Business Cycle Models and Stylized Facts in Germany

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Abstract

The aim of this paper is to test to what extent a benchmark real and monetary business cycle model can account for some basic stylized facts with a particular emphasis on monetary variables. We calibrate the model on German data using the method proposed by Cooley and Prescott [1995]. First we will analyze the dynamic properties of the models, the Impulse Response Functions and propose a variance decomposition (for the monetary BC Models). We find that even though money is not neutral in the short run, the effect of a monetary shock is only marginal compared to the productivity shock, i.e. the share of the variance of the monetary shock in the total variance of the forecast error is small and decreases rapidly. We simulate the models and compare the properties of the model economies with those of the observed data. The evidence suggests that the benchmark RBC model can account for some stylized facts in Germany. The general pattern of the relative volatilities of investment, output and consumption is replicated by the model. Nevertheless, the overall volatility is too high and the level of the relative volatilities is not well reproduced. The introduction of exogenous monetary shocks and a cash–in–advance constraint increases the relative volatilities and the cross correlation of consumption. In general the second order moments of money ($M1$) and inflation are not well reproduced.

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1 Introduction

The purpose of this paper is to present an extensive analysis of the dynamic properties of the monetary BC models using Impulse Response Functions and a Variance Decomposition. We test to what extend a Real (RBC) or Monetary Business Cycle model can account for some important stylized facts in Germany using a country specific calibration.

Since the early 1980's, RBC theorists have engaged in an attempt to explain the basic features of business cycles in the US economy with stochastic general equilibrium models capable of generating artificial data (For example Kydland and Prescott [1980] or King, Plosser and Rebelo [1988])[1]. The derivation and interpretation of these model's results have been controversial issues[2]. Most of the extensions of the benchmark RBC model focus on a particular subset of business cycle features or address simulation or statistical inference problems. It is only recently that it was attempted to confront the RBC models with alternative data sets. Backus and Kehoe [1992] were one of the first to examine the properties of business cycle fluctuations in many countries from a RBC perspective. Fiorito and Kollintzas [1994] investigate the basic stylized facts of business cycles in the G7 countries using the benchmark RBC model (Kydland and Prescott [1982]) as guidance. They did not, however, present a country specific calibration nor do they use the extended model with money and cash–in–advance constraints. Country specific analysis have also been undertaken such as in Danthine and Girardin [1989] for Switzerland or Blackburn and Ravn [1992] for the UK. In particular, Brandner and Neusser [1992] establish some stylized facts for Austria and the Federal Republic of Germany. Their aim was to provide *basic statistical properties of economic time series without pretending to have too much a priori economic theory.*

Our benchmark RBC model is based on Hansen [1985], who presented a RBC model with indivisible labor (hours are more volatile than employment just as was observed for the US Economy.). For the Monetary Business Cycle Model we add an exogenous monetary shock. This Model relies on previous work by Cooley and Hansen [1989]. We assume that money is valuable because of a cash–in–advance constraint on consumption only or on both consumption and investment.

After a monetary shock, output decreases due to the intertemporal substitution effects related to the inflation tax. The total variance of the forecast error of output is only marginally influenced by the variance of the monetary shocks. With a cash–in–advance constraint on consumption only, this is true even if the persistence of the monetary shock is very high. For the second model (cash–in–advance constraint on both consumption and investment), the increase in persistence will give the monetary shock a substantial and lasting effect.

As for a model based on U.S data, the Hansen [1985] RBC model can only account for a limited number of stylized facts. The introduction of a cash–in–advance constraint on consumption only increases slightly the ability to account for real facts but the nominal

[1] See Plosser [1989] or McCallum [1989]). For the methodological issues involved by RBC modeling, see Cooley [1995] or Danthine and Donaldson [1993]

[2] For example Summers [1986], Eichenbaum [1991] Hansen and Heckman [1996] or Sims [1996].

dimension is not well reproduced. Generalizing the constraint to investment will even worsen this results.
We conclude that the cash–in–advance constraint and the resulting inflation tax effect alone cannot account for the role of money in business cycle models.

The paper is organized as follows: in section 2, we present the Monetary Business Cycle Model. We follow with a detailed discussion of the calibration method (section 3) and in section 4, we present an extensive discussion about the transmission mechanisms of the shocks as well as the Impulse Response Functions. Section 5, will be devoted to the Variance Decomposition and in section 6 we present the cyclical properties of the model Economies. Finally, a few conclusive remarks are collected in section 7.

2 The monetary Business Cycle Model

The model is an extension of the benchmark RBC model presented by King et al. [1988] with the indivisible labor assumption used by Hansen [1985]. Money is introduced in the model using a cash–in–advance constraint. We will both study the case when consumption and investment are subject to such a cash-in-advance constraint[3]. In this section we describe the competitive cash–in–advance Model and compute the competitive equilibrium as a set of policy rules.

2.1 The Model

We present the representative households and firm's problem as well as the money supply process. We then discuss the transformation of the economy into a stationary one and finally give some intuition about the optimality conditions.

2.1.1 Technology and preferences

The Economy is composed by a continuum of households and firms. All firms use the same technology with constant returns to scale in a perfect competition environment. All produce the same good using the technology:

$$Y_t \leq A_t K_t^{\alpha} (X_{H,t} H_t)^{1-\alpha} \tag{2.1.1}$$

A_t follows an exogenous stochastic process:

$$log(A_t) = \rho_A log(A_{t-1}) + (1-\rho_A) log A + \epsilon_{A,t} \tag{2.1.2}$$

where the $\epsilon_{A,t}$ are i.i.d following a normal law of mean zero and of variance σ_A^2 and where $\mid \rho_A \mid < 1$. The total factor productivity A_t is a technological shock common to all firms of the Economy and we assume that A_t is revealed to the agents at the beginning of the period t.
$X_{H,t}$ grows at a constant rate $\gamma_{XN} > 1$ and denotes the labor augmenting technology progress (Harrod neutral).

[3]See also Stockman [1981], Cooley and Hansen [1989] or Hairault and Portier [1995].

The representative household maximize the following utility criteria:

$$\begin{aligned} U_0 &= E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, L_t) \\ &= E_0 \sum_{t=0}^{\infty} \beta^t \left[log(C_t) + v(L_t)\right] \\ &= E_0 \sum_{t=0}^{\infty} \beta^t \left[log(C_t) + \theta(1 - H_t)\right] \end{aligned} \tag{2.1.3}$$

where $\beta_t \in]0,1[, C_t$ is commodity consumption in period t and L_t is leisure in period t. Each household has to allocate one unit of time between work and leisure. We normalize total time available to one and thus we define hours as being $1 - L_t$. Households supply labor and accumulate capital that they rent to firms. The accumulation of capital is linear: one unit of consumption invested produces one unit of productive capital in the next period. The existing capital depreciates exponentially at the rate δ.

$$K_{t+1} = (1 - \delta)K_t + I_t. \tag{2.1.4}$$

We suppose that the household is constrained by the existing money balances at the beginning of the period. These balances have been chosen at the end of the previous period before knowing the shocks the economy is facing in t. The theoretical foundations of the basic cash–in–advance model of money are specified in Lucas and Stokey [1983],[1987] and Svenson [1985]. The initial empirical implementation can be found in Cooley and Hansen [1989]. We also use an extension of this model based on Hairault and Portier [1995] in which the cash–in–advance constraint is generalized to investment.

The general form of the cash–in–advance constraint can be written:

$$C_t + \nu(K_{t+1} - (1 - \delta)K_t) \leq \frac{M_t}{P_t} \tag{2.1.5}$$

where $\nu \in [0, 1]$. This general form of allows for the two particular cases

- **Model I** only consumption is constrained ($\nu = 0$);
- **Model II** both consumption and investment are constrained ($\nu = 1$).

The money supply The monetary aggregate M_t grows at the rate $(g_t - 1)$:

$$M_{t+1} = g_t \, M_t$$

where g_t follows a stochastic process:

$$log(g_t) = \rho_g log(g_{t-1}) + (1 - \rho_g) log\bar{g} + \epsilon_{g,t} \tag{2.1.6}$$

where the $\epsilon_{g,t}$ are i.i.d following a normal law of mean zero and of variance σ_g^2 and where $\rho_g < 1$. We suppose that the growth rate g_t is revealed to the household at the beginning of the period and that all injected money in period t is distributed to the households:

$$(g_t - 1)M_t = N_t$$

Each household enters period t with a level of money balances, M_t corresponding to his money demand of the previous period. Additionally he gets a monetary lump-sum transfer, N_t, that cannot be used for current purchases of goods, a wage and capital income. z_t represents the real cost of capital gross of depreciation[4]. At period t the household chooses the level of consumption, of his labor supply, of his money demand (M_{t+1}), and the capital (K_{t+1}) it will transfer to the next period.
His budget constraint at period t is given by:

$$P_t K_{t+1} + M_{t+1} \leq P_t(1-\delta)K_t + M_t + N_t + P_t z_t K_t + W_t H_t - P_t C_t. \tag{2.1.7}$$

The representative household maximizes at K_0, M_0, g_0, A_0 given, in $C_t, M_{t+1}, H_t, K_{t+1}, t \in [0, +\infty[$, the expected discounted sum of utility flows given the period budget constraint and cash-in-advance constraint in period t. We will denote λ_t and μ_t the multiplier of the budget and cash–in–advance constraints, respectively.

2.1.2 Deterministic stationary growth path

The model satisfies the restrictions on preferences and technologies to exhibit steady state growth at the rate γ_{XN}[5]. All aggregate and individual variables grow at a constant rate γ_{XN}. Since time devoted to work H is bounded by the endowment, it cannot grow in the steady state. Thus, the only admissible constant growth rate for H is zero. The standard method of analyzing models with steady state growth is to transform the economy into a stationary one where the dynamics are more amendable to analyze. In the present context, this involves dividing all variables (aggregate and individual) in the system by the growth component $X_{H,t}$, so that $y_t = Y_t/X_{H,t}, m_t = M_t/(X_{H,t}\, P_{t-1})$, etc.
We also define inflation in t being

$$f_t = \frac{P_t}{P_{t-1}}$$

(i) The objective function becomes

$$E_0 \sum_{t=0}^{\infty} \beta^t [\, log(c_t) + \theta(1 - H_t) + log X_{H,t}\,]$$

where $X_{H,t}$ is in each period an additive constant independent of the choices of the household.

(ii) The cash–in–advance constraint becomes[6]

$$m_t \frac{1}{f_t} \leq c_t - \nu(\gamma_{XH} k_{t+1} - (1-\delta)k_t]$$

[4] The real interest rate is then $r_t = z_t - \delta$.

[5] See King, Plosser and Rebelo [1987] or Fairise, Hairault, Langot and Portier [1991].

[6] We immediately replace the capital accumulation constraint $\gamma_{XN} k_{t+1} = (1-\delta)k_t + i_t$

(iii) $\gamma_{XH}(k_{t+1}+m_{t+1}) = (1-\delta)k_t + \frac{1}{f_t}m_t + \frac{1}{f_t}n_t + z_t k_t + w_t H_t - c_t$

As proved in Stokey and Lucas [1989] (chap 9), we can write the following value function and its solution verifies the Bellman equation for an optimal path of the capital stock:

$$V(k_t, m_t, \tau_t) = max\{u(c_t, L_t) + \beta E_t[V(k_{t+1}, m_{t+1}, \tau_{t+1})]\} \tag{2.1.8}$$

s.t

$$m_t \frac{1}{f_t} = c_t - \nu(\gamma_{XH} k_{t+1} - (1-\delta)k_t]$$

$$\gamma_{XH}(k_{t+1}+m_{t+1}) = (1-\delta)k_t + \frac{1}{f_t}m_t + \frac{1}{f_t}n_t + z_t k_t + w_t H_t - c_t$$

Where τ_t is the informational set of the households at period t: $\tau_t = \{g_t, A_t, P_t, w_t, z_t\}$.

We assume that the cash–in–advance constraint is always binding. The probabilities that this is true are very high as long as $\bar{g} > \beta$ and the monetary shocks are small. This is true for both versions of the model as the steady state equation of the multiplier of the constraint is $\mu = \lambda(\bar{g}/\beta - 1)$ and with the calibrated values[7] for $\bar{g}$ and β and with a standard deviation of ϵ_g of 1.1 percent.

2.2 Resolution of the model

The household's optimality conditions:

$$\frac{1}{c_t} = \lambda_t + \mu_t \tag{2.2.1}$$

$$\lambda_t w_t = \theta \tag{2.2.2}$$

$$\frac{\beta}{\gamma_{XH}} E_t[\lambda_{t+1}(1-\delta+z_{t+1}) + \nu\mu_{t+1}(1-\delta)] = (\lambda_t + \nu\mu_t) \tag{2.2.3}$$

$$\frac{\beta}{\gamma_{XH}} E_t\left[(\frac{(\lambda_{t+1}+\mu_{t+1})}{f_{t+1}})\right] = \lambda_t \tag{2.2.4}$$

$$\lambda_t[\,(1-\delta)k_t + \frac{1}{f_t}m_t + \frac{1}{f_t}n_t + z_t k_t + w_t H_t - c_t - \gamma_{XH}(k_{t+1}+m_{t+1})\,] = 0 \tag{2.2.5}$$

$$\mu_t[\,m_t \frac{1}{f_t} - c_t - \nu\ \gamma_{XH}(k_{t+1}+m_{t+1}) - (1-\delta)k_t] = 0 \tag{2.2.6}$$

$$\lim_{\tau\to+\infty} E_t\left[\beta^{t+\tau} E_{t+\tau}\left[\frac{\partial V_{t+1+\tau}}{\partial k_{t+1+\tau}}\right] k_{t+1+\tau}\right] = 0 \tag{2.2.7}$$

$$\lim_{\tau\to+\infty} E_t\left[\beta^{t+\tau} E_{t+\tau}\left[\frac{\partial V_{t+1+\tau}}{\partial m_{t+1+\tau}}\right] m_{t+1+\tau}\right] = 0 \tag{2.2.8}$$

Compared to the benchmark RBC model, the first optimality condition is different as a new term has appeared in addition to the previous opportunity cost of consuming the good. This additional cost is linked with the cash-in-advance constraint and appears via the multiplier of this constraint, μ. It is a shadow price of money and represent the cost (in terms of utility) of being more constrained if you consume one more unit of good today

[7] See section 3.

or the gain of being less constrained tomorrow as you transfer one more unit of money in the next period. So equation (2.2.1) is a combination of these two opportunity costs.

Equation (2.2.2) is the same as is in the standard RBC model and indicates that the marginal utility of leisure is equal to the gain in terms of utility of working one unit of time more today (the marginal product of labor valued in terms of utility).

For the intuition behind equation (2.2.3) we need to distinguish the two possibilities of cash constraints. If the cash constraint affects only consumption ($\nu = 0$), we find the same optimality condition than in the standard RBC model. This condition indicates that the anticipated discounted value of capital tomorrow depends on tomorrow's marginal productivity of capital (net of depreciation) and also on the value of capital the period thereafter. By successive substitutions one can show that the value of λ_t depends on all future net returns on capital and on the value of capital and the end of time.
If $\nu = 1$, the investment purchases will also be submitted to the cash constraint. Equation (2.2.3) can be rewritten in the following way:

$$\lambda_t = \frac{\beta}{\gamma_{XH}} E_t[\lambda_{t+1}(1 - \delta + z_{t+1})] - [\mu_t - \frac{\beta}{\gamma_{XH}} E_t(\mu_{t+1}(1 - \delta))]$$

where the new term (compared to the model I) is the difference between the cost (in terms of utility) of bearing a cash constraint for investing in period t and the gain of having an additional $(1 - \delta)$ investment good in period $t + 1$ that the household can invest without bearing the cash constraint cost. In both models this equations ensures optimality for the wealth transfer via investment.

Equation (2.2.4) ensures that the household is indifferent between transferring wealth via investment or money. The advantage of investing is that it generates a measurable return (λ_t) in the next period but it requires cash to be purchased. Money does not give any direct return in the next period but it reduces the cost of bearing a cash constraint (μ_t). The optimality for this trade off is given by equation (2.2.4). To see why, let's write the equation in a slightly different way:

$$\lambda_t = \frac{\beta}{\gamma_{XH}} E_t[\lambda_{t+1} \frac{1}{f_{t+1}}] + \frac{\beta}{\gamma_{XH}} E_t[\mu_{t+1} \frac{1}{f_{t+1}}]$$

The first term on the right side gives the expected and discounted return of one unit invested in t, times the units of goods purchasable with one unit of money in period $t+1$ (purchasing power). The second term represents the gain in $t+1$ of having an additional unit of money with purchasing power $\frac{1}{f_{t+1}}$ in period $t + 1$ and that avoids the cost (in terms of utility) for the purchase of the investment or consumption good.

The optimality conditions for the representative firm are

$$z_t = \alpha A_t k_t^{\alpha-1} H_t^{1-\alpha} \tag{2.2.9}$$
$$w_t = (1 - \alpha) A_t k_t^{\alpha} H_t^{\alpha} \tag{2.2.10}$$

Finally, we add the following equilibrium conditions and definitions:

$$c_t + i_t = y_t \tag{2.2.11}$$

$$\gamma_{XH} m_{t+1} = g_t \frac{1}{f_t} m_t \quad (2.2.12)$$

$$y_t = A_t k_t^{\alpha} H_t^{1-\alpha} \quad (2.2.13)$$

Equations (2.2.1) to (2.2.13) define the competitive equilibrium of the economy.

The resolution strategy will be based on King et al. [1988]. They choose to log-linearize directly the Euler equations and derive efficiency conditions under certainty and approximate these around the steady state to obtain linear decision rules. They justify the coincidence of this solution with the solution of the stochastic model by invoking certainty equivalence. We proceed at a first-order approximation around the steady state of the equations that define the competitive equilibria[8]. We neglect the second-order terms so that the decision rules are independent of the variance of the stochastic shocks to which the economy is subject. The equations constitute a system of linear difference equations of order one. This problem is analogous to Blanchard and Kahn [1980].

3 Calibration

We calibrate the model for the German economy, using data from 1960 to 1989[9]. We use seasonally adjusted quarterly data. Most of the series are taken from the Deutsche Institut für Wirtschaftsforschung (DIW) just as for Brandner and Neusser [1992]. Details on the data used can be found in Appendix I.

To calibrate the model we followed the method initiated by Kydland and Prescott [1982] and developed by Cooley and Prescott [1995]. This calibration exercise consists in choosing parameter values so that the balanced growth path (steady state) of our model economy matches certain long-term features of the measured economy.

The firm's problem The firm's production possibilities are summarized by the following Cobb-Douglas production function:

$$Y_t \leq A_t K_t^{\alpha} (X_{H,t} H_t)^{1-\alpha}$$

This functional form is suggested by the basic observation that capital and labor shares of output have been approximately constant over time even though the relative price of the inputs has changed. The parameter α is referred to as the capital's share in output in a competitive environment. $1-\alpha$ is fixed at the mean share of labor income in real GNP : 0.66 over the sample.

We chose to use a benchmark value for the capital depreciation parameter (0.025 per quarter) and construct a capital series by using the law of motion of capital:

$$\gamma_{XN} k_{t+1} = (1-\delta) k_t + i_t$$

γ_{XN} is fixed at the average real growth factor of real GNP which is about 1.0067 per quarter.

[8]Danthine, Donaldson and Mehra [1989] show that this method leads to a low approximation error.

[9]This choice is related to the break in 1990 due the unification.

The specification of the stochastic process followed by the technology shocks is based on the estimation of the Solow residual process. With perfect competition and constant returns to scale, the growth rate of the Solow residual represent a measure of the growth rate of technical progress augmenting the global productivity of factors[10]. Let RS_t be the Solow residual :

$$\log(RS_t) = \log(Y_t) - \alpha \log(K_t) - (1 - \alpha) \log(H_t)$$

Knowing that RS is a measure of the shock, the persistence (ρ_a) and the standard deviation (σ_a) of the shock are obtained by estimating a first-order equation AR(1), on RS_t, given a deterministic trend.

Table 1: Firm's Structural Parameters

γ	δ	α	ρ_a	ϵ_a
1.0067	0.025	0.34	0.96	0.01

The household's problem We considered the following utility function

$$U_0 = log(C_t) + \theta(1 - H_t)$$

To calibrate β we use the second equation of the steady state system:

$$\alpha \frac{y}{k} = \frac{\gamma - \beta(1 - \delta)}{\beta}$$

First we compute the average output-capital ratio which is about 0.126 for the considered period. For $\nu = 0$, we have the following expression[11]:

$$\beta = \frac{\gamma}{[\alpha \frac{y}{k} + (1 - \delta)]}$$

The value for β is then 0.992.
We normalize the total time available to work to one and calibrate the parameter θ such that the steady state number of hours is 0.4 which corresponds to the historical share of total disposable time endowment. This leads to a value for θ around 2.2.

The money supply To assign values to the parameters of the money supply process, we estimate an AR(1) on the relative deviation of the money growth rate to its mean (1.0184) over the period. For $M1$, we use a seasonally adjusted series from the Bundesbank . The persistence of the monetary shock is thus estimated to be 0.495 with a standard deviation of 1.1%.

[10] See Hairault [1995]

[11] In the case of $\nu = 1$, we have to compute the roots of a second order equation but the result is very similar.

Table 2: Household's Structural Parameters

β	θ
0.992	2.2

Table 3: Money Supply Structural Parameters

$\bar{g}$	ρ_g	ϵ_g
1.0184	0.495	0.011

4 The transmission mechanism of the shocks

4.1 The productivity shock

For both monetary BC models, the adjustment mechanism are the same as in the benchmark RBC model (direct and indirect effects). This is true because the cash–in–advance constraint will only induce an adjustment in prices after a technological shock. Prices will fall after the productivity shock (positive supply shock) and will reduce, temporarily the inflation tax effect. For the model with a constraint on consumption only (Model I), the instantaneous responses (direct effects) will be identical to those of the benchmark RBC model.

Concerning the response of consumption and investment, the wealth effects related to the basic adjustment mechanism will be sufficient for both variables to be increase instantaneously after the shock. So except for inflation, all the variables will react positively to the productivity shock.

This arbitrage between consumption and investment is conditioned by the value of the future consumption in terms of present consumption - the value of the inter temporal elasticity of substitution of consumption. With our logarithmic utility function, this elasticity is always one.

The direct effect is measured by the coefficients $\Pi_{.A}$ presented in table 4 Except for Π_{zA}, the Π coefficients should be interpreted as the elasticities of the flow variables with respect to deviations of the total factor productivity from its steady state value.

Table 4: Elasticities $\Pi_{.A}$

	π_{kA}	π_{mA}	π_{cA}	π_{HA}	π_{wA}	π_{zA}	π_{yA}	π_{fA}	π_{iA}
Model I	0.143	0.439	.439	1.33	0.439	1.773	1.773	-0.439	4.950
Model II	0.129	1.608	.452	1.049	0.559	1.608	1.608	-1.608	4.466

The indirect effects are due to the deviation of the capital stock away from its steady state . The total response to a productivity shock is a combination of the direct and indirect effects.

The impulse response function will give the shape of the total response of the different variables after a productivity shock.

4.1.1 Persistence of the productivity shock

Given the criticism of the calibration method[12] used for the persistence of the productivity shock, it will be interesting to analyze the sensitivity of the responses of the variables to alternative values of this parameter.

In model I (and the benchmark RBC model), an increase in the persistence of the technological shock reinforces the wealth effects and reduces the inter temporal substitution effect. These effects will respectively lower the positive response of the hours and lower the positive response of investment while augmenting the positive effect on consumption. The effects of increasing persistence in the second model are quite different. Except for

Table 5: Persistence of the productivity shock: Model I

	π_{kA}	π_{mA}	π_{cA}	π_{HA}	π_{wA}	π_{zA}	π_{yA}	π_{fA}	π_{iA}
ρ_A=0	0.206	0.13	0.13	2.07	0.13	2.2	2.2	-0.13	7.134
ρ_A=0.5	0.1992	0.164	0.164	1.99	0.164	2.15	2.15	-0.164	6.89
ρ_A=0.96	0.143	0.44	0.44	1.33	0.44	1.77	1.77	-0.44	4.95

the elasticity of the marginal productivity of labor, all other elasticities are increased with the persistence of the shock. The cash constraint is always binding, and in Model II it affects both components of output. With increased persistence, the agent anticipates a lasting decrease in prices, as a consequence both components of output will increase. We also observe that the absence of persistence in Model II implies that the instantaneous effect on hours worked is negative indicating that the wealth effect dominates in the first period.

Table 6: Persistence of the productivity shock: Model II

	π_{kA}	π_{mA}	π_{cA}	π_{HA}	π_{wA}	π_{zA}	π_{yA}	π_{fA}	π_{iA}
$\rho_A = 0$	0.094	0.98	0.058	-0.036	1.015	0.98	0.98	-0.98	3.25
$\rho_A = 0.5$	0.12	1.32	0.126	0.55	0.77	1.32	1.32	-1.32	4.26
$\rho_A = 0.96$	0.13	1.61	0.45	1.05	0.56	1.61	1.61	-1.61	4.47

[12]In particular the issue of the exogeneity of the Solow residual. See Hairault [1992] for an extensive discussion.

4.2 The monetary shock

In contrast with other models, there is no money illusion in this economy. Non neutralities will arise only because anticipated inflation acts as a distortion tax on activities involving the use of cash. The model economy is neutral with respect to unanticipated money supply shocks.
As for the productivity shock, there are two propagation mechanism after the money injection. (i) An direct and (ii) indirect effect (due to the deviation of the capital stock)

(i) the direct effect

In Model I, after a positive monetary shock (increase in the growth rate of the money supply $\bar{g}$), both current and anticipated inflation increases. Thus the purchasing power of the transferred monetary balances decreases, and so does consumption via the cash–in–advance constraint. This is the so–called inflation tax effect. Household's reaction to this is to adopt a behavior allowing him to avoid this tax. The household will turn its consumption willingness to leisure and investment that do not bear the inflation tax. So he will substitute goods consumption to future periods, in which inflation will be lower. The decrease in hours worked implies that output will instantaneously fall below its steady state level, since capital is predetermined.

In the second Model the only way to avoid the inflation tax is leisure. In contrast with Model I, investment will fall and the increase in leisure will be a lot stronger. With a fall in both consumption and investment, output will fall more sharply.

Table 7: Elasticities $\Pi_{.g}$

	π_{kg}	π_{mg}	π_{cg}	π_{Hg}	π_{wg}	π_{zg}	π_{yg}	π_{fg}	π_{ig}
Model I	0.066	0.08	-0.92	-0.22	0.08	-0.15	-0.15	0.92	2.09
Model II	-0.11	0.09	-0.06	-1.37	0.47	-0.91	-0.91	0.91	-3.45

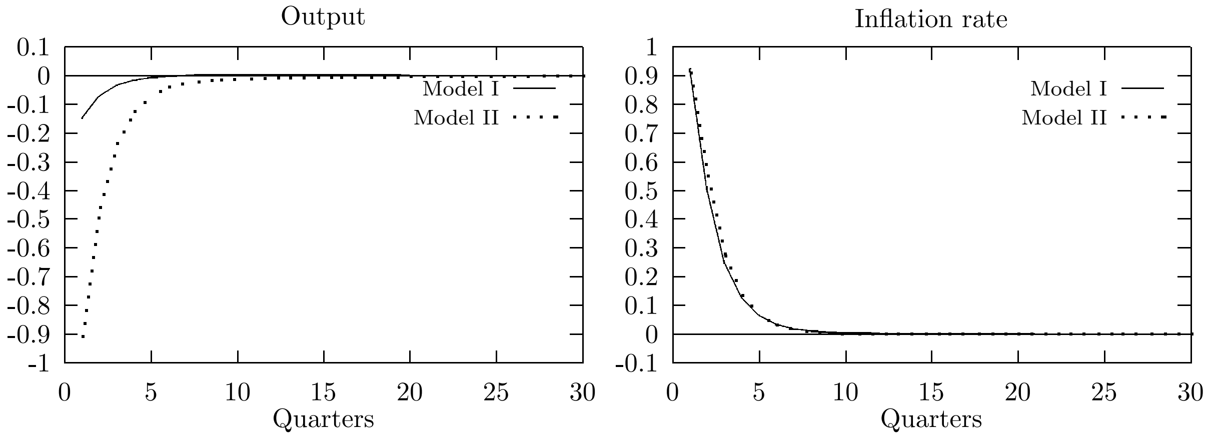
(ii) The indirect effect

In Model I, as the instantaneous reaction of investment is positive, the capital stock will be above its steady state level in the second period after the shock. In Model II, the reaction is the opposite. The instantaneous response will be only due to the direct effect while the subsequent responses will be combinations of the two effects as there is some persistence of the shock. The impulse response functions will be representations of these effects (see figure 1).

4.2.1 The persistence of the monetary shock

The results of the calibration of the persistence of the monetary shock (ρ_g) are somewhat different in Germany and the U.S. (0.495 and 0.377 respectively). This parameter can be seen as an indicator of the continuity in monetary policy. We will see that considerably different responses can only be observed for extreme values of the parameter.

Figure 1: Impulse response functions to a monetary shock



In Model I, when there is no persistence in the monetary shock, the incentive to substitute for future consumption will be maximum (highest instantaneous response of investment) while the response of leisure will be weak. Increasing the persistence will progressively induce households to avoid the inflation tax more via leisure than via investment.

Table 8: Persistence in the Monetary shock: Model I

	π_{kg}	π_{mg}	π_{cg}	π_{Hg}	π_{wg}	π_{zg}	π_{yg}	π_{fg}	π_{ig}
$\rho_g = 0$	0.077	0.04	-0.96	-0.12	0.04	-0.08	-0.08	0.96	2.45
$\rho_g = 0.495$	0.066	0.08	-0.92	-0.22	0.08	-0.15	-0.15	0.92	2.09
$\rho_g = 0.96$	-0.02	0.35	-0.65	-1.02	0.35	-0.68	-0.68	0.65	-0.75

In Model II, there is no possibility to transfer wealth into the future without being subject to the inflation tax as there is no other credit good than leisure. Higher persistence, increases the overall effect of the inflation tax and increases the instantaneous response of leisure.

Table 9: Persistence in the Monetary shock: Model II

	π_{kg}	π_{mg}	π_{cg}	π_{Hg}	π_{wg}	π_{zg}	π_{yg}	π_{fg}	π_{ig}
$\rho_g = 0$	-0.08	0.36	-0.04	-0.97	0.33	-0.64	-0.64	0.64	-2.43
$\rho_g = 0.495$	-0.11	0.09	-0.06	-1.37	0.47	-0.91	-0.91	0.91	-3.45
$\rho_g = 0.96$	-0.18	-0.51	-0.09	-2.29	0.78	-1.51	-1.51	1.51	-5.77

4.2.2 The average growth rate of money

This sensitivity test allows one to see whether high inflation economies react differently to the considered shocks. This was one of the main purposes of the pioneering monetary BC Model by Cooley and Hansen [1989]. Of course we confirm their result i.e. that "The model economy predicts that the business cycle will be the same in a high inflation economy and in a low inflation economy" for Model I but not for Model II as shown in Hairault and Portier [1995].
In Model I, varying $\bar{g}$ does not affect the elasticities and in particular the speed of convergence π_{kk} is unchanged[13]. In Model II, the results are quite different. An increase in $\bar{g}$ implies a higher speed of convergence (smaller value of π_{kk}) due to a stronger response of investment to deviations of capital to its steady state level. The intuition is the following: In Model II, a higher growth rate of the money supply ($M1$) leads to a lower steady state capital output ratio, $\frac{k}{y}$, and this reduces the wish to smooth consumption and increases the elasticity of investment (in absolute value). For the same reason as below, the elasticities

Table 10: Elasticities $\Pi_{.k}$: Model II

	π_{kk}	π_{mk}	π_{ck}	π_{Hk}	π_{wk}	π_{zk}	π_{yk}	π_{fk}	π_{ik}
$\bar{g} = 1.00$	0.9498	.206	.595	-0.369	0.575	-0.794	0.206	-0.206	-0.737
$\bar{g} = 1.4$	0.9492	.271	.542	-0.258	0.528	-0.729	0.271	-0.271	-0.759

of the different variables to a productivity and monetary shock will also be altered in Model II with different values of the parameter $\bar{g}$.

Table 11: Elasticities $\Pi_{.A}$: Model II

	π_{kA}	π_{mA}	π_{cA}	π_{HA}	π_{wA}	π_{zA}	π_{yA}	π_{fA}	π_{iA}
$\bar{g} = 1.00$	0.128	1.614	0.447	1.06	0.555	1.614	1.614	-1.614	4.442
$\bar{g} = 1.4$	0.144	1.484	0.564	0.836	0.649	1.485	1.485	-1.485	4.978

Table 12: Elasticities $\Pi_{.g}$: Model II

	π_{kg}	π_{mg}	π_{cg}	π_{Hg}	π_{wg}	π_{zg}	π_{yg}	π_{fg}	π_{ig}
$\bar{g} = 1.00$	0.128	1.614	0.447	1.06	0.555	1.614	1.614	-1.614	4.442
$\bar{g} = 1.4$	0.144	1.484	0.564	0.836	0.649	1.485	1.485	-1.485	4.978

Testing for different values of $\bar{g}$ we have to test for extreme values to have significant changes in the elasticities.

[13] see Abel [1985] for a theoretical analysis.

5 Variance Decomposition

The impulse response functions and variance decomposition of the forecast error $y_{t+s} - y_{t+s} \mid_t$ summarize the main information contained in the dynamic system. The variance decomposition indicates the importance of the variance of the different shocks on the total forecast error for a given variable.

5.1 The general case

The aim is to decompose the total variance of the forecast error[14] for any variable of the system into the share of variance due to the technological and monetary shock respectively. We can write the equation of the variance of the forecast error for an horizon s

$$Var(y_{t+s} - E_t[y_{t+s} \mid I_t]) = \sigma_A^2 \sum_{i=0}^{s-1} C_1(i)^2 + \sigma_g^2 \sum_{j=0}^{s-1} C_2(j)^2$$

where $C_1(i)$ is a vector whose elements corresponds to the response after i periods of a particular variable to a technological shock that occurred in period t. $C_2(i)$ being the corresponding vector for a monetary shock that occurred in period t. σ_A^2 and σ_g^2 are the variance of the technological and monetary shock respectively. The share of total variance of the forecast error (in percent) due to technological or monetary shock is respectively

$$\frac{\sigma_A^2 \sum_{i=0}^{s-1} C_1(i)^2}{Var(y_{t+s} - E_t[y_{t+s} \mid I_t])}$$

and

$$\frac{\sigma_g^2 \sum_{j=0}^{s-1} C_2(j)^2}{Var(y_{t+s} - E_t[y_{t+s} \mid I_t])}$$

5.1.1 The special case

The question that Variance Decomposition will allow us to answer is the following: Suppose the economy is at the steady state (no previous shocks), and there are two types of shocks with a given variance that occur. How much of the variance of the forecast error at a given horizon and for a given variable will be due to the variance of each shock ?
In other words, what are the different weights of the two shocks (measured in terms of variance) in the future periods after the shocks occur.

The first striking feature is that the variance of the monetary shock has only a marginal impact on the total forecast error of output and fades away progressively. For consumption the variance of the monetary shock dominates but only for the first quarters and decreases rapidly thereafter. This is of course due to the cash-in-advance constraint and the lower persistence of the monetary shock (see the section on calibration).
For inflation, the variance of the monetary shock dominates in every period. The effect of the monetary shock is immediate given the cash–in–advance constraint. The effect of

[14]See Hamilton [1994] section 11.4 and 11.5

Table 13: Sensitivity to persistence of monetary shocks: Model I (only V_g)

horizon	$\rho_g = 0$		$\rho_g = 0.495$		$\rho_g = 0.8$		$\rho_g = 0.96$	
	$\hat{f}$	$\hat{y}$	$\hat{f}$	$\hat{y}$	$\hat{f}$	$\hat{y}$	$\hat{f}$	$\hat{y}$
1 quarter	78.1%	0.23%	76.8%	0.77%	73.42%	3.15%	62.2%	13.8%
1 year	77.6%	0.06%	81.65%	0.28%	88.6%	2.0%	92.1%	13.8%
5 years	77.3%	0.0%	81.5%	0.09%	90.5%	0.83%	97.4%	13.6%
20 years	76.8%	0.02%	81.0%	0.08%	90.2%	0.66%	97.8%	13.5%

the productivity shock is to increase consumption for a given money supply, thus inflation will fall (via the cash-in-advance constraint).

One direct consequence of the generalized cash–in–advance constraint ($c + i \leq \frac{m}{f}$ with m predetermined) is that the instantaneous response of f and y is identical. As the cash-in-advance constraint affects both components of output, the share of the variance of the technological shock is somewhat weaker for output than in model I. The striking feature in this case is that even for inflation, the variance of the forecast error depends mainly on the variance of the technological shock whatever the horizon. In Model II, the increase in productivity will rise the money demand more as investment is a cash good and thus inflation will fall more sharply than in Model I. As shown in section 5.2, all responses of inflation to a monetary shock are lower (in absolute value) than in the case of a technological shock.

Table 14: Sensitivity to persistence of monetary shocks: Model II (only V_g)

horizon	$\rho_g = 0$		$\rho_g = 0.495$		$\rho_g = 0.8$		$\rho_g = 0.96$	
	$\hat{f}$	$\hat{y}$	$\hat{f}$	$\hat{y}$	$\hat{f}$	$\hat{y}$	$\hat{f}$	$\hat{y}$
1 quarter	15.4%	15.4%	26.8%	26.8%	42.2%	42.2%	50.4%	50.4%
1 year	19.4%	4.76%	35.1%	11.9%	58.6%	32.5%	68.1%	50.5%
5 years	19.3%	1.5%	34.9%	4.2%	62.0%	15.9%	83.1%	51.1%
20 years	19.2%	1.2%	34.8%	3.3%	61.9%	12.2%	85.7%	51.3%

Sensitivity to the persistence of the monetary shock We will only focus our attention on the persistence of the monetary shock and on the two extreme values 0 and 0.96 (the persistence of the technological shock). The following tables give the results for Model I and II respectively. Note that only the share of the total variance of the forecast error due to the variance of the monetary are presented (V_g).

The general intuition behind the sensitivity test to the persistence of the monetary shock is the same as for the IRF analysis. In model I with low persistence, the first period substitution effect away from consumption is high and so is the price adjustment.

In subsequent periods the effect will be weaker. The same is true for the share of the variance of the monetary shock in the total variance of the forecast error of the different variables. Even with high persistence of the monetary shock, the variance of the forecast error will be largely dominated by the variance of the technological shock. In model II, there is no possibility to transfer wealth into the future without being subject to the inflation tax. We already discussed that the increased persistence will necessarily sharpen the fall in output. This is an explanation for the very share of total variance due to the variance of the monetary shock when the persistence is high.

It is only in model II and with very high persistence of the monetary shock that the monetary shock has a substantial long run effect (measured in terms of variance decomposition) on consumption and output. The variance decomposition analysis shows clearly that monetary shocks in a cash–in–advance framework have only very short run effects (few quarters) on real variables.

sensitivity to the average growth rate of money As mentioned earlier, varying $\bar{g}$ in model I does not affect the elasticities and in particular the speed of convergence π_{kk} is unchanged. It is therefore that $\bar{g}$ will not alter the results in terms of variance decomposition. In Model II, the higher average growth rate of money will increase the weight of monetary shocks relative to the productivity shock (measured by the relative share in total variance of the forecast error of output and inflation). We already argued that a higher value of the parameter $\bar{g}$ increases the response of investment to deviations of the capital stock.

Table 15: Sensitivity to the average growth rate of money: Model II (only V_g)

horizon	$\bar{g} = 1.0$		$\bar{g} = 1.0184$		$\bar{g} = 1.1$		$\bar{g} = 1.4$	
	$\hat{f}$	$\hat{y}$	$\hat{f}$	$\hat{y}$	$\hat{f}$	$\hat{y}$	$\hat{f}$	$\hat{y}$
1 quarter	26.6%	26.6%	26.8%	26.8%	27.6%	27.6%	30.1%	30.1%
1 year	34.8%	11.8%	35.1%	11.9%	36.2%	12.3%	39.5%	13.7%
5 years	34.7%	4.2%	35.0%	4.2%	36.1%	4.3%	39.4%	4.5%
20 years	34.6%	3.3%	34.8%	3.3%	35.9%	3.3%	39.3%	3.4%

6 Cyclical properties of the Model Economies

In the following section, we simulate both type of models. Before computing the second order moments, the simulated data are logged and detrended using the Hodrick-Prescott filter. Given the set of parameter values (calibration), simulated time series with 120 observations (the number of observations in the data sample) are computed using the method described in section 2.2. We simulate the economy 100 times and the averages of the statistics over these simulations are reported.

Table 16: table 6.1: Cyclical Properties of the Models

	German data	RBC Model	Model I	Model II
$\sigma_{\hat{y}}$	1.62	2.4	2.38	2.36
$\sigma_{\hat{c}}/\sigma_{\hat{y}}$	0.92	0.35	0.57	0.35
$\sigma_{\hat{i}}/\sigma_{y}$	2.83	3.06	3.23	3.2
$\sigma_{\hat{h}}/\sigma_{\hat{y}}$	0.8	0.69	0.7	0.85
$\sigma_{\hat{f}}/\sigma_{\hat{y}}$	0.23	–	0.49	0.82
$\sigma_{\hat{M}}/\sigma_{\hat{y}}$	1.39	–	0.93	0.98
$\mathrm{Corr}(\hat{c}, \hat{y})$	0.69	0.89	0.61	0.85
$\mathrm{Corr}(\hat{i}, \hat{y})$	0.83	0.98	0.91	0.98
$\mathrm{Corr}(\hat{h}, \hat{y})$	0.69	0.97	0.97	0.88
$\mathrm{Corr}(\hat{f}, \hat{y})$	0.042	–	-0.31	-0.51
$\mathrm{Corr}(\hat{M}, \hat{y})$	0.29	–	0.006	0.12

The RBC Model The variability introduced by the technological shock is too high which suggests that the variance of the shock is either overestimated (see the section on calibration) and/or that the model should include stabilizing mechanism[15]. This first observation suggests to focus on the relative variabilities . The general pattern of relative volatilities of investment, output and consumption is replicated by the model. This supports the assumption that there is a consumption smoothing behavior linked to the intertemporal substitution mechanism. The sign of the cross-correlations with output are also conform with those of the observed data and indicates that all real variables are procyclical. This is an inevitable consequence of the fact that there is only one shock in this economy (only one source of uncertainty). But the model economy fails to capture some other important facts. The level of the relative volatilities is not well reproduced. The cross correlation with output are too high.

Model I It was first tested by Cooley and Hansen [1989] for the US series. They found that if the economy is only hit by technological shocks, "the statistics summarizing the behavior of the real variables are the same as would be obtained in the same model without money (Hansen [1985]). This result is verified here as it is independent of the calibration of the parameter values. Here again the general volatility is too high and we will focus on relative variabilities. Concerning the real variables, the second order moments of consumption are the only to be strongly affected compared to the benchmark RBC Model. The relative variability of consumption is increased and the auto-correlation and cross-correlation are weaker. These results are directly linked to the assumption that money introduced via a cash-in-advance constraint. As this constraint is always binding (see calibration), every change in inflation will affect consumption and will thus be a source of variability that is affected by both shocks. The fact that inflation is negatively

[15] Hairault [1995] finds a similar result for France but using the King Plosser and Rebello framework, i.e. without indivisible labor assumption

correlated with output will reduce the cross correlation of consumption with output.
The countercyclical behavior of inflation generated by the model is opposite to what we can observe in the German data. To understand why the cross correlation of inflation is negative in this model, we will analyze the effects of the exogenous shocks on the two variables separately. The positive productivity shock shifts the aggregate supply of output up along a relatively stable ("consumption smoothing") downward sloping demand function. Output goes up while inflation falls.
After a positive monetary shock, inflation goes up while output falls due to the negative response of hours (responses to the "inflation tax effect"). So we see why for both shocks the responses of the two variables are opposite. The monetary aggregate we are interested in, given the structure of the model, is M1. The relative volatility is too low and money is acyclical. This does not match the observed positive cross correlation of money and output observed in the data.

Model II With both monetary and technological shocks the relative volatility and cross-correlations of consumption are weaker than in the previous model. This is due to fact that there is no more distortion between consumption, investment and output ($y = c + i$) and the relative volatilities are close to those of the benchmark RBC Model. The second order moments of inflation are worsen in this model and the relative volatility is still far too low.

7 Concluding remarks

The purpose of this paper was to examine whether the benchmark real or monetary business cycle model can account for some basic stylized facts of the business cycle in Germany.

The evidence suggests that the benchmark RBC model can do so for some stylized facts in Germany. The general pattern of relative volatilities of investment, output and consumption is replicated. Nevertheless, the level of the relative volatilities is not well reproduced and the cross correlation with output are too high.

If we assume that the money growth follows an process and calibrate it on observed data, the model with a cash-in-advance constraint on consumption does not alter strongly the properties of the benchmark RBC model presented by Hansen [1985]. There is one exception that appears important particularly for Germany. The relative volatility of consumption is increased sharply but remains below what we observe in the German data. The fact that the model contains a nominal dimension, allows one to confront the model with a broader range of stylized facts. It is on those features that the model fails as inflation appears to be strongly countercyclical in this type of model and the relative volatility is too low. The results obtained for the model with a cash-in-advance constraint on both consumption and investment is also disappointing in this sense. The relative volatility of all real variables is very similar to the benchmark RBC model while the second order moments for inflation and to a certain extend of money are far from those observed in the data.

Monetary growth distorts allocations because of the tax associated with inflation. The inflation tax induces substitutions effects that push output down. Money is not neutral in the short run but the variance decomposition indicates that the variance of forecast error of output is largely dominated by the variance of the productivity shock. It is only in Model II and with very high persistence of the monetary shock that the variance of the shocks have similar weights.

The initial aim of the RBC theorists[16] was to establish that the optimal responses of economic agents confronted with real shocks can generate cyclical features close to those observed in the data but without taking into account monetary shocks. If we wish to introduce money in a neoclassical general equilibrium framework, the cash–in–advance constraint appears to be an appropriate way. Nevertheless, we confirm that this mechanism alone cannot account for the role of money in business cycle models. Several extensions of the benchmark monetary business cycle model have already been developed but the observation that comovements of output, prices, money and interest rates differ across countries suggests that we should introduce endogenous monetary effects instead or in addition to exogenous monetary shocks. These inside money effects mostly transit via a financial intermediary as in the seminal paper by King and Plosser [1984]. We must also include the line of research that presents a more comprehensive description of how the financial sector works or account for the role of liquidity effects.

[16]In particular, the articles by Kydland and Prescott [1982] and Long and Plosser [1983].

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APPENDIX I

If not indicated otherwise, data are from the Deutsche Institut für Wirtschaftsforschung, Berlin (DIW). As in Brandner and Neusser (1990) annual values for total population (Source: Austrian Institute of Economic Reserch (WIFO) database) have been interpolated to get quarterly series for per capita calculations. All series have been seasonally adjusted (Census X-11).

- *Output*: Real gross national product (GNP), at constant prices 1980, per capita.
- *Consumption*: Real private consumption, at constant prices 1980, per capita.
- *Fixed investment*: Real gross investment, at constant prices 1980, per capita.
- *Hours*: Total hours worked, per capita.
- *Real wage*: Compensation of employees, divided by the deflator of private consumption, per employee.
- *Share of profits in GNP*: IMF statistics.
- *Price level*: Consumer price index (CPI), IMF statistics.
- *Inflation*: Δ LN (CPI).
- *Money supply*: M1, Seasonally adjusted (Census X-11) business statistics.