TECHNOLOGICAL INNOVATIONS AND THE INTEREST RATE

Emanuel Reis Leão

Dezembro 2002

WP nº 2002/28

DOCUMENTO DE TRABALHO

WORKING PAPER

DINÂMIA
CENTRO DE ESTUDOS SOBRE A MUDANÇA SOCIOECONÓMICA

FCT
Fundação para a Ciência e a Tecnologia

Emanuel Leão is Auxiliary Professor at the Departament of Economics of the Instituto Superior de Ciências do Trabalho e da Empresa (ISCTE) and Research Fellow of the Dinâmia (Centro de Estudos sobre a Mudança Socioeconómica).

The author has received helpful comments from Alan J. Sutherland, Peter N. Smith, Michael R. Wickens, Morten O. Ravn and John P. Hutton. They are not in any way responsible for anything written in this paper.

DINÂMIA CENTRO DE ESTUDOS SOBRE A MUDANÇA SOCIOECONÓMICA

TECHNOLOGICAL INNOVATIONS AND THE INTEREST RATE

Emanuel Reis Leão
(eccl@iscte.pt)

WP 2002/28

Dezembro de 2002

ÍNDEX

Abstract	**2**
List of Symbols	**3**
1. Introduction	**5**
2. The Economic Environment	**6**
3. The Typical Bank's Behaviour	**8**
4. The Typical Firm's Behaviour	**8**
5. The Typical Household's Behaviour	**9**
6. The Market Clearing Conditions	**11**
7. The Competitive general Market Equilibrium	**11**
8. Calibration	**13**
9. The Dynamic Properties of the Model	**15**
9.1. Technological innovations in nonbank firms	**15**
9.2. Technological innovations in the banking sector	**16**
10. Conclusion	**19**
References	**20**
Tables	**21**
Figures	**23**

ISCTE - INSTITUTO SUPERIOR DE CIÊNCIAS DO TRABALHO E DA EMPRESA
Av. das Forças Armadas, 1649-026 Lisboa, PORTUGAL
Tel. 217938638 Fax. 217940042 E-mail: dinamia@dinamia.iscte.pt Internet: www.dinamia.iscte.pt

Abstract

We build a dynamic general equilibrium model where there are banks that charge interest for their loans to the private sector. We look at the response of the interest rate to innovations in the banks' technology and to innovations in the nonbank firms' technology. We find that whereas technological innovations in the nonbanking sector put upward pressure on the interest rate, technological innovations in banks exert downward pressure on the interest rate. This property of the model is behind our main result: in stochastic simulation experiments where the technological shocks in banks are highly positively correlated with the technological shocks in firms, we obtain a strong negative correlation between the current interest rate and future values of real output. This corresponds to what the data show us [see King and Watson (1996)].

Keywords: Dynamic general equilibrium, technological innovations, behaviour of the interest rate.

JEL Classification: E17, E24, E32, E43 (The full list of JEL codes can be found at http://www.aeaweb.org/journal/elclasjn.html).

List of Symbols

	HOUSEHOLD VARIABLES
c_t	household's consumption in real terms
ℓ_t	leisure
n_t^s	household's supply of labour
$B_{t+1}/(1+R_t)$	the amount the household borrows at the beginning of period t
B_{t+1}	household's debt at the beginning of period (t+1)
z_t^f	% of firm f that the household buys at beginning of period (t-1) and sells at beginning of period t
$z_t^{bank,l}$	% of bank l that the household buys at beginning of period (t-1) and sells at beginning of period t
CD_t	amount of checkable deposits the household decides to hold at the beginning of period t
λ_t	shadow price (marginal utility of consumption, in this model)
β	intertemporal discount factor
	FIRM VARIABLES
y_t	firm's output
k_t	firm's stock of capital
n_t^d	firm's labour demand
i_t	firm's investment
Π_t^f	nominal profits of firm f in period t
δ	per period rate of depreciation of the firm's capital stock
α	firm Cobb-Douglas parameter
	BANK VARIABLES
B_t^s	bank's nominal supply of credit at the beginning of period t
b_t^s	bank's real supply of credit at the beginning of period t
n_t^b	bank labour demand in period t
Π_t^{bank}	nominal profits of the typical bank in period t
	PRICE VARIABLES
P_t	price of physical output
W_t	nominal wage rate
R_t	nominal interest rate between the beginning of period t and the beginning of period (t+1)
Q_t^f	nominal price of firm f at beginning of period t (amount necessary to buy 100% of firm f)
$Q_t^{bank,l}$	nominal price of bank l at beginning of period t (amount necessary to buy 100% of bank l)
	SHOCK VARIABLES
A_t	firm's technological parameter
D_t	bank's technological parameter

x	steady-state value of variable x_t
$\widehat{x_t}$	the percentage deviation of variable x_t from its steady-state (in period t)
$E_t\left[.\right]$	expectation conditional on information pertaining to the beginning of period t and earlier of the indicated argument
H	number of households
F	number of firms
L	number of banks

$$q_t^f = \frac{Q_t^f}{P_t}$$

$$q_t^{bank,l} = \frac{Q_t^{bank,l}}{P_t}$$

$$\pi_t^f = \frac{\Pi_t^f}{P_t}$$

$$\pi_t^{bank,l} = \frac{\Pi_t^{bank,l}}{P_t}$$

$$b_{t+1} = \frac{B_{t+1}}{P_t}$$

$$w_t = \frac{W_t}{P_t}$$

$$1 + \tilde{p}_{t+1} = \frac{P_{t+1}}{P_t}$$

$$\overline{k}_t = \frac{F}{H}\ k_t$$

$$\overline{n}_t^d = \frac{F}{H}\ n_t^d$$

$$\overline{n}_t^b = \frac{L}{H}\ n_t^b$$

$$\overline{q}_t^f = \frac{F}{H} q_t^f$$

$$\overline{q}_t^{bank,l} = \frac{L}{H} q_t^{bank,l}$$

$$\overline{\pi}_t^f = \frac{F}{H} \pi_t^f$$

$$\overline{\pi}_t^{bank,l} = \frac{L}{H} \pi_t^{bank,l}$$

1 Introduction

In a world where technological innovations occur both in the banking sector and in the nonbanking sector, the marginal product of labour (MPL) is constantly being changed in both sectors. At the same time we know that, in a general equilibrium, the MPL in each sector must be equal to the economy-wide real wage and hence the MPL must be the same in both sectors. Since the interest rate charged by commercial banks affects the MPL in banks, we would like to know what pressure is exerted on this variable (the interest rate) to help the MPL in the two sectors match in spite of the exogenous technological shocks.

In order to try to obtain an answer to this question, we have built a dynamic general equilibrium model where there are only households, nonbank firms and commercial banks in operation (in this paper, we shall refer to "nonbank firms" simply as "firms"; likewise, we shall refer to "commercial banks" simply as "banks"). We have log-linearized the competitive equilibrium around the steady-state values of its variables and then calibrated it using Postwar data. Afterwards, we examined the response of the model to shocks in the firms' technology and to shocks in the banks' technology.

In the impulse response exercises, we found that whereas positive shocks to the firms' technology put upward pressure on the interest rate, positive shocks to the banks' technology exert downward pressure on the interest rate. This made us think that by performing a stochastic simulation exercise where the technological shocks in firms and the technological shocks in banks are highly positively correlated, we might be able to approximately replicate the important business cycle fact, reported in King and Watson (1996), that the current interest rate is strongly negatively correlated with future values of real output. In fact, if the shocks are highly positively correlated, in most periods we will have upward pressure on the interest rate coming from the positive shocks in the firms' technology and simultaneous downward pressure on the interest rate coming from the positive shocks in the banks' technology. If the shocks in the banks' technology are strong enough, the combined effect of the two shocks will be a fall in the interest rate. At the same time, both technological shocks make output go up. As a consequence, a negative correlation should appear.

In choosing to look at the impact of purely sectoral technology shocks in a general equilibrium model, we have been inspired by Horvath (2000). However, unlike this author, we explicitly model the banking sector as a separate sector because this sector has specificities that may be important for our purpose of studying interest rate behaviour in the presence of technological innovations: foremost, the fact that the interest rate charged by a commercial bank directly affects its MPL.

The structure of the article is as follows. In section 2, we present the economic environment: preferences, technology, resource constraints and market structure. In section 3, we describe the typical bank's behaviour. In section 4, we outline the typical firm's behaviour. In section 5, we describe the typical household's behaviour. In section 6, we write down the market clearing conditions. In section 7, we write the set of equations that describes the competitive equilibrium. In section 8, we describe the calibration of the model. In section 9, we look at the response of the model to shocks in the firms' technology and to shocks in the banks' technology, and we then discuss the main results of the paper. In section 10, we make an overview and conclusion.

2 The Economic Environment

This is a closed economy model with no government. There are H homogeneous households, F homogeneous firms and L homogeneous banks in operation. In the model we use, firms and banks are owned by the households. As a consequence, both the firms' profits and the banks' profits are distributed to households (the shareholders) at the end of each period. There is only one physical good produced in this economy which we denote physical output. There are two possible uses for this output: it can either be consumed or used for investment (i.e., used to increase the capital stock).

In our model, bank loans are the only source of money to the economy. Commercial banks make loans to households and households then use the money obtained in this way to buy consumption goods from the firms. In performing their role of suppliers of credit, banks incur labour costs. In fact, each time they make a loan, banks create deposits. Since households can write cheques on these deposits, banks have to process the cheques and therefore need to hire hours of work in the labour market. The fact that banks have costs of operation is enough to bind the supply of credit.

In each period, the complete description of monetary flows among economic agents is as follows. At the beginning of each period, the typical household borrows from the banks the amount that she needs in order to be able to buy consumption goods from the firms during the period that is beginning. Loans obtained from a bank initially take the form of checkable deposits held in the households' bank accounts. During the period, the typical household spends her checkable deposits buying consumption goods from the firms (she makes payments by cheque or using her debit card to directly transfer deposits to the firms' accounts). As they receive these payments, firms make a deposit of the amounts received in one or more banks. Hence, the checkable deposits that were created at the beginning of the period continue to exist but are gradually transferred, during the period, from the households' bank accounts to the firms' bank accounts. At the end of the period, households receive back from the firms these checkable deposits (as wage payments and dividend payments). Then, households pay the banks interest on the amount borrowed at the beginning of the period (the amount of interest due is paid by reducing the amount of checkable deposits they own at the banks). However, households immediately receive back the amount of interest paid to the banks. They receive that amount in the following ways (see the definition of banks' profits below): (i) part is received in the form of wages paid by banks to households; (ii) the remaining part is paid to the households in the form of bank dividends. Afterwards, households use all checkable deposits received to pay the banks the principal of the debt contracted at the beginning of the period. The structure of the model is such that, after all these payments, households are left with nothing and must therefore borrow again from the banks at the start of the new period.

The fact that all money in our model takes the form of bank deposits which are an asset to their holders and a liability to the banks (i.e. all money is simultaneously an asset and a liability of the private sector) makes it an inside money model.

We next examine the typical household's preferences, the technology available in the economy (production function and capital accumulation equation), the resource constraints that exist in a given period, and the market structure. Let us suppose that we are at the beginning of period 0 and that households, firms and banks are considering decisions for periods t with $t = 0, 1, 2, 3, ...$

Let us start by describing the preferences of the typical household. The typical household seeks to maximize lifetime utility. Utility in period t is given by $u(c_t, \ell_t)$, where c_t is the flow amount of consumption and ℓ_t is the amount of leisure enjoyed in that period. The function $u(.,.)$ has the usual properties. At the beginning of period 0, the household maximizes $U_0 = E_0 \left[\sum_{t=0}^{t=\infty} \beta^t u(c_t, \ell_t) \right]$, where β is a discount factor $(0 < \beta < 1)$.

Let us now describe the technology available in this economy. Each firm's production function is described by $y_t = A_t F(k_t, n_t^d)$, where y_t is the physical output of the firm, A_t is a technological parameter, k_t is the firm's (pre-determined) capital stock, and n_t^d is the firm's labour demand in period t. The typical firm's capital accumulation equation is $k_{t+1} = (1 - \delta)k_t + i_t$, where i_t is the flow of investment in period t and δ is the per-period rate of depreciation of the capital stock. For each bank, there is a production function that tells how many hours of work the bank must hire in order to be able to supply each amount of credit in real terms. The technology available to all banks can be summarized by

$$b_t^s = D_t (n_t^b)^\gamma \tag{1}$$

where b_t^s is the bank's supply of credit in real terms, D_t is a technological parameter, and n_t^b is the number of work hours hired by the bank. Note that we are implicitly assuming that physical capital in banks is fixed and does not depreciate. Note also that an improvement in the bank's technology can be modelled as an increase in D_t.

The resource constraints that exist in this economy are as follows. Each firm starts period t with a capital stock k_t which is pre-determined [which was determined at the beginning of period $(t - 1)$]. In other words, the stock of capital that will enter the production function in period t cannot be changed by decisions taken at the beginning or during period t. Each household has an endowment of time per-period which is normalized to be equal to *one* by an appropriate choice of units. This amount of time can be used to work or to rest. Therefore, we can write $n_t^s + \ell_t = 1$, where n_t^s is the household's supply of labour during period t.

Let us now describe the market structure. There are five markets: the goods market, the labour market, the bank loans' market, the market for firms' shares and the market for banks' shares. We assume that labour is homogeneous and perfectly mobile between the two industries in the economy (the physical output industry and the banking industry). We assume that each household behaves as a price-taker, each firm behaves as a price-taker, and each bank also behaves as a price-taker. Prices are perfectly flexible and adjust so as to clear all markets in every period.

3 The Typical Bank's Behaviour

We treat banks as profit maximizing firms that create deposits (money) each time they make a loan. The deposits thus created imply costs of operation to the bank which in our case are only labour costs. We assume that the bank hires nonskilled work hours in the labour market in order to perform the operations that the creation of deposits entails. In period t, the nominal profits of each bank are given by interest income minus wage payments to the bank's employees

$$\Pi_t^{bank} = R_t B_t^s - W_t n_t^b \tag{2}$$

where R_t is the interest rate charged by the bank for loans that start at the beginning of period t and end at the beginning of period $(t+1)$, B_t^s is the nominal amount of credit that the bank supplies at the beginning of period t, and W_t is the nominal wage rate. We assume that banks pay wages at the end of each period. Also, the profits earned by each bank during period t are distributed to households (the shareholders) at the end of the period in the form of dividends. Equation 2 can be rewritten as

$$\Pi_t^{bank} = R_t P_t b_t^s - W_t n_t^b$$

where P_t is the price level (price of physical output) and, as already mentioned, b_t^s is the amount of credit supplied by the bank in real terms. Using equation 1, this last equation becomes

$$\Pi_t^{bank} = R_t P_t D_t (n_t^b)^\gamma - W_t n_t^b \tag{3}$$

Each bank maximizes the Value of its Assets (VA), i.e., the expected discounted value of its stream of present and future dividends. Therefore, when we are at the beginning of period 0, the typical bank's optimization problem is

$$\underset{n_t^b}{Max} VA = E_0 \left[\sum_{t=0}^{t=\infty} \frac{1}{1+R_{0,t+1}} \Pi_t^{bank} \right]$$

where Π_t^{bank} is given by 3. Given the economic environment we are working with, we think it is appropriate to assume that $(1+R_{0,t+1}) = (1+R_0)(1+R_1)(1+R_2)...(1+R_t)$. Note that we are at the beginning of period 0. Therefore, because dividends are only distributed at the end of the period, we discount period 0 dividends by multiplying them by $1/(1+R_0)$, we discount period 1 dividends by multiplying them by $1/[(1+R_0)(1+R_1)]$, and so on. There are also non-negativity constraints.

4 The Typical Firm's Behaviour

In nominal terms, the profits of each firm in period t are given by income from the sale of output minus the wage bill minus investment expenditure

$$\Pi_t = P_t A_t F(k_t, n_t^d) - W_t n_t^d - P_t[k_{t+1} - (1-\delta)k_t] \tag{4}$$

The firm pays wages to households at the end of the period. The profits earned by each firm during period t are distributed to households (the shareholders) at the end of the period in the form of dividends. Each firm f ($f = 1, 2, ..., F$) maximizes the Value of its Assets (VA). Therefore, when we are at the beginning of period 0, the typical firm's optimization problem is

$$\underset{n_t^d, k_{t+1}}{Max}\; VA = E_0 \left[\sum_{t=0}^{t=\infty} \frac{1}{1+R_{0,t+1}} \Pi_t \right]$$

where Π_t is given by 4. There is also an initial condition for the capital stock, the standard transversality condition for the capital stock, and non-negativity constraints.

5 The Typical Household's Behaviour

The way bank loans work in this model is as follows. We have mentioned that R_t denotes the interest rate between the beginning of period t and the beginning of period (t+1). At the beginning of period t, the household borrows from banks the amount $\frac{B_{t+1}}{1+R_t}$. This means that the household receives $\frac{B_{t+1}}{1+R_t}$ monetary units at the beginning of period t and that she will have to pay $\frac{B_{t+1}}{1+R_t}(1+R_t) = B_{t+1}$ monetary units at the end of period t [beginning of period $(t+1)$]. Hence, B_{t+1} denotes the debt the household has at the beginning of period (t+1).

The way shares work in this model is as follows. Q_t^f is the nominal price that someone would have to pay to buy 100% of firm f at the beginning of period t. z_t^f is the percentage of firm f [i.e. the share of firm f] that the household bought at the beginning of period (t-1) and sells at the beginning of period t. z_{t+1}^f is the percentage of firm f that the household buys at the beginning of period t. These percentages are measured as a number belonging to the closed interval [0,1]. Therefore, z_t^f Q_t^f is the nominal value of the shares of firm f that the household sells at the beginning of period t. On the other hand, $z_{t+1}^f Q_t^f$ is the nominal amount that the household spends buying shares of firm f at the beginning of period t. The shares of banks work in the same way: $Q_t^{bank,l}$ is the nominal price that someone would have to pay to buy 100% of bank l at the beginning of period t. $z_t^{bank,l}$ is the percentage of bank l that the household bought at the beginning of period (t-1) and sells at the beginning of period t. $z_{t+1}^{bank,l}$ is the percentage of bank l that the household buys at the beginning of period t.

The typical household's budget constraint is

$$W_{t-1}n_{t-1}^s + \sum_{f=1}^{f=F} z_t^f \Pi_{t-1}^f + \sum_{f=1}^{f=F} z_t^f Q_t^f + \sum_{l=1}^{l=L} z_t^{bank,l} \Pi_{t-1}^{bank,l} + \sum_{l=1}^{l=L} z_t^{bank,l} Q_t^{bank,l} + \frac{B_{t+1}}{1+R_t} =$$

$$= B_t + P_t c_t + \sum_{f=1}^{f=F} z_{t+1}^f Q_t^f + \sum_{l=1}^{l=L} z_{t+1}^{bank,l} Q_t^{bank,l} \quad (5)$$

This equation simply states that the total amount of money the household obtains at the beginning of period t [wage earnings, dividend earnings from firms, money received from selling the shares of firms bought at the beginning of period (t-1), dividend earnings from banks, money received from selling the shares of banks bought at the beginning of period (t-1), and the amount she borrows from the banks at the beginning of period t] must be equal to the amount the household spends at the beginning or during period t [payment of the debt contracted from banks at the beginning of period (t-1), consumption expenditure during period t, purchase of shares of firms at the beginning of period t, and purchase of shares of banks at the beginning of period t]. In section 5 of Leao (2001) it is shown that this budget constraint can be derived from the combination of a portfolio allocation constraint and a cash-in-advance constraint [in the spirit of Lucas (1982)]. Let us now normalize the household's budget constraint. We can do this by dividing both sides of the constraint by P_t , rearranging, and then defining the following new variables: $w_t = \frac{W_t}{P_t}$, $q_t^f = \frac{Q_t^f}{P_t}$, $q_t^{bank,l} = \frac{Q_t^{bank,l}}{P_t}$, $b_{t+1} = \frac{B_{t+1}}{P_t}$, $\pi_t^f = \frac{\Pi_t^f}{P_t}$, $\pi_t^{bank,l} = \frac{\Pi_t^{bank,l}}{P_t}$, and $1+\tilde{p}_{t+1} = \frac{P_{t+1}}{P_t}$. What we obtain is

$$\frac{w_{t-1}}{1+\tilde{p}_t}n_{t-1}^s + \sum_{f=1}^{f=F} z_t^f \frac{\pi_{t-1}^f}{1+\tilde{p}_t} + \sum_{f=1}^{f=F} z_t^f q_t^f + \sum_{l=1}^{l=L} z_t^{bank,l}\frac{\pi_{t-1}^{bank,l}}{1+\tilde{p}_t} + \sum_{l=1}^{l=L} z_t^{bank,l} q_t^{bank,l} + \frac{b_{t+1}}{1+R_t} =$$

$$= \frac{b_t}{1+\tilde{p}_t} + c_t + \sum_{f=1}^{f=F} z_{t+1}^f q_t^f + \sum_{l=1}^{l=L} z_{t+1}^{bank,l} q_t^{bank,l} \tag{6}$$

for t = 0,1,2,3,...

We use the following initial condition to describe the household's debt position at the beginning of period 0

$$B_0 = W_{-1}n_{-1}^s + \sum_{f=1}^{f=F} z_0^f \Pi_{-1}^f + \sum_{l=1}^{l=L} z_0^{bank,l}\Pi_{-1}^{bank,l} \tag{7}$$

This initial condition simply states that the household begins period 0 with a debt which equals the sum of the wage earnings, dividend earnings from firms and dividend earnings from banks she receives at the beginning of period 0 because of the hours she worked during period (-1) and because of the shares of firms and of banks she bought at the beginning of period (-1). Note that period 0 is not the period where the household's life starts but rather the period where our analysis of the economy begins (the household has been living for some periods and we catch her in period 0 and try to model her behaviour). In the appendix of Leao (2001) it is shown that this initial condition is the initial condition which naturally arises when we think back to its initial moment a closed economy without government and where firms don't borrow. This initial condition can also be normalized by dividing both sides by P_0 giving

$$\frac{b_0}{1+\tilde{p}_0} = \frac{w_{-1}}{1+\tilde{p}_0}n_{-1}^s + \sum_{f=1}^{f=F} z_0^p \frac{\pi_{-1}^f}{1+\tilde{p}_0} + \sum_{l=1}^{l=L} z_0^{bank,l}\frac{\pi_{-1}^{bank,l}}{1+\tilde{p}_0} \tag{8}$$

Consequently, at the beginning of period 0, the household is looking into the future and maximizes $U_0 = E_0\left[\sum_{t=0}^{t=\infty}\beta^t u(c_t,\ell_t)\right]$ subject to 6, 8 and $n_t^s + \ell_t = 1$. The choice variables are c_t, ℓ_t , n_t^s, b_{t+1} , z_{t+1}^f and $z_{t+1}^{bank,l}$. There are also initial conditions on holdings of shares [assuming market clearing in the shares market in period (-1), these initial conditions will be $z_0^f = \frac{1}{H}$ and

$z_0^{bank,l} = \frac{1}{H}$], a standard transversality condition on the pattern of borrowing, and non-negativity constraints.

We can summarize by saying that the way we have set the household's problem means that we are adding a specific initial condition to a cash-in-advance format. In section 7 of Leao (2001), it is shown that the initial condition we use combined with the cash-in-advance structure implies that the household will borrow from the banks at the beginning of each period an amount equal to the amount she needs to buy consumption goods from the firms during the period (i.e., the household faces a credit-in-advance constraint in every period). The reason why it seems important to work with this kind of credit structure is the fact that, in modern economies, most money has its origin in loans from commercial banks to households, firms or the government (to verify this we only have to look at the aggregate balance sheet of the Monetary Sector).

6 Market Clearing Conditions

With H homogeneous households, F homogeneous firms and L homogeneous banks, the market clearing conditions for period 0 are as follows. In the goods market, the condition is $Hc_0 + Fi_0 = Fy_0$. In the labour market, the condition is $Hn_0^s = Fn_0^d + Ln_0^b$. In the bank loans market, the condition is $H\frac{B_1}{1+R_0} = LB_0^s$. The market clearing condition in the shares market is that each firm and each bank should be completely held by the households (the only owners of shares in this model). Since households are all alike, each household will hold an equal share of each firm and an equal share of each bank. Therefore, the market clearing conditions in the shares market are $Hz_1^f = 1$ and $Hz_1^{bank,l} = 1$.

7 The Competitive General Market Equilibrium

To obtain the system of equations that describes the competitive equilibrium, we put together in a system the typical household's first order conditions (which give, in an implicit way, the household's demand and supply functions), the typical firm's first order conditions (which give, in an implicit way, the firm's demand and supply functions), the typical bank's first order conditions (which give, in an implicit way, the bank's demand and supply functions), and the market clearing conditions. We then assume Rational Expectations and use a Certainty Equivalence argument. After all these steps and if we also assume that the production function of each firm is homogeneous of degree one and define the following new variables $\overline{k}_t = \frac{F}{H}\ k_t$, $\overline{n}_t^d = \frac{F}{H}\ n_t^d$, $\overline{n}_t^b = \frac{L}{H}\ n_t^b$, $\overline{q}_t^f = \frac{F}{H}\ q_t^f$, $\overline{\pi}_t^f = \frac{F}{H}$ π_t^f , $\overline{q}_t^{bank,l} = \frac{L}{H} q_t^{bank,l}$ and $\overline{\pi}_t^{bank,l} = \frac{L}{H} \pi_t^{bank,l}$, we can write the system describing the Competitive Equilibrium assuming H homogeneous households, F homogeneous firms and L homogeneous banks plus Rational Expectations and Certainty Equivalence as

$$u_1(c_t, 1 - n_t^s) = \lambda_t \tag{9}$$

$$u_2(c_t, 1-n_t^s) = \beta E_t\left[\lambda_{t+1}\right] \frac{w_t}{1+E_t\left[\tilde{p}_{t+1}\right]} \tag{10}$$

$$\lambda_t = \beta E_t\left[\lambda_{t+1}\right] \frac{1+R_t}{1+E_t\left[\tilde{p}_{t+1}\right]} \tag{11}$$

$$\lambda_t \overline{q}_t^f = \beta E_t\left[\lambda_{t+1}\right] \left(\frac{\overline{\pi}_t^f}{1+E_t\left[\tilde{p}_{t+1}\right]} + E_t\left[\overline{q}_{t+1}^f\right] \right) \tag{12}$$

$$\lambda_t \overline{q}_t^{bank,l} = \beta E_t\left[\lambda_{t+1}\right] \left(\frac{\overline{\pi}_t^{bank,l}}{1+E_t\left[\tilde{p}_{t+1}\right]} + E_t\left[\overline{q}_{t+1}^{bank,l}\right] \right) \tag{13}$$

$$\frac{b_{t+1}}{1+R_t} = c_t \tag{14}$$

$$A_t F_2(\overline{k}_t, \overline{n}_t^d) = w_t \tag{15}$$

$$E_t\left[A_{t+1}\right] F_1\left(\overline{k}_{t+1}, E_t\left[\overline{n}_{t+1}^d\right]\right) + (1-\delta) = \frac{1+E_t\left[R_{t+1}\right]}{1+E_t\left[\tilde{p}_{t+1}\right]} \tag{16}$$

$$R_t D_t \gamma \left(\frac{L}{H}\right)^{1-\gamma} \left(\overline{n}_t^b\right)^{\gamma-1} = w_t \tag{17}$$

$$c_t + \left[\overline{k}_{t+1} - (1-\delta)\overline{k}_t\right] = A_t F(\overline{k}_t, \overline{n}_t^d) \tag{18}$$

$$n_t^s = \overline{n}_t^d + \overline{n}_t^b \tag{19}$$

$$\frac{b_{t+1}}{1+R_t} = \left(\frac{L}{H}\right)^{1-\gamma} D_t \left(\overline{n}_t^b\right)^{\gamma} \tag{20}$$

$$z_{t+1}^f = \frac{1}{H} \tag{21}$$

$$z_{t+1}^{bank,l} = \frac{1}{H} \tag{22}$$

$$\overline{\pi}_t^f = A_t F(\overline{k}_t, \overline{n}_t^d) - w_t \overline{n}_t^d - \left[\overline{k}_{t+1} - (1-\delta)\overline{k}_t\right] \tag{23}$$

$$\overline{\pi}_t^{bank,l} = R_t D_t \left(\frac{L}{H}\right)^{1-\gamma} \left(\overline{n}_t^b\right)^{\gamma} - w_t \overline{n}_t^b \tag{24}$$

for $t = 0, 1, 2, 3, ...$

Equations 9-14 have their origin in the typical household's first order conditions. Equation 14 is the credit-in-advance constraint which results from combining the household's budget constraint with the initial condition and then using the market clearing conditions from the shares' market. In section 7 of Leao (2001), it is explained in detail how this credit-in-advance constraint appears in period 0 and how, under Rational Expectations, it is propagated into future periods. Equations 15 and 16 have their origin in the typical firm's first-order conditions. Equation 17 has its origin in the typical bank's first-order condition. Equations 18-22 have their origin in the market clearing conditions. Equation 23 results from multiplying the definition of firm profits in real terms by (F/H). Equation 24 results from multiplying the definition of bank profits in real terms by (L/H). We have 2 exogenous variables (A_t and D_t) and 16 endogenous variables. The supply of credit in real terms is given by $b_t^s = D_t(n_t^b)^{\gamma}$. If we consider equation 17 in the context of the whole system, we can understand how this model binds the real supply of credit. As long as the market determined ratio (w_t/R_t) is finite, equation 17 determines the variable $\overline{n}_t^b$ which through the banks' production function determines the real supply of credit. The firm's production function and household's utility function used in the simulations were $A_t F(k_t, n_t^d) = A_t (k_t)^{1-\alpha} \left(n_t^d\right)^{\alpha}$ and $u(c_t, \ell_t) = \ln c_t + \phi \ln \ell_t$.

8 Calibration

In order to be able to study the dynamic properties of the model, we have log-linearized each of the equations in the system 9-24 around the steady-state values of its variables. The log-linearized system was then calibrated. To calibrate the log-linearized system we used the following parameters. With the specific utility function we are using, we obtain

Elasticity of the MU of consumption with respect to consumption	-1
Elasticity of the MU of consumption with respect to leisure	0
Elasticity of the MU of leisure with respect to consumption	0
Elasticity of the MU of leisure with respect to leisure	-1

where MU denotes "Marginal Utility". From the U.S. data, we obtain

Investment share of total expenditure in the s.s.	0.167	Barro (1993)
Firm workers' share of the firm's income (α)	0.58	King et al. (1988)
Labour supply in the steady-state	0.2	King et al. (1988)
Real interest rate in the steady-state	0.007060	FRED and Barro (1993)
Banks' share of total "hours of work" in the s.s.	0.014	BLSD
Bank workers' share of the bank's income (γ)	0.271	FDIC

In order to calibrate the steady-state real interest rate, we have computed the average quarterly value of the real interest rate for the period 1949-1986. To do this, we used the Federal Reserve Economic Data (FRED) to obtain quarterly values for the Bank Prime Loan Rate for the period 1949-1986 and data from Barro (1993) to obtain quarterly values for the inflation rate in the same period. To calibrate the Banks' share of "total hours of work" in the steady-state, we have computed the average value of the ratio (total hours of work in U.S. commercial banks / total hours of work in the U.S. economy) for the period 1972:1-1986:12. To do this, we used data from the web site of the Bureau of Labour Statistics Data (BLSD).

The parameter γ is equal to the bank workers' share of the bank's income. In our model, the only income banks have is interest income. To calibrate γ we have used the "Historical Statistics on Banking" from the Federal Deposit Insurance Corporation (FDIC) to compute the average value of the ratio (commercial banks' wage payments in the U.S. / commercial banks' interest income in the U.S.) for the period 1966-1986. The values for the wage payments of commercial banks we used were the values for "Employee Salaries & Benefits" which were taken from the table "Noninterest Income and Noninterest Expense of Insured Commercial Banks" of the FDIC's web site[1]. The values for the commercial banks' interest income were the values for "Interest Income on Loans and Leases" which were obtained from the table "Interest Income of Insured Commercial Banks" in their web site. The values in the preceding tables of the present section of our article imply

Consumption share of total expenditure in the s.s.	0.833
Household's discount factor (β)	0.993
Per-quarter rate of depreciation of the firm's capital stock (δ)	0.0047

With these parameter values, the model has steady-state values of physical output, consumption and investment which are 1.4% lower than in a zero growth version of the model presented in King,

[1] The internet address is www2.fdic.gov/hsob

Plosser and Rebelo (1988) calibrated with our parameters. This is what we would expect because in their model transactions occur without the need to use money whereas in our model households have to borrow from the banks to finance their consumption expenditure (and the supply of credit by the banking industry involves spending some of the resources of the economy, namely "hours of work"). As a consequence, the amount of "hours of work" left to be used by the physical output industry is now lower (note that the total supply of "work effort" in the steady-state in this economy is still calibrated as $n^s = 0.2$, i.e., the same value used by King, Plosser and Rebelo).

9 The Dynamic Properties of the Model

The response of the log-linearized model to shocks in the exogenous variables (A_t and D_t) can be obtained using the King, Plosser and Rebelo (1988) method. First, we examine the impact of shocks in the firms' technology. Afterwards, we look at the impact of shocks in the banks' technology.

9.1 Technological Innovations in Nonbank Firms

We next examine the results of two experiments that use shocks in the firms' technological parameter (A_t): impulse response and stochastic simulation. In order to perform these two exercises, we assumed that the firms' technological parameter evolves according to the following process

$$\hat{A}_t = 0.9\hat{A}_{t-1} + \varepsilon_t \tag{25}$$

where $\hat{A}_t$ denotes the % deviation of A_t from its steady-state value and ε_t is a white noise.

9.1.1 Impulse Response

The first impulse response experiment we carried out with the model was a 1% shock to the firms' technological parameter (assuming that there are no shocks to the banks' technology). The results are plotted in figures 1 to 8. The first important thing to notice is that, in spite of the fact that ours is a monetary economy, it is capable of reproducing the key results that the King, Plosser and Rebelo (1988) nonmonetary model is able to reproduce. First: consumption, investment and "hours of work" are procyclical. Second: consumption is less volatile than output and investment is more volatile than output. These are very well documented stylized facts about the United States economy [references on this include Kydland and Prescott (1990) and Backus and Kehoe (1992)].

The figures for $\hat{y}_t$, $\hat{c}_t$, $\hat{\imath}_t$, $\hat{n}_t^s$ and $\hat{w}_t$ are very close to the figures we obtain with the zero growth version of the model in King, Plosser and Rebelo calibrated with our parameters.

We have mentioned, above in this article, that the steady-state value of consumption in this model is 1.4% lower than in the zero growth version of the King, Plosser and Rebelo model. In the present impulse response exercise, we find that the response of c_t is slightly weaker than in the zero growth version of their model (0.1169% instead of 0.1220% in terms of % deviation from the steady-state). Both these results are due to the fact that in our model any unit of consumption requires the household who is willing to consume it to borrow that amount from commercial banks at the beginning of the period. Because in our model the supply of credit by the banks involves a real cost in terms of resources (the "hours of work" that have to be spent supporting it), it seems natural that consumption should be lower (than in the case of the King, Plosser and Rebelo model where consumption did not involve this extra cost).

In our model, a positive technological shock implies more physical output and higher wage and dividend payments in real terms. Knowing these payments (which will only be made at the end of the period) to be higher, households want to consume more and, therefore, borrow more at the beginning of the period. The banking industry responds to this increased demand for credit by hiring more people in order to be able to supply a higher amount of credit in real terms (figure 5).

Note that, as mentioned in the abstract of this article, the interest rate reacts positively to a positive shock in the firms' technology (figure 8). This can be explained as follows. When the positive shock to the firms' technology occurs, the marginal product of labour (MPL) increases in firms. Because in equilibrium the MPL in banks must be equal to the MPL in firms (see equations 15 and 17 above), the interest rate charged by commercial banks has to increase in order to make the MPL in banks rise as well. The interest rate must necessarily rise because the increase in $\overline{n}_t^b$, which is needed to allow a higher supply of credit in real terms, acts in the direction of reducing the MPL in banks.

9.1.2 Stochastic Simulation

Table 1 shows the results of a stochastic simulation exercise where it was assumed that there are only shocks to the firms' technological parameter (no shocks to the banks' technological parameter). The results for the real variables $\hat{y}_t$, $\hat{c}_t$, $\hat{\imath}_t$, $\hat{n}_t^s$ and $\hat{w}_t$ are very close to the results we obtained with a zero growth version of the model in King, Plosser and Rebelo (1988) calibrated with our parameters. The main explanation for this is as follows: in our model we have a banking industry but since this banking industry is very small (as can be seen in the values we obtained for the parameters that calibrate its weight) it spends only a tiny fraction of the total amount of resources of the economy. The results for $\hat{n}_t^d$ are almost exactly the same as the results for $\hat{n}_t^s$. This, of course, is a consequence of the market clearing condition in the labour market (equation 19) and of the fact that the weight of the demand for labour by firms is huge when compared with the weight of the demand for labour by banks (see section 8). The results for $\widehat{R}_t$ and for $\hat{n}_t^b$ are easy to understand if we take into account the results we obtained in the impulse response experiment.

9.2 Technological innovations in the banking sector

We next examine the results of experiments that consider shocks to the banks' technological parameter (shocks in D_t). In order to perform the experiments which follow, we assumed that the banks' technological parameter evolves according to

$$\widehat{D}_t = 0.9\widehat{D}_{t-1} + \varphi_t \tag{26}$$

where $\widehat{D}_t$ denotes the % deviation of D_t from its steady-state value and φ_t is a white noise.

9.2.1 Impulse Response

Let us first examine what happens when a 1% shock occurs in the banks' technology (with no shock in the firms' technology). The results are plotted in figures 9 to 16. It is interesting to see how the economy uses the technological gift in the banking industry to improve the general welfare of the people that live in it. We can see that consumption and leisure, the variables that give utility to households, both increase slightly (figures 10 and 12).

The banking industry now has a more powerful technology and can therefore perform its role of supplier of credit using fewer hours of work. Work hours in banks are reduced by almost 4% (figure 13) and this reduction is used to increase work hours in firms (figure 14) and to increase leisure (figure 12).

The increase in firm labour demand makes the MPL in firms fall (this can be seen in figure 15). Since the positive shock in D_t and the ensuing decrease in work hours in banks both work in the direction of making the MPL rise in banks, the interest rate has to fall (figure 16) so that the MPL in banks can follow the decrease of the MPL in firms. This result was mentioned in the abstract of this article.

We have also looked at the results of an impulse response experiment where a 1% technological shock occurs simultaneously in the two industries. The results we obtained were the sum of the results of the two separate impulse response exercises we have examined in this article (the exercise with a shock only in firms and the exercise with a shock only in banks). In particular, the overall effect on the interest rate and on bank labour demand is negative.

9.2.2 Stochastic simulation

The results mentioned in the previous paragraph suggest that if we perform a stochastic simulation experiment where the shocks to the banks' technology are perfectly correlated with the shocks to the firms' technology and have the same size, then we will obtain negative correlations between the current interest rate and the future values of real output. The interest rate will suffer downward pressure from the positive shocks in D_t stronger than the upward pressure it will suffer from the accompanying positive shocks in A_t. Output, on the other hand, will undergo upward pressure from both the positive shocks in A_t and the positive shocks in $D_{t.}$

Table 2 reports the results of a stochastic simulation experiment where in each period the % deviation from its steady-state of the banks' technological parameter is exactly the same as the % deviation from its steady-state of the firms' technological parameter, i.e., the case where the shocks in the banking industry are perfectly correlated with the shocks in the physical output industry and have the same size. In this exercise, the firms' technological parameter (A_t) was assumed to evolve according to the process given by 25 and we assumed that in each period $\widehat{D}_t = \widehat{A}_t$. We can see that the only results in table 2 that are markedly different from the results in table 1 are the results for $\widehat{R}_t$ and $\hat{n}_t^b$.

Let us compare the results we obtained for $\widehat{R}_t$ with the results we obtain from the U.S. data. King and Watson (1996) report the following cross-correlations between the interest rate and real output

Variable	correlation with								
	y_{t-4}	y_{t-3}	y_{t-2}	y_{t-1}	y_t	y_{t+1}	y_{t+2}	y_{t+3}	y_{t+4}
R_t	0.58	0.60	0.57	0.47	0.30	0.07	-0.19	-0.43	-0.61

We can see that in the data there is a strong negative correlation between the current interest rate and future values of real output. Our results in table 2 also show a strong negative correlation between the current interest rate and future values of real output. Let us explain why this happened in our stochastic simulation experiment. In our model, a high level of real economic activity comes mainly from the positive shocks in A_t. Because a positive shock in A_t is propagated into the following periods by the process which generates the shocks (equation 25), so is a high level of real economic activity propagated into the following periods. And what are the consequences of positive shocks in A_t for the interest rate? We have already seen that when a positive shock in A_t occurs the MPL rises in firms. When there is no accompanying shock in D_t, the interest rate has to rise in order to make the MPL rise in banks as well. In the present case, however, each positive shock in A_t is accompanied by a positive shock in D_t which makes the MPL rise in banks. Hence, the interest rate doesn't have to rise and can even fall. We conclude that simultaneous positive shocks in A_t and D_t may make real output and the interest rate go in opposite directions. This happens not only in the period of the shock but also in the following periods because the process which generates the shocks propagates each period's shock into the following periods.

The case of perfectly correlated technological shocks in banks and firms is important because many technological innovations affect most industries (e.g. innovations in computer technologies and in telecommunications). If instead of perfect correlation between the two technological shocks we consider the case where the correlation coefficient between the two technological shocks is between 0 and 1, then the correlation between the current interest rate and the future values of real output in our model will still be negative but will be lower in absolute value (it will decrease in absolute value as we decrease the correlation coefficient between the two technological shocks). The reason for this is that while perfect correlation means that the shocks always go in the same direction, a correlation coefficient between 0 and 1 means that the shocks go in the same direction in a majority of times.

Let us now compare the results we obtained for $\hat{n}_t^b$ with the results we obtain from the U.S. data. Using quarterly data for the period 1972-1986 and using a Hodrick-Prescott filter to estimate the trends, we have obtained a correlation between "Percentage deviations from trend of total work hours in U.S. commercial banks" and "Percentage deviations from trend of Real GDP in fixed 1992 dollars" equal to -0.158. The data we used were obtained from the BLSD and from the FRED, respectively. The correlation we obtained between "Percentage deviations from trend of total work hours in U.S. commercial banks" and "Percentage deviations from trend of Real GDP in chained 1992 dollars" for the same period was -0.128. While these values do not completely match the contemporaneous correlation between $\hat{n}_t^b$ and $\hat{y}_t$ that we obtained with our model (which was -0.61 as can be seen in table 2B), they suggest a slightly negative correlation between the two variables in the U.S. economy. It is obvious from the impulse response exercises and stochastic simulation exercises we have examined that this negative correlation could only arise in our model if there are technological innovations in the banking industry. With Real GDP in fixed 1992 dollars, the whole set of correlations we obtained from the data was as follows

Variable	Correlation with										
	$\hat{y}_{t-12}$	$\hat{y}_{t-8}$	$\hat{y}_{t-4}$	$\hat{y}_{t-2}$	$\hat{y}_{t-1}$	$\hat{y}_t$	$\hat{y}_{t+1}$	$\hat{y}_{t+2}$	$\hat{y}_{t+4}$	$\hat{y}_{t+8}$	$\hat{y}_{t+12}$
$\hat{n}_t^b$	0.37	0.53	0.53	0.22	0.07	-0.16	-0.39	-0.59	-0.77	-0.51	-0.013

Also using Real GDP in fixed 1992 dollars, the ratio (standard deviation of $\hat{n}_t^b$ / standard deviation of $\hat{y}_t$) that we obtain from the data is 0.64.

It may be noted that our results in table 2B also show negative correlations between $\hat{n}_t^b$ and the current and future values of real output. In the case of our stochastic simulation exercise, these negative correlations can be explained as follows. When A_t rises, the real income of each household rises which makes them wish to increase consumption. This causes an increase in the demand for credit in real terms. Since the rise in A_t is accompanied by a rise in D_t, the real supply of credit can rise without the need for an increase in n_t^b.

10 Conclusion

We have built a dynamic general equilibrium model with a banking sector and a nonbanking sector. We have used the model to look at the response of the interest rate to innovations in the banks' technology and to innovations in the firms' technology. We have concluded that, while the technological innovations in the nonbanking sector put upward pressure on the interest rate, technological innovations in the banking sector exert downward pressure on the interest rate. Hence, if there are only shocks to the nonbank firms' technology, then we obtain a positive correlation between the interest rate and real output. If we add shocks to the banks' technology that are highly positively correlated with the shocks to the nonbank firms' technology, then we obtain a negative correlation between the current interest rate and future values of real output. This corresponds to what the data show us.

References

[1] Backus, D. and Kehoe, P. 1992. International evidence on the historical properties of business cycles. *American Economic Review* 82: 864-888.

[2] Barro, R. 1993. *Macroeconomics*, john Wiley & Sons, Inc.

[3] Horvath, M. 1998. Ciclicality and sectoral linkages: aggregate fluctuations from sectoral shocks. *Review of Economic Dynamics* 1: 781-808.

[4] Horvath, M. 2000. Sectoral shocks and aggregate fluctuations. *Journal of Monetary Economics* 45: 69-106.

[5] Kalulumia, P. and Nyankiye, F. 2000. Labour Adjustment Costs, Macroeconomic Shocks and Real Business Cycles in a Small Open Economy. *Journal of Macroeconomics* 22: 671-694.

[6] King, R., Plosser, C. and Rebelo, S. 1988. Production, growth and business cycles: I. The basic neoclassical model. *Journal of Monetary Economics* 21: 195-232.

[7] King, R. and Watson, M. 1996. Money, prices, interest rates and the business cycle. *Review of Economics and Statistics* 78: 35-53.

[8] Kydland, F. and Prescott, E. 1990. Business cycles: real facts and a monetary myth. *Quarterly Review.* Federal Reserve Bank of Minneapolis, Spring.

[9] Leao, E. 2001. Monetary policy in a credit-in-advance economy. Working Paper No 2001/20, Dinamia (Centro de Estudos para a Mudanca Socioeconomica).

[10] Lucas, R., Jr. 1982. Interest rates and currency prices in a two-country world. *Journal of Monetary Economics* 10: 335-359.

Table 1. Stochastic simulation. Shocks in the nonbank firms' technological parameter only.

A. Standard deviations (s.d.)

Variable	s.d.	s.d. of the variable divided by the s.d. of $\hat{y}_t$
$\hat{y}_t$	4.45	1.00
$\hat{c}_t$	1.92	0.43
$\hat{\imath}_t$	22.60	5.08
$\hat{n}_t^s$	2.92	0.66
$\hat{w}_t$	2.27	0.51
$\hat{n}_t^d$	2.95	0.66
$\hat{n}_t^b$	7.08	1.59
$\hat{R}_t$	7.35	1.65

B. Cross-correlations

Variable	Correlation with										
	$\hat{y}_{t-12}$	$\hat{y}_{t-8}$	$\hat{y}_{t-4}$	$\hat{y}_{t-2}$	$\hat{y}_{t-1}$	$\hat{y}_t$	$\hat{y}_{t+1}$	$\hat{y}_{t+2}$	$\hat{y}_{t+4}$	$\hat{y}_{t+8}$	$\hat{y}_{t+12}$
$\hat{y}_t$	0.36	0.50	0.71	0.84	0.92	1.00	0.92	0.84	0.71	0.50	0.36
$\widehat{c}_t$	0.65	0.64	0.62	0.60	0.58	0.57	0.53	0.49	0.43	0.33	0.26
$\hat{\imath}_t$	0.15	0.32	0.58	0.74	0.83	0.94	0.86	0.79	0.66	0.46	0.32
$\hat{n}_t^s$	0.10	0.27	0.53	0.70	0.80	0.90	0.83	0.76	0.63	0.43	0.30
$\hat{w}_t$	0.61	0.66	0.73	0.76	0.78	0.80	0.74	0.69	0.59	0.44	0.33
$\hat{n}_t^d$	0.08	0.25	0.51	0.68	0.78	0.89	0.81	0.74	0.62	0.42	0.29
$\hat{n}_t^b$	0.65	0.64	0.62	0.60	0.58	0.57	0.53	0.49	0.43	0.33	0.26
$\widehat{R}_t$	0.64	0.66	0.66	0.66	0.65	0.65	0.60	0.56	0.48	0.37	0.29

Table 2. Stochastic simulation. Identical and perfectly correlated shocks in the firms' technological parameter and in the banks' technological parameter.

A. Standard deviations (s.d.)

Variable	s.d.	s.d. of the variable divided by the s.d. of $\hat{y}_t$
$\hat{y}_t$	4.22	1.00
$\hat{c}_t$	1.72	0.41
$\hat{\imath}_t$	21.32	5.05
$\hat{n}_t^s$	2.76	0.65
$\hat{w}_t$	1.99	0.47
$\hat{n}_t^d$	2.89	0.68
$\hat{n}_t^b$	7.57	1.79
$\hat{R}_t$	7.09	1.68

B. Cross-correlations

Variable	Correlation with									
	$\hat{y}_{t-12}$	$\hat{y}_{t-8}$	$\hat{y}_{t-4}$	$\hat{y}_{t-2}$	$\hat{y}_{t-1}$	$\hat{y}_t$	$\hat{y}_{t+1}$	$\hat{y}_{t+2}$	$\hat{y}_{t+4}$	$\hat{y}_{t+8}$	$\hat{y}_{t+12}$
$\hat{y}_t$	0.31	0.46	0.68	0.83	0.91	1.00	0.91	0.83	0.68	0.46	0.31
$\widehat{c}_t$	0.62	0.63	0.63	0.62	0.61	0.60	0.55	0.50	0.42	0.30	0.23
$\hat{\imath}_t$	0.12	0.29	0.55	0.73	0.83	0.95	0.86	0.78	0.64	0.42	0.28
$\hat{n}_t^s$	0.07	0.24	0.51	0.70	0.80	0.92	0.83	0.75	0.61	0.40	0.26
$\hat{w}_t$	0.57	0.63	0.71	0.75	0.77	0.80	0.73	0.67	0.56	0.39	0.28
$\hat{n}_t^d$	0.06	0.23	0.50	0.69	0.79	0.91	0.82	0.75	0.61	0.40	0.26
$\hat{n}_t^b$	0.24	0.07	-0.19	-0.38	-0.48	-0.61	-0.54	-0.49	-0.39	-0.25	-0.15
$\widehat{R}_t$	0.27	0.10	-0.16	-0.34	-0.45	-0.57	-0.51	-0.46	-0.37	-0.23	-0.13

Figure 1
1% shock in A
Output as % dev. from steady state

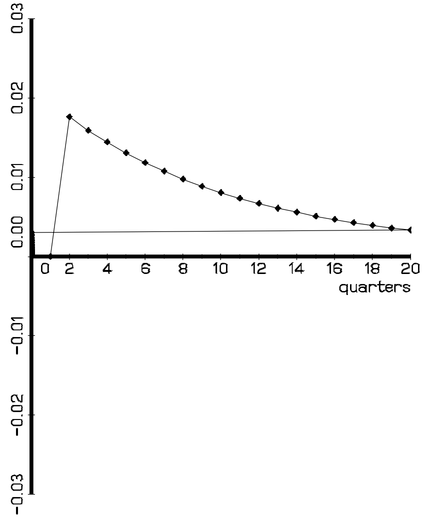

Figure 2
1% shock in A
Consumption as % dev from steady state

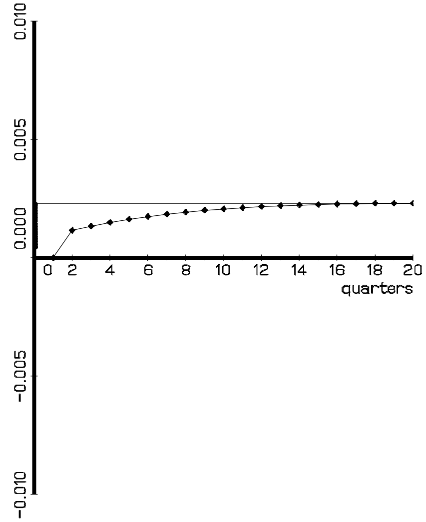

Figure 3
1% shock in A
Investment as % dev. from steady state

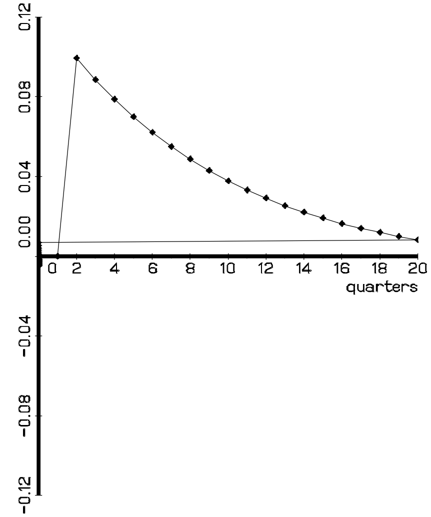

Figure 4
1% shock in A
Labour supply as % dev. from s.s.

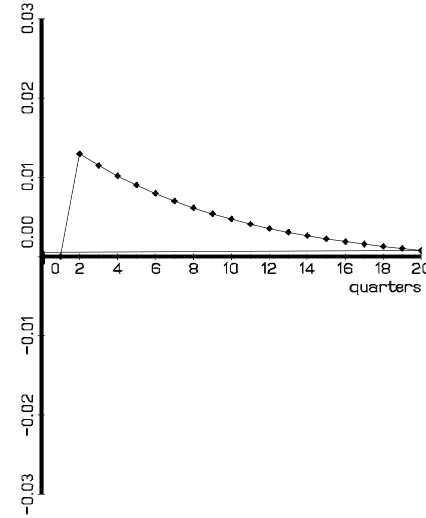

Figure 5
1% shock in A
Bank labour demand as % dev. from s.s.

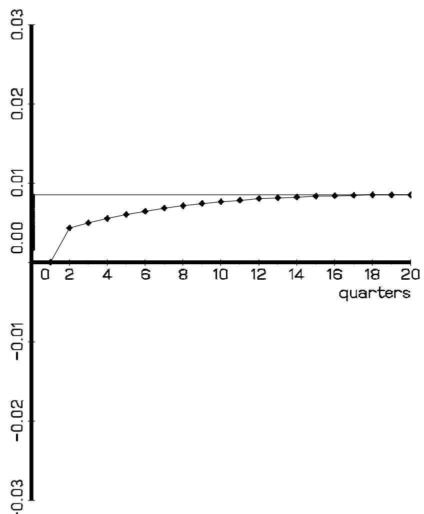

Figure 6
1% shock in A
Firm labour demand as % dev. from s.s.

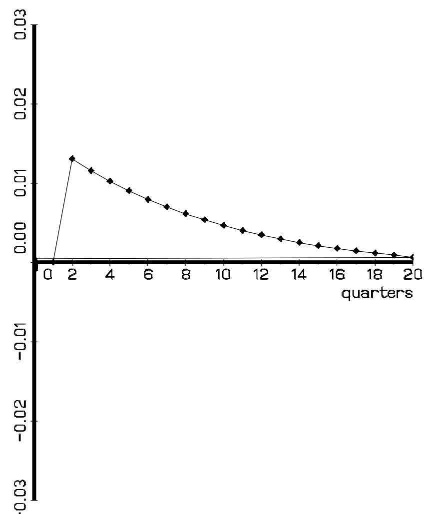

Figure 7
1% shock in A
Real wage as % dev. from steady state

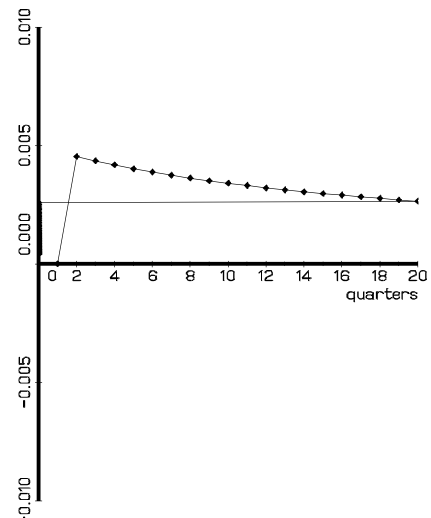

Figure 8
1% shock in A
Interest rate as % dev from steady state

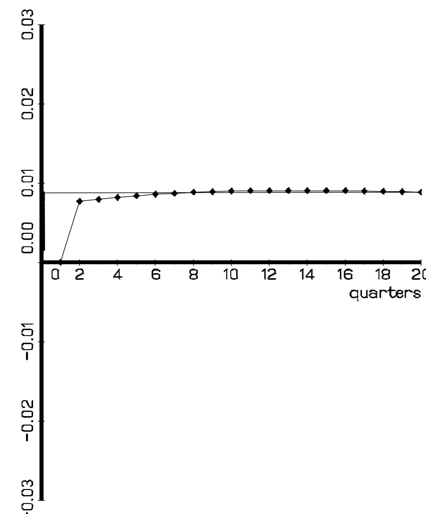

Figure 9
1% shock in D
Output as % dev. from steady state

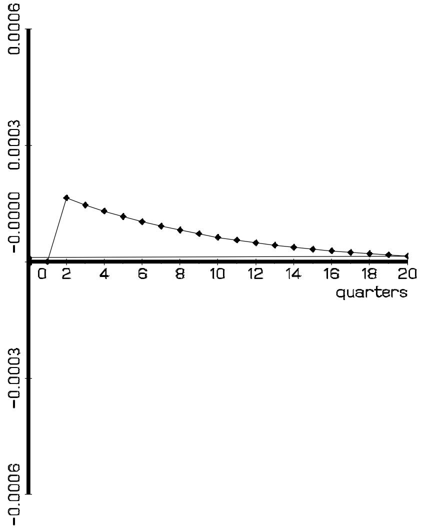

Figure 10
1% shock in D
Consumption as % dev from steady state

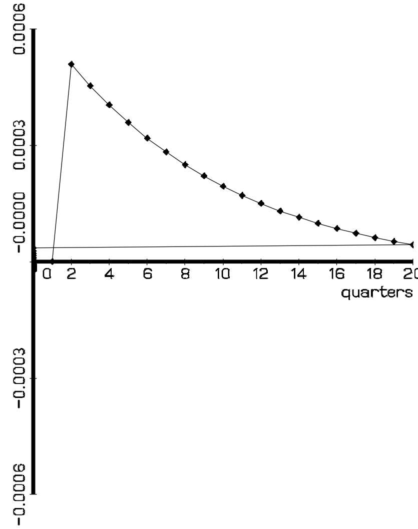

Figure 11
1% shock in D
Investment as % dev from steady state

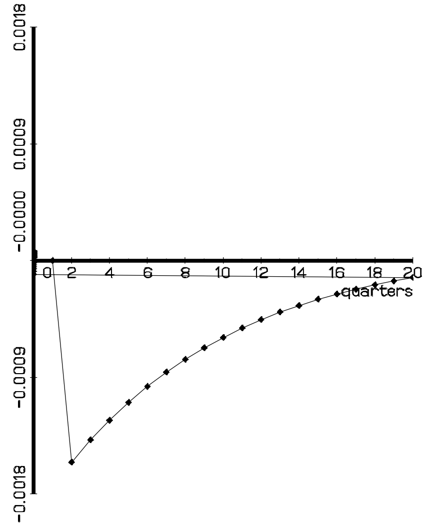

Figure 12
1% shock in D
Labour supply as % dev. from s.s.

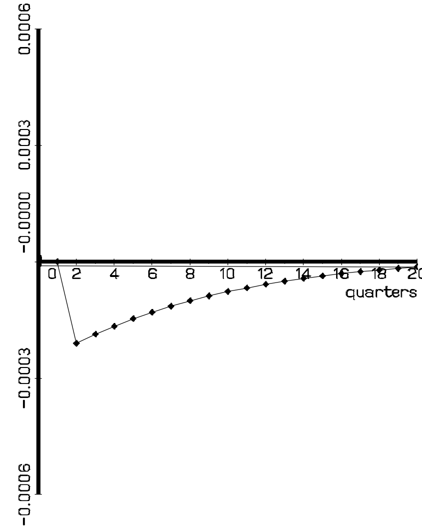

Figure 13
1% shock in D
Bank labour demand as % dev. from s.s.

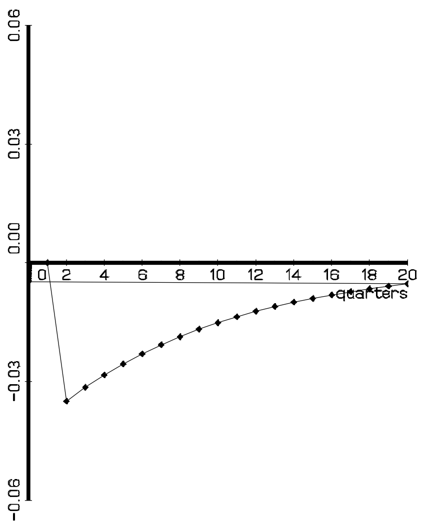

Figure 14
1% shock in D
Firm labour demand as % dev. from s.s.

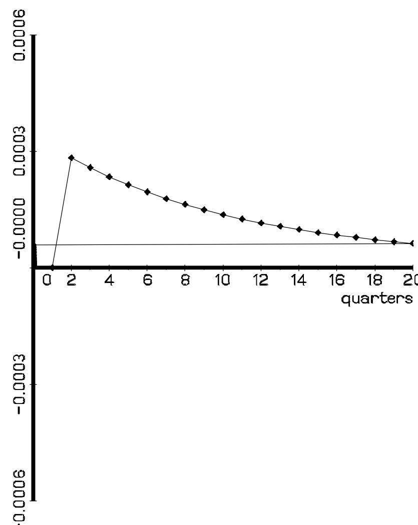

Figure 15
1% shock in D
Real wage as % dev. from steady state

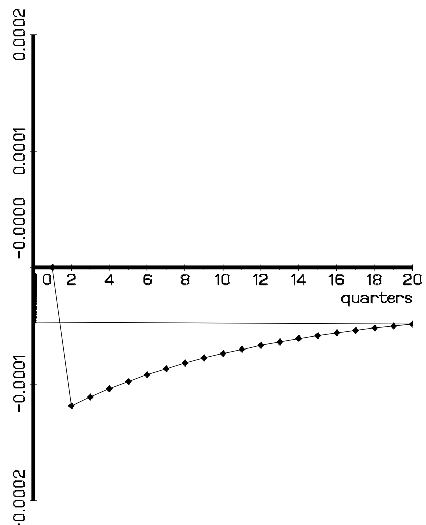

Figure 16
1% shock in D
Interest rate as % dev from steady state