
	(1971-1974)	British government stocks. Total.
	(1975-1981)	(Reserve assets) British government stocks 0-1 year + (Investments) British government

stocks over one year and undated.

(1982-1985) Investments. British government stocks.

OTI6: (1965-1972) (Investments). Total - British government stocks.

(1975-1985) Investments. Other.

LA7: (1965-1971) Advances to customers and other accounts.

(1972-1974) Advances. Total + Loans to UK local authorities - Overseas residents other currencies - UK residents other currencies.

(1975-1977) (Market loans)Banks in the UK + UK local authorities + other + Advances. UK + Advances. Overseas.

(1978-1985) (Market loans)Banks in the UK + UK local authorities + Other UK + Overseas + (Advances)UK public sector + UK private sector + Overseas.

OCL8: (1972-1975) Advances. UK residents other currencies + Overseas residents other currencies.

(1976-1985) Other currency assets. Market loans and advances. Total.

OTAS9: (1965-1971) Special deposits with Bank of England.

(1972-1973) Special deposits with Bank of England + Other assets + Acceptances.

(1974) Special deposits with Bank of England + Balances with other UK banks + negotiable sterling Certificates of deposit + Other assets + Acceptances.

(1975-1981) Special deposits with Bank of England + (Market loans)Certificates of deposit + Other currency Bills + Other currency investments + Sterling and other currencies miscellaneous assets + Acceptances.

(1982-1985) (Balances with Bank of England)Special and cash ratio deposits + (Market loans)Certificates of deposit + (Other currency assets) Bills + (Other currency assets)Investments + Sterling and other currencies:miscelaneous assets + Acceptances.

*Capital: The data for the period 1965-1974 are taken from the Annual Abstract of Financial Statistics.Thereafter they are calculated from data taken from the balance sheets of the four major Clearing Banks (Barclays,Lloyds,Middland,National Westminster).

Notes on data.

***Figures for the period 1965-1973 are taken from the Annual Abstract of Statistics.**

*For 1971,1972 and 1973 data are a combination of information taken from the Annual Abstrat of Statistics and the Bank of England Quarterly Bulletin. In particular:

For 1971, I calculated from BEQB the following:

CD12:	147 (£ millions)	Three months averages
OC13:	361 (")	Three months averages

In the Annual Abstract of Statistics (for 1971) we find:

TOTAL DEPOSITS:	11,328 (£ millions)
CURRENT ACCOUNTS:	6,053 (")
DEPOSIT ACCOUNTS:	4,781 (")
£ CERTIFICATES OF DEPOSIT:	147 (")
OTHER ACCOUNTS:	347 (")

We assume that OC13 are equally distributed between current and deposit accounts. So, we substract 180 from the figures for SD10 and TD11 to estimate their actual values for 1971.

SD10:	6,053 - 180 =	5,873 (£ millions)
TD11:	4,781 - 180 =	4,601 (")
CD12:		147 (")
OTHER DEPOSITS:		347 (")
TOTAL DEPOSITS:		11,329 (")

Using the same method we estimate the values for 1972 and 1973.

	SD10	TD11	CD12	OC13	OCCD14	OTHER DEPOSITS	TOTAL DEPOSITS
1972/	6,867	6,492	761	884	18	441	14,579
	- 442	- 442					
	6,425	6,050					
1973/	7,367	9,871	1,780	1,660	64	626	19,708
	- 830	- 830					
	6,537	9,041					

*Figures for 1974-1982 are calculated (as 12-month averages) from the Bank of England Quarterly Bulletin.

*In 1974 we estimated SD10 and TD11 as following: We observed that SD10 represents 42% of the sum of current and deposit accounts in 1973. This percentage becomes 43% in 1975. We assume that in 1974 SD10 represent 42.5% of the sum of current and deposit accounts (average percentage between 1973, 1975) and therefore TD11 represent the remaining 57.5%. So, we calculated them accordingly.

	SD10	%[SD10/(SD10+TD11)]	TD11	%[TD11/(SD10+TD11)]	SD10+TD11
1973/	6,537	42%	9,041	58%	15,578
1974/	**8,344**	**42.5%**	**11,289**	**57.5%**	**19,633**
1975/	9,325	43%	12,415	57%	21,740

*Figures for 1974 are calculated as 8-month averages.

*Figures for SRC16 are taken from the Annual Abstract of Statistics for the period 1965-1974. Thereafter they are calculated from data taken from the balance sheets of the four major London Clearing Banks.

*Figures for LC17 and PFRN18 are taken from the balance sheets of the four major London Clearing Banks.

*Other liabilities' are calculated as following:

OL15=TOTAL ASSETS-TOTAL DEPOSITS(including other deposits)-
TOTAL CAPITAL

*In 1973 and 1974 the sum of TOTAL CAPITAL+TOTAL DEPOSITS exceeds TOTAL ASSETS. I calculated the difference and considered it as an addition to OTAS8. However, not all of the difference was finally added to OTAS8 since part of this difference accounts for OTI6. I estimated that OTI6 represent 1.1% of TOTAL ASSETS in 1972 and 2.7% in 1975. I assumed that in the two years in between, the increase in this percentage was evenly distibuted. Therefore, OTI6 represent 1.63% of TOTAL ASSETS in 1973 and 2.16% in 1974. So:

	TOTAL ASSETS	OTI6
1973/	21,754	(x1.63%=) 355
1974/	27.446	(x2.16%=) 593

We now turn to calculate the new values for OTAS9:

	Calculated OTAS9 (from BEQB data)	Additional Assets (difference between: TOTAL DEP+CAPITAL-TOTAL ASSETS)	Additional OTAS9 (we substract OTI6)	New OTAS9
1973/	4,160	1,166	(1,166-355) 811	4,971
1974/	5,232	2,383	(2,383-593) 1,790	7,022

*Figures for 1982-1985 are calculated (as 12-month averages) from data taken from the Committee of London and Scottish Clearing Banks. Data for 1985 are 8-month averages.

APPENDIX 6

Tables used for χ^2 tests

FINANCIAL INNOVATIONS
(Including changes in funds above 60%)

Model 1
Year of introduction

SD10	CD12	OC13	OCCD14	SRC16	LC17	PFRN18	(1)
1981	1971	1971	1972	1970	1968	1975	1975
1984	1972	1972	1973	1975*	1970	1985	1981
-	1973	1973	1974	1978*	1973	-	-
-	1982	-	1975	1983*	1975*	-	-
-	-	-	1980	-	-	-	-
-	-	-	1981	-	-	-	-
-	-	-	1982	-	-	-	-
-	-	-	1985	-	-	-	-

* these years were included because there were rights issues introduced by the clearing banks and they can be seen as an innovative response to capital adequacy pressures.
* introduction of floating rate notes.

FINANCIAL INNOVATIONS
(Including changes in funds above 60%)

Model 2
Year of introduction

X8	X10	X11	X13	(1)
1981	1971	1971	1968	1975
1984	1972	1972	1970	1981
-	1973	1973	1975	-
-	1982	1974	1978	-
-	-	1975	1983	-
-	-	1980	1985	-
-	-	1981	-	-
-	-	1982	-	-
-	-	1985	-	-

Major Peaks in shadow prices

3year averages

MODEL 1A

SD10	CD12	OC13	OCCD14	SRC16	LC17	PFRN18	con. (1)
1969	1976	1971	1970	1968	1966	1966	1969
1975	1983	1976	1982	1975	1975	1975	1975
1981		1978	1985	1985	1985	1985	1980
		1982					
		1985					

MODEL 1B

SD10	CD12	OC13	OCCD14	SRC16	LC17	PFRN18	con. (1)
1970	1970	1968	1968	1966	1966	1966	1970
1975	1977	1970	1970	1974	1972	1972	1975
1980	1984	1978	1978	1981	1981	1981	1980
		1982	1982				
		1985	1985				

MODEL 1C

SD10	CD12	OC13	OCCD14	SRC16	LC17	PFRN18	con. (1)
1975	1971	1966	1966	1967	1967	1967	1975
1980	1977	1971	1971	1975	1975	1975	1980
	1983	1977	1977	1981	1981	1981	
		1985	1985	1985	1985	1985	

MODEL 1D

SD10	CD12	OC13	OCCD14	SRC16	LC17	PFRN18	con. (1)
1975	1971	1966	1966	1975	1972	1980	1975
1980	1976	1972	1971	1980	1979	1985	1980
	1983	1976	1976	1985	1985		
		1985	1985				

Major Peaks in shadow prices

3year averages

MODEL 2A

X8	X10	X11	X13	con. (1)
1975	1971	1966	1969	1975
1980	1977	1971	1974	1980
	1982	1977	1980	
		1982	1985	
		1985		

MODEL 2B

X8	X10	X11	X13	con. (1)
1974	1971	1971	1974	1974
1982	1976	1981	1979	
	1981		1985	

MODEL 2C

X8	X10	X11	X13	con. (1)
1974	1971	1966	1974	1974
1983	1976	1971	1980	
	1981	1978		
	1985			

MODEL 2D

X8	X10	X11	X13	con. (1)
1975	1971	1966	1969	1975
1980	1976	1971	1980	1980
	1985	1978		
		1982		
		1985		

MODEL 2E

X8	X10	X11	X13	con. (1)
1975	1971	1966	1969	1975
1980	1977	1971	1974	1980
	1983	1977	1980	
		1982		
		1985		

Major Peaks in shadow prices

(Unsmoothed results)

MODEL 1A

SD10	CD12	OC13	OCCD14	SRC16	LC17	PFRN18	con. (1)
1969	1967	1971	1969	1967	1967	1967	1969
1974	1971	1975	1973	1972	1972	1972	1974
1976	1975	1977	1975	1974	1974	1974	1976
1980	1977	1979	1977	1977	1977	1977	1980
	1982	1982	1979	1980	1980	1980	1985
		1985	1982	1985	1985	1985	
			1985				

MODEL 1B

SD10	CD12	OC13	OCCD14	SRC16	LC17	PFRN18	con. (1)
1970	1971	1967	1967	1967	1967	1967	1970
1974	1974	1971	1969	1973	1973	1973	1974
1980	1977	1973	1971	1976	1976	1976	1980
1985	1983	1977	1974	1980	1980	1980	1985
		1983	1977	1984	1984	1984	
		1985	1983				
			1985				

MODEL 1C

SD10	CD12	OC13	OCCD14	SRC16	LC17	PFRN18	con. (1)
1974	1970	1967	1967	1966	1966	1966	1970
1976	1974	1972	1971	1968	1968	1968	1974
1980	1977	1977	1977	1975	1975	1975	1976
	1984	1983	1983	1980	1980	1980	1980
		1985	1985	1985	1985	1985	1985

MODEL 1D

SD10	CD12	OC13	OCCD14	SRC16	LC17	PFRN18	con. (1)
1970	1967	1967	1967	1968	1968	1976	1970
1974	1972	1972	1971	1969	1973	1980	1974
1980	1977	1975	1975	1976	1976	1985	1976
	1981	1977	1977	1980	1980		1980
		1983	1983	1985	1985		1985
		1985	1985				

Major Peaks in shadow prices

(Unsmoothed results)

MODEL 2A

X8	X10	X11	X13	con. (1)
1969	1967	1967	1969	1969
1974	1972	1972	1973	1974
1980	1977	1975	1976	1980
	1981	1977	1980	1985
		1983	1985	
		1985		

MODEL 2B

X8	X10	X11	X13	con. (1)
1974	1975	1967	1974	1969
1982	1980	1970	1980	1974
	1982	1978	1985	
	1985	1981		

MODEL 2C

X8	X10	X11	X13	con. (1)
1974	1972	1967	1973	1973
1983	1977	1972	1979	1983
	1980	1975	1985	
	1985	1979		

MODEL 2D

X8	X10	X11	X13	con. (1)
1969	1967	1967	1969	1969
1975	1972	1972	1973	1975
1981	1975	1975	1976	1981
	1977	1977	1979	
	1985	1985		

MODEL 2E

X8	X10	X11	X13	con. (1)
1969	1967	1967	1969	1969
1974	1972	1972	1973	1974
1980	1975	1975	1976	1980
	1977	1977	1980	
	1984	1983	1985	
		1985		

APPENDIX 7

Computer programs used.

-The Computer program used for solving the linear programming program of Model 1 is: AMSTAT 4 (RESOURCE MANAGEMENT), by S.C.Coleman for the Amstrad PCW8512 Computer. The algorithm used in this program is Dantzig's Revised Simplex Method.

-Model 2 is a quadratic programming problem. The Gould PN6040 system (CITY UNIVERSITY computer unit) was used to solve it. The program created is based on the E04NAF -NAG Fortran Library Subroutine.

E04NAF is designed to solve quadratic problems and in particular the minimisation of a quadratic function subject to a set of linear constraints on the variables. The problem is stated in the following general form:

$$\text{minimise } c^T x + \tfrac{1}{2} x^T \Sigma x \quad \text{subject to } l \leq \begin{vmatrix} x \\ Ax \end{vmatrix} \leq u$$

where c is a constant n-vector and Σ is a constant $n \times n$ symmetric matrix. The matrix A is $m \times n$, where m may be zero. The form of the constraints is general and although it sets upper and lower bounds for all the variables and the linear constraints it can easily accomodate other forms of linear constraints. In particular, an equality constraint can be specified by setting $l_i = u_i$. If certain bounds are not present, the associated elements of l or u can be set equal to special values that will be treated as $-\infty$ or $+\infty$. If Σ is positive definite or positive semi-definite, E04NAF will obtain a global minimum; otherwise the solution obtained will be a local minimum.

The general form of Model 2 is:

$$\text{Max } E(U^*) = [r_1\ r_2 \ldots r_9 \ldots r_{13}] \begin{vmatrix} X_1 \\ \vdots \\ -X_9 \\ \vdots \\ -X_{13} \end{vmatrix} - \frac{b}{2} [X_1 \ldots -X_9 \ldots -X_{13}] \begin{vmatrix} c_1^2 & \cdots & c_{1,9} & \cdots & c_{1,13} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & c_9^2 & \cdots & c_{9,13} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ c_{13,1} & \cdots & \cdots & & c_{13}^2 \end{vmatrix} \begin{vmatrix} X_1 \\ \vdots \\ -x_9 \\ \vdots \\ -X_{13} \end{vmatrix}$$

We have to make a series of transformations in order to bring our model to the general form required by the computer program:

(a) We transfer the minus signs from the vector of assets x (liabilities are treated as negative assets). So, we have:

$$\text{Max } E(U^*) = [r_1\ r_2\ \ldots\ -r_8\ \ldots\ -r_{13}] \begin{vmatrix} x_1 \\ \vdots \\ x_8 \\ \vdots \\ x_{13} \end{vmatrix} - \frac{b}{2} [x_1\ \ldots\ x_8\ \ldots\ x_{13}] \begin{vmatrix} c_1^2 & \ldots & -c_{1,8} & \ldots & -c_{1,13} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ -c_{8,1} & \ldots & c_8^2 & \ldots & c_{8,13} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ -c_{13,1} & - & \ldots & & c_{13}^2 \end{vmatrix} \begin{vmatrix} x_1 \\ \vdots \\ x_8 \\ \vdots \\ x_{13} \end{vmatrix}$$

(b) We multiply the objective function by -1 to change the problem from maximisation to the equivalent minimisation problem:

$$\text{Max } E(U^*) = [-r_1\ -r_2\ \ldots\ r_8\ \ldots\ r_{13}] \begin{vmatrix} x_1 \\ \vdots \\ x_8 \\ \vdots \\ x_{13} \end{vmatrix} + \frac{b}{2} [x_1\ \ldots\ x_8\ \ldots\ x_{13}] \begin{vmatrix} c_1^2 & \ldots & -c_{1,8} & \ldots & -c_{1,13} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ -c_{8,1} & \ldots & c_8^2 & \ldots & c_{8,13} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ -c_{13,1} & - & \ldots & & c_{13}^2 \end{vmatrix} \begin{vmatrix} x_1 \\ \vdots \\ x_8 \\ \vdots \\ x_{13} \end{vmatrix}$$

The program is:

```
C       PROGRAM WHICH USES E04NAF SUBROUTINE FOR THE
C       SOLUTION OF A CONSTRAINT MAXIMISATION
C       QUADRATIC PROBLEM
C
C       PORTFOLIO MODEL FOR THE LONDON CLEARING BANKS
C
C       ...LOCAL SCALARS..
        DOUBLE PRECISION BIGBND, EPSMCH, OBJ, RTEPS, ZERO
        INTEGER I, IFAIL, ITER, ITMAX, J, LIWORK
       *LWORK, MSGLVL, N, NCLIN, NCOLH, NCTOTL, NIN, NOUT,
       *NROWA, NROWH
        LOGICAL COLD, LP, ORTHOG
C       ...LOCAL ARRAYS..
```

```
      DOUBLE PRECISION A(6,13),BL(19),BU(19),CLAMDA(19),
     *CVEC(13),FEATOL(19),HESS(13,13),TITLE(7),
     *WORK(500),X(13)
      INTEGER ISTATE(19),IWORK(40)
C     ...FUNCTION REFERENCES...
      DOUBLE PRECISION SQRT,X02AAF
C     ...SUBROUTINE REFERENCES...
C     E04NAF,X04ABF
C     ...
      EXTERNAL QPHES1
      DATA NIN, NOUT /5, 6/
      DATA NROWA, NROWH,NCOLH /6, 13, 13/
      DATA LIWORK,LWORK /40, 500/
C
      READ (NIN,99999) (TITLE(I),I=1,7)
      WRITE (NOUT,99998) (TITLE(I),I=1,6)
C
C     WE NOW INSERT EXPLICITLY THE VALUES FOR:
C     A(6,13), BL(19), BU(19), CVEC(13), HESS(13,13), X(13)
C     ...
      CALL X04ABF(1,NOUT)
      N = 13
      NCLIN = 6
      NCTOTL = N+NCLIN
      ITMAX = 100
      MSGLVL = 25
      BIGBND = 10000000000
      EPSMCH = X02AAF(ZERO)
      RTEPS = SQRT(EPSMCH)
      DO 20 J=1,NCTOTL
      FEATOL(J) = RTEPS
20    CONTINUE
      COLD = .TRUE.
      LP = .FALSE.
      ORTHOG = .TRUE.
C     ...
```

```
C       SOLVE THE PROBLEM FROM A COLD START
C       HESSIAN IS DEFINED EXPLICITLY BY SUB QPHES1
C       ...
        IFAIL = 1
        CALL E04NAF(ITMAX,MSGLVL,N,NCLIN,NCTOTL,NROWA,NROWH,
       *NCOLH,BIGBND,A,BL,BU,CVEC,FEATOL,HESS,QPHES1,COLD,
       *LP,ORTHOG,X,ISTATE,ITER,OBJ,CLAMDA,IWORK,LIWORK,WORK,
       *LWORK,IFAIL)
C       ...
        WRITE (NOUT,99995) IFAIL
        STOP
99999   FORMAT (6A4,1A3)
99998   FORMAT (4(1X/),1H,5A4,1A3,/HRESULTS/1X)
99995   FORMAT (/31H E04NAF TERMINATED WITH IFAIL=,I3)
        END
C       ...
        SUBROUTINE QPHES1(N,NROWH,NCOLH,JTHCOL,HESS,X,HX)
C       THE MATRIX H IS STORED IN HESS AS A FULL
C       TWO-DIMENSIONAL ARRAY.
C       ...SCALAR ARGUMENTS..
        INTEGER JTHCOL,N,NCOLH,NROWH
C       ...ARRAY ARGUMENTS...
        DOUBLE PRECISION HESS(NROWH,NCOLH),HX(N),X(N)
C       ...
C       ...LOCAL SCALARS..
        INTEGER I,J
C       ...
        IF (JTHCOL.EQ.0) GO TO 60
C       SPECIAL CASE--EXTRACT ONE COLUMN OF H
        DO 40 I=1,N
         HX(I) = HESS(I,JTHCOL)
   40   CONTINUE
        RETURN
C       NORMAL CASE
   60   DO 80 I=1,N
         HX(I) = 0.0
```

```
80    CONTINUE
      DO 120 J=1,N
       DO 100 I=1,N
         HX(I) = HX(I) + HESS(I,J)*X(J)
100   CONTINUE
120   CONTINUE
      RETURN
      END
```

-For the estimation of the variance-covariance matrices as well as for the χ^2 tests of the results, the statistical package "QUASAR" from Goode Software was used (for the Amstrad PCW 8512 computer).

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