ESSAYS ON MONETARY BUSINESS CYCLE WITH CREDIT

by
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Abstract

This thesis examines the role of the banking sector and credit shocks, as candidates for causing some of the fluctuations in output, inflation or money velocity. The approach here is a stochastic extension of the cash-in-advance economy with a banking sector that allows for the production of credit as an alternative to cash. The stochastic extension, and in particular the productivity shocks of the banking sector allows a convenient setup for analyzing credit and banking history, where for instance, positive credit shocks could be consistent with financial deregulatory periods, and negative shocks consistent with credit crises.

This work consists of six chapters. The first chapter sets up the methodological framework used in the subsequent chapters for the analysis. In particular, it presents a model economy that encompasses the models derived in the various chapters and shows the calibration and the solution. Further, it illustrates the method used to identify the various shock series, and finally the variance decomposition procedures are shown separately by shocks and by spectral frequencies. Chapter 2, "A comparison of exchange economies within a monetary business cycle" compares the performance of the cash-only, shopping time and credit production models in explaining the puzzles of the monetary business cycle theory. The credit model improves the ability to explain the procyclic movement of monetary aggregates, inflation and the nominal interest rate. Chapter 3, "Credit shocks in the financial deregulatory era: Not the usual suspects" constructs goods productivity, money and credit productivity shocks in a robust way and shows the contribution of the credit shock to US GDP movements together with the ability to correlate the shock-induced GDP movements with the financial deregulatory measures. In this way credit shocks are interpreted in terms of changes in banking legislation during the US financial deregulation era, being also a candidate that matters in determining GDP fluctuations.

Chapter 4, "Money Velocity in an Endogenous Growth Business Cycle with Credit Shocks" extends the credit model to an endogenous growth framework. Money and credit shocks explain much of the velocity variation, although the role of the shocks varies across sub-periods. Chapter 5, "Volatility Cycles of Output and Inflation, 1919-2004: A Money and Banking Approach to a Puzzle", explains the close comovement of volatilities of GDP growth and inflation over 1919-2004 period using money and credit shocks that have different effects in different subperiods. The two great volatility cycles over the historical period are identified, characterized and contrasted. The post-1983 moderation also coincided with an ahistorical divergence in the money aggregate growth and velocity volatilities away from the downward trending GDP and inflation volatilities. The volatility divergence is explained by the upswing in the credit volatility that kept money supply variability from translating into inflation and

GDP volatility.

Chapter 6, "Money and credit effects on the business cycle in Eastern Europe: Three countries, one story" extends the analysis to three transition economies, Hungary, Poland and Czech Republic, identifies the main shocks in the recent monetary and financial history and investigates whether and how monetary and financial shocks influenced the movements in output, inflation and money velocity. It exploits the fact that several similar events happened in each country at different times, in particular, the refinancing of bad loans, the privatization of the bank sector and the reform of the central bank acts and the introduction of the inflation targeting regime. Further, it documents the evolution of the volatilities of output, inflation, money and money velocity emphasizing a puzzling bifurcating pattern between the volatilities of money and money velocity on the one hand and that of inflation and output on the other hand. This patters shows similarities to what has been observed in US data, the explanation to such behavior being offered here within the credit model.

Introduction

This thesis examines the role of credit and the banking sector in explaining business cycle fluctuations. The underlying motivation for this work comes from a variety of sources:

First, there is a set of literature that studies the contribution of monetary factors to business cycle movements using the cash-in-advance approach in Cooley and Hansen (1989a), Cooley and Hansen (1995), Cooley and Hansen (1998), and the shopping time model of Gavin and Kydland (1999) and Dittmar, Gavin, and Kydland (2005). They identify puzzles left unexplained, and how different modeling features help in some areas but not in others. Yet some puzzles are not well explained by either nominal rigidities, the standard exchange technologies, or feedback rules. These include the procyclic movement of the income velocity of money, of monetary aggregates, of inflation and of the nominal interest rate. And a model that is more encompassing of the various answers to the puzzles still is not evident.

Second, the focus of recent research has been directed towards identifying the sources of shocks that influence the real business cycle. Chari, Kehoe, and McGrattan (2003) and Kehoe and Prescott (2002) consider how policy may explain capital, labor and goods distortions that contribute to business cycle fluctuations. Uhlig (2003) in contrast takes an atheoretical approach to decomposing fluctuations into certain candidate shocks, finding that a medium range output productivity shock and a shorter range less discernible shock together explain a good portion of the fluctuations.

Third, an approach to business cycles is offered also by the finance and credit literature. Kiyotaki and Moore (1997) illustrate how financial shocks can be amplified in a non-monetary framework. Einarsson and Marquis (2001) examine the credit aggregates in a monetary model with banking. Li (2000) specifies a production function for credit as an alternative to money and shows how liquidity effects result when open market operations must pass through financial intermediaries. Gillman and Kejak (2004) explain velocity trends with a similar credit production approach. They argue that credit productivity can explain departures of M1 velocity trends from what the nominal interest rate movements alone would predict. Empirical studies, like Jayaratne and Strahan (1996) and Strahan (2003) examine the real effects on the economy from the US bank deregulation and show that the bank deregulations of the 1980s and 1990s can be linked to structural changes in the banking industry, to higher profits and assets growth and to increased output growth rates. Berger (2003) also documents technological progress in the banking sector.

Fourth, a rich literature is concerned with explaining money velocity at business cycle frequencies. Freeman and Kydland (2000), Hodrick, Kocherlakota, and Lucas (1991) and Cooley and Hansen (1995) endogenize money velocity in models with shocks to the goods sector productivity and the money supply. In their model the goods sector productivity shock drives velocity changes, in a way similar to Friedman and Schwartz's (1963b) velocity theory as based on the application of the permanent income hypothesis to money demand. However the most common explanation of velocity, that it depends on monetary-induced inflation effects on the nominal interest rate, as in McGrattan (1998), has no role in explaining velocity at business cycle frequencies, as Wang and Shi (2006) note in their alternative search-theoretic approach to velocity. Also missing is a role for financial sector shocks (King and Plosser 1984), financial innovation (Ireland 1991), technological progress (Berger 2003), or deregulation (Stiroh and Strahan 2003).

This thesis addresses within a common framework the issues raised above. In this framework, the banking sector and credit shocks may make viable candidates for causing some of the fluctuations in output, inflation or money velocity, while this source of fluctuations has been little explored within the business cycle framework. The approach we take extends the cash-in-advance economy (Cooley and Hansen (1989a),Cooley and Hansen (1995)) with a banking sector that allows for the production of credit as an alternative to cash. The model around which this research is built is a stochastic extension of Gillman and Kejak (2005), put first into an exogenous growth framework, then extended with human capital induced endogenous growth. The stochastic extension and in particular the productivity shocks of the banking sector allows a convenient setup for analyzing credit and banking history, where for instance, positive credit shocks could be consistent with financial deregulatory periods and negative shocks consistent with credit crises.

The first chapter of this thesis sets up the methodological framework used in the subsequent chapters for the analysis. In particular, it presents a model economy that encompasses the models derived in the various chapters, it shows the calibration and the solution of the model. Then it illustrates the method used to identify the various shock series, and finally the variance decomposition procedures are shown separately by shocks and by spectral frequencies.

Chapter 2, "A comparison of exchange economies within a monetary business cycle" sets out a monetary business cycle model with three alternative exchange technologies: the cash-only, shopping time and credit production models. The goods productivity and money shocks affect all three models, while the credit model has in addition a credit productivity shock. It compares the performance of the models in explaining the puzzles of the monetary business cycle theory. We show that the credit model improves the ability to explain the procyclic movement of monetary aggregates, inflation and the nominal interest rate.

Chapter 3, "Credit shocks in the financial deregulatory era: Not the usual suspects" constructs goods productivity, money and credit productivity shocks robustly by using quarterly US data on key variables, and the solution to the credit model. The contribution of the credit shock to US GDP movements is found together with the ability to correlate the shock-induced GDP movements with the financial deregulatory measures, therefore shocks are interpreted in terms of changes in banking legislation during the US financial deregulation era. The results put forth the credit shock as a candidate shock that matters in determining GDP, including in the sense of Uhlig (2003).

Chapter 4, "Money Velocity in an Endogenous Growth Business Cycle with

Credit Shocks" extends the credit model to an endogenous growth framework. We find that money and credit shocks explain much of the velocity variation. The role of the shocks varies across sub-periods in an intuitive fashion. Endogenous growth is key to the construction of the money and credit shocks since these have similar effects on velocity, but opposite effects upon growth. The model matches the data's average velocity and simulates well velocity volatility.

In Chapter 5, "Volatility Cycles of Output and Inflation, 1919-2004: A Money and Banking Approach to a Puzzle", we explain the close comovement of volatilities of GDP growth and inflation over 1919-2004 period, using money and credit shocks that have different effects in different subperiods. With these two shocks, plus standard productivity shocks we identify, characterize and contrast the two great volatility cycles over the historical period with our endogenous growth monetary DSGE model with micro-based banking production. The post-1983 moderation also coincided with an ahistorical divergence in the money aggregate growth and velocity volatilities away from the downward trending GDP and inflation volatilities. The volatility divergence is explained by the upswing in the credit volatility that kept money supply variability from translating into inflation and GDP volatility.

Chapter 6, "Money and credit effects on the business cycle in Eastern Europe: Three countries, one story" extends the analysis to three transition economies: Hungary, Poland and Czech Republic, identifies the main shocks in the recent monetary and financial history and investigates whether and how monetary and financial shocks influenced the movements in output, inflation and money velocity. It exploits the fact that several similar events happened in each country at different times, in particular, the refinancing of bad loans, the privatization of the bank sector and the reform of the central bank acts and the introduction of the inflation targeting regime. Further, it documents the evolution of the volatilities of output, inflation, money and money velocity, emphasizing a puzzling bifurcating pattern between the volatilities of money and money velocity on the one hand, and that of inflation and output on the other hand. This pattern shows similarities to what has been observed in US data and documented in Benk, Gillman, and Kejak (2009), the explanation to such behavior being offered here within the credit model.

Chapter 1

Methodological framework for credit analysis

1.1 The model economy

The representative economy is a stochastic extension of Gillman and Kejak (2005). The model described below is an encompassing framework that nests the various versions of the models of chapters.2-6.

The representative agent divides its resources among three sectors: he works in a constant-returns-to-scale consumption goods producing sector, that employs physical capital and effective labour. Effective labour is defined as labour time adjusted by the human capital stock. The agent also devotes resources to two additional sectors. He produces human capital by involving physical capital and effective labour, and produces credit services that involves effective labour and deposited funds.

The agent faces four constraints on the maximization of utility over goods and leisure: the flow of human capital, the flow of financial capital that is comprised of money and physical capital, the stock of financial capital and the exchange technology.

The representative agent observes three shocks that occur before the decision process at the beginning of the period, and follow a vector first-order autoregressive process. The shocks affect the goods sector productivity, z_t, the money supply growth rate, u_t, and bank sector productivity, v_t:

$$Z_t = \Phi_Z Z_{t-1} + \varepsilon_{Zt}, \tag{1.1}$$

where the shocks are $Z_t = [z_t \; u_t \; v_t]'$, the autocorrelation matrix is $\Phi_Z = diag\{\varphi_z, \varphi_u, \varphi_v\}$ and $\varphi_z, \varphi_u, \varphi_v \in (0,1)$ are autocorrelation parameters, and the shock innovations are $\varepsilon_{Zt} = [\epsilon_{zt} \; \epsilon_{ut} \; \epsilon_{vt}]' \sim N(\mathbf{0}, \mathbf{\Sigma})$. The general structure of the second-order moments is assumed to be given by the variance-covariance matrix $\mathbf{\Sigma}$. These shocks affect the economy as described below.

Consumer Problem

A representative consumer maximizes its expected lifetime utility derived from consumption of goods, c_t, and leisure, x_t; with $\beta \in (0,1)$ and $\theta > 0$, this is given by

$$U = E_0 \sum_{t=0}^{\infty} \beta \frac{(cx^{\Psi})^{1-\theta}}{1-\theta}. \tag{1.2}$$

Output of goods, y_t, and human capital h_t are produced with physical capital and effective labor each by applying a Cobb-Douglas constant-return-to-scale technology. The agent allocates fraction s_{Gt} of its physical capital stock to the goods production (G) and fraction s_{Ht} to human capital investment (H) such that:

$$s_{Gt} + s_{Ht} = 1. \tag{1.3}$$

The unit time endowment is allocated amongst leisure, x_t, labor in goods production, l_t, time spent investing in the stock of human capital, n_t, and time spent working in the bank sector, denoted by f_t:

$$l_t + n_t + f_t + x_t = 1. \tag{1.4}$$

Output of goods is divided between consumption goods c_t and investment i_t. Thus, the capital stock used for production in the next period is given by current investment and capital depreciated from the last period:

$$k_{t+1} = (1-\delta_k)k_t + i_t = (1-\delta_k)k_t + y_t - c_t. \tag{1.5}$$

The human capital investment is produced using physical capita $s_{Ht}k_t$ and effective labor $n_t h_t$ (King and Rebelo 1990):

$$H(s_{Ht}k_t, n_t h_t) = A_H (s_{Ht}k_t)^{1-\eta}(n_t h_t)^{\eta}, \tag{1.6}$$

such that the human capital flow constraint is:

$$h_{t+1} = (1-\delta_h)h_t + H(s_{Ht}k_t, n_t h_t). \tag{1.7}$$

The consumer can purchase the goods by using either money M_t or credit services. With the lump sum transfer of cash T_t coming from the government at the beginning of the period, and with money and credit equally usable to buys goods, the consumer's exchange technology is

$$M_t + T_t + P_t q_t \geq P_t c_t. \tag{1.8}$$

The consumer deposits all income that is not invested, of $y_t - i_t = c_t$, in its bank, makes purchases of goods c_t with the cash and credit taken out of deposits d_t, where $d_t = [(M_t + T_t)/P_t] + q_t = c_t$. As a bank, the consumer uses a case of the Clark (1984) financial services technology to produce the exchange credit q_t. Clark assumes a constant returns to scale function in labor, physical capital, and financial capital that equals deposited funds.[1] Here for simplicity no physical capital enters; with $A_F > 0$ and $\gamma \in (0,1)$, the CRS production technology is $q_t = A_F e^{v_t} (f_t h_t)^{\gamma} d_t^{1-\gamma}$, where v_t is the shock to factor productivity; since deposits equal consumption, this can be written as

$$q_t = A_F e^{v_t} (f_t h_t)^{\gamma} c_t^{1-\gamma}. \tag{1.9}$$

[1] Many studies have empirically verified this CRS specification including deposits as the third factor, and this specification has become dominant in current work, for example Wheelock and Wilson (2006).

Let w_t and r_t denote competitive wage and rental rates. Nominal wages ($P_t w_t l_t h_t$) and rents ($P_t r_t k_t$) plus any unspent cash ($M_t + T_t - a_t P_t c_t$), make up the consumer's income, while set-aside cash (M_{t+1}) plus end-of-period credit debt payments $[c_t (1 - a_t)]$, and investment (i_t) are expenditures (where $a_t \in (0, 1]$ denotes the fraction of consumption goods that are purchased with money):

$$P_t w_t l_t h_t + P_t r_t k_t + T_t + M_t - M_{t+1} - P_t c_t - P_t k_{t+1} + P_t(1-\delta_k)k_t \geq 0. \quad (1.10)$$

Given M_0, the consumer maximizes utility subject to the exchange, credit and budget constraints (1.8)-(1.10).

Producer Problem

The firm maximizes profit given by $y_t - w_t l_t h_t - r_t s_{Gt} k_t$, subject to a standard Cobb-Douglas production function in effective labor and capital. This is given as

$$y_t = G(s_{Gt}k_t, l_t h_t, z_t) = A_G e^{z_t} (s_{Gt} k_t)^{1-\alpha} (l_t h_t)^{\alpha}. \quad (1.11)$$

The first order conditions for the firm's problem yield the following expressions for the wage rate and the rental rate of capital:

$$w_t = \alpha A_G e^{z_t} \left(\frac{s_{Gt} k_t}{l_t h_t} \right)^{1-\alpha}, \quad (1.12)$$

$$r_t = (1-\alpha) A_G e^{z_t} \left(\frac{s_{Gt} k_t}{l_t h_t} \right)^{-\alpha}. \quad (1.13)$$

Government Money Supply

It is assumed that the government policy includes sequences of nominal transfers which satisfy:

$$T_t = \Theta_t M_t = (\Theta^* + e^{u_t} - 1) M_t, \qquad \Theta_t = [M_t - M_{t-1}]/M_{t-1}, \quad (1.14)$$

where Θ_t is the growth rate of money and Θ^* is the stationary growth rate of money.

Competitive Equilibrium

The representative agent's optimization problem can be written recursively as:

$$V(s) = \max_{c,x,l,n,f,s_G,a,k',h',M'} \{u(c,x) + \beta E V(s')\} \quad (1.15)$$

subject to the conditions (1.3)-(1.11), where the state of the economy is denoted by $s = (k, h, M, z, u, v)$ and a prime (') indicates the next-period values. A competitive equilibrium consists of a set of policy functions $c(s)$, $x(s)$, $l(s)$, $n(s)$, $f(s)$, $s_G(s)$, $a(s)$, $k'(s)$, $h'(s)$, $M'(s)$, pricing functions $P(s)$, $w(s)$, $r(s)$ and a value function $V(s)$, such that:

(i) households maximize utility: given the pricing functions and the policy functions, $V(s)$ solves the functional equation (1.15).

(ii) firms maximize profits, the functions w and r being given by (1.12) and (1.13).

(iii) goods and money markets clear, in equations (1.10) and (1.14).

Calibration

The calibration of the model implies choosing values for the model parameters such that certain features of the model match the corresponding values observed in the time series of the real economy over a certain time horizon. Throughout the chapters of this theses various calibrations will be employed, ranging from matching the model with the US economy over various data frequencies and time horizons to matching the observed quarterly data of a set of European transition countries. Calibrations are performed in two dimensions: The first is that the "deep" parameters of the model are chosen such that features of the nonstochastic steady state of the model match as much as possible the data averages over certain time period. Second, the parameters of the shock processes (autocorrelation structure and variance-covariance matrix) are set such that the simulated stochastic properties of the model match the statistical properties of the fluctuations in the observed data.

The calibration sets the capital share parameter in the goods sector, $1-\alpha$, the annual discount factor β, the utility function parameters θ and Ψ, the depreciation rates of physical and human capital δ_K and δ_H to values that are in the range of that observed in the literature (e.g. Gomme (1993), Jones, Manuelli, and Siu (2005)). In the banking sector we set the value of the fraction of goods purchased by cash to equal the inverse of the consumption velocity of money, $m/c = a$ observed in data over a well-defined period. Inflation and money growth rates are also set to their observed values.

The credit sector parameter γ is calibrated using financial industry data. It should be noted that the Cobb-Douglas function implies a decentralized bank sector profit of $Rq\,(1-\gamma)$: since R is the unit credit equilibrium price (equal to the real wage divided by the marginal product of labor in credit production, or the marginal cost), profit equals $Rq - wfh$ subject to $q = A_F\,(fh)^{\gamma}\,d^{1-\gamma}$; by the CRS technology property, $\gamma Rq = wfh$; so $Rq(1-\gamma)$ is profit returned to the consumer (interest dividend on deposits); and γRq is the resource cost of the credit. Per unit of credit this is γR, so γ is the per unit cost of credit divided by R. Now, since credit is given by $q = c - m$, and $m = ac$, then $q = c(1-a)$. Then γ can be termined by using the formula $\gamma = creditcost/[Rc(1-a)]$. The annual exchange credit cost for a single person can be approximated for example with the annual price of an exchange credit card.

The parameters of the shock structure (the persistence Φ_Z and the variance-covariance Σ) are chosen in a different way from the literature: The business cycle literature usually sets the persistence and the volatility of productivity shocks such that the second moments of the model's simulated output match the values observed in data, while money supply parameters are directly estimated from data. While the models of next two chapters are still calibrated in this way, chapters 4-6 apply a different method, according to the following steps:

1. Shocks are derived from real data as described in the next section

2. The parameter structure of the shocks is directly estimated from the shock series, by estimating the system of equations (1.1) with the method of seemingly unrelated regressions (SUR)

3. The estimated parameters are fed back into the model and the model is solved again with the new parameter set.

4. Shocks are re-constructed from the new model.

This iterative process continues until convergence is achieved in the parameter structures.

Solution of the model

The first order conditions of the competitive equilibrium together with the resource constraints imply a set of equilibrium conditions. Solving the model means finding the set of policy functions that describe the competitive equilibrium.

In order to put the problem into a form for which standard solution techniques can be applied, the model need to be transformed into a stationary form. Growing real variables are normalized by the stock of human capital h_t so that all variables in the deterministic version of the model converge to a constant steady state. We define $\tilde{c} \equiv c/h$, $\tilde{\imath} \equiv i/h$, $\tilde{k} \equiv k/h$, $\tilde{m} \equiv M/Ph$ and $\tilde{s} \equiv (\tilde{k}, 1, 1, z, u, v)$, by $\tilde{}$ denoting the stationary (normalized) counterpart of a variable. The transformed model is then log-linearized around the steady state and then written in terms of percentage deviations (log-deviations) from the steady state (denoted by $\hat{}$ such that $\hat{x} = \frac{x - x_{ss}}{x_{ss}} \simeq \log(x) - \log(x_{ss})$). The resulting system of stochastic linear equation is solved by using standard techniques, described for example in Uhlig (1995).

By stacking the linear policy functions, the solution of the model can be written in matrix form, each variable being a linear function of the state $(\widehat{\tilde{k}}, z, u, v)$:

$$X_t = A \left[\begin{array}{c} \widehat{\tilde{k}}_t \end{array} \right] + B \left[\begin{array}{ccc} z_t & u_t & v_t \end{array} \right]', \tag{1.16}$$

where $X = \left[\begin{array}{cccccccccc} \widehat{\tilde{c}} & \hat{x} & \hat{l} & \hat{n} & \hat{f} & \hat{s}_G & \hat{a} & \hat{\pi} & \widehat{\tilde{m}} & \widehat{\tilde{k}}' \end{array} \right]'$,while A and B are matrices whose values depend on the model's parameters.

1.2 Identification of shocks

The linear solution of the model can be written in matrix form as in equation (1.16). From here one can construct the solution of any variable of the model, by forming the appropriate linear combination of the appropriate rows of (1.16), the linear combinations being given by the linearized versions of equations (1.3)-(1.13).

Given the model solution (1.16) (that is, knowing the value of matrices A and B), the series of shocks $\left[\begin{array}{ccc} z_t & u_t & v_t \end{array} \right]$ can be constructed by using data on X_t and $\widehat{\tilde{k}}_t$ and "solving" the system of linear equations (1.16). Alternatively, one may also use external information on some of the shocks, and solve the system only for the remaining unknown shocks.

It can be easily seen that in order to identify n series of shocks we need data on at least n variables from X_t and external information on $m-n$ shocks, where m is the number of total shocks in the system. For example, in a three-shocks three-variable case ($m = n = 3$) the shocks represent the solution of a system of three linear equations, while if we used external information on one shock ($m = 3$, $n = 2$) then one would end up with a system of two linear equations. If more that n variables are used, then the shocks are "overidentified" as we have more equations than unknowns. Ingram, Kocherlakota, and Savin (1994) term such model as "singular" and argue that it is impossible to identify the shocks in such a model where there are more endogenous variables than shocks. While this is true, we overcome this problem by applying a minimum squared distance procedure as illustrated below. This amounts to finding the shock series that fit best the data (although with errors) by minimizing the deviations.

In the procedure of constructing the shocks, we employ the variables on which we were able to find reliable data. We construct stationary variables c/y, i/y and m/y, and on which we use data to construct the shocks. We also use data on inflation, labor hour in banking sector f. and on the wage rate in banking - the latter series being used as a proxy for the marginal product of labor in banking (*mplb*).

The data series on $\widehat{\tilde{k}}$ is constructed by using for k the capital accumulation equation (1.5), data on investment to compute $\widehat{\tilde{\imath}}_t$ and the initial condition $\widehat{\tilde{k}}_{-1} = 0$. Regarding human capital, however, there is a lack of good estimates, especially for longer time horizons, and especially for Central and Eastern European countries. For the US Jorgenson and Stiroh (2000) published annual estimates for the period 1959-1998, estimates that actually show a rather smooth trend. Using this series as a stating point, we constructed our human capital series by interpolating this annual data into quarterly frequencies, and also by extrapolating its trend to the years that have not been covered initially by Jorgenson. For Central and Eastern European countries, in the absence of any human capital estimates a smooth trendhas been used in the place of human capital.

Having the data series on $\widehat{\tilde{k}}$, $\widehat{c/y}$, $\widehat{i/y}$, $\widehat{m/y}$, $\hat{\pi}$, $\hat{f}$ and $\widehat{mplb}$, we set up a system of linear equations:

$$\mathbb{X}_t = \mathbb{A} \left[\begin{array}{c} \widehat{\tilde{k}}_t \end{array} \right] + \mathbb{B} \left[\begin{array}{ccc} z_t & u_t & v_t \end{array} \right]', \tag{1.17}$$

where $\mathbb{X} = \left[\begin{array}{cccccc} \widehat{c/y} & \widehat{i/y} & \widehat{m/y} & \hat{\pi} & \hat{f} & \widehat{mplb} \end{array} \right]'$ and the rows of the matrices $\mathbb{A}$ and $\mathbb{B}$ result from the linear combinations of the corresponding rows of matrices A and B, the appropriate linear combinations being given by the linear equations that define the variables from $\mathbb{X}$ as functions of the variables from X. The marginal product of labor in banking, is derived from equation (1.9), while the definition of the other terms of the matrix $\mathbb{X}$ is straightforward.

The minimum squared distance estimates, given that we estimate jointly all the three shocks ($m = n = 3$), are computed as follows:

$$est \left[\begin{array}{ccc} z_t & u_t & v_t \end{array} \right]'_t = (\mathbb{B}'\mathbb{B})^{-1}\mathbb{B}'(\mathbb{X}_t - \mathbb{A} \left[\begin{array}{c} \widehat{\tilde{k}}_t \end{array} \right]). \tag{1.18}$$

Another option is – as mentioned above – to use external information to estimate some of the shocks separately. For instance, it is possible to construct separately the money shock series by recovering money shocks (u_t) from equation (1.14) by using M1 data, and then estimate jointly the productivity and credit shocks ($m = 3, n = 2$ case). For this purpose equation (1.17) is written in the form

$$\mathbb{X}_t = \mathbb{A} \left[\begin{array}{c} \widehat{\tilde{k}}_t \end{array} \right] + \mathbb{B}_1 \left[\begin{array}{cc} z_t & v_t \end{array} \right]' + \mathbb{B}_2 \left[\begin{array}{c} u_t \end{array} \right]', \tag{1.19}$$

where matrix $\mathbb{B}$ is split into $\mathbb{B} = \left[\begin{array}{cc} \mathbb{B}_1 & \mathbb{B}_2 \end{array} \right]$. Then the estimates of the z_t and v_t shocks are given by

$$est \begin{bmatrix} z_t & v_t \end{bmatrix}_t' = (\mathbb{B}_1'\mathbb{B}_1)^{-1}\mathbb{B}_1'(\mathbb{X}_t - \mathbb{A} \begin{bmatrix} \widehat{\widetilde{k}}_t & -\mathbb{B}_2 \begin{bmatrix} u_t \end{bmatrix}' \end{bmatrix}). \tag{1.20}$$

This approach uses six variables to construct the economy's three shocks (the size of $\mathbb{X}$ is six), and the model setup is subject to the critique formulated by Ingram, Kocherlakota, and Savin (1994), who claim that such model is "singular" and it is impossible to identify uniquely the shocks. Indeed, depending on the choice of the variables in matrix $\mathbb{X}$, there are many different ways to construct the shocks However, to test for the robustness of the process of shock construction, we repeated the computation by using all the possible combinations combinations of the six variables taken five at a time, six variables taken four at a time, and six taken three at a time, allowing for thirty-one more possible ways to construct the shocks. Empirical results indicate that all combinations that include both real, nominal and banking variables generate nearly the same shock series, while other combinations show more randomness and lack of conformity. Thus the results proved to be empirically robust as long as all the variables are included that correspond to the model's three sectors in which the three shocks occur.

1.3 Variance decomposition

The role of various shocks in explaining fluctuations can be seen by decomposing the variance of the variable in question. We decompose the fluctuations in GDP growth, money velocity and inflation along two dimensions: First, we show how much of the total variance is explained within each subperiod by each of the shocks, the productivity (PR), money (M) and credit (CR) shocks. Second, we further decompose the variance based on frequencies, across various subperiods, and by shock.

By shocks

The decomposition of the variance by shocks is based on the principle described in Ingram, Kocherlakota, and Savin (1994), and has been done as follows: Let z, v and u be the three, possibly correlated shocks. Let's assume the ordering z-v-u, that is, the movements in z are responsible for any comovements between z and v or z and u, and that movements in v are responsible for any comovements between v and u. We can formalize this notion by defining v_t^e to be the residuals in a regression of v_t on the vector $(z_t, ..., z_{t-s})$ and u_t^e to be the residuals in a regression of u_t on the vector $(z_t, ..., z_{t-s}, v_t, ..., v_{t-s})$. Thus we interpret v_t^e as capturing the movements of v that are not associated with current, future, or past movements in z.

Given this particular ordering, consider the decomposition of the variance of GDP growth ($\dot{\triangle} y_t$) into the components due to the various shocks that is obtained by running the regression:

$$\dot{\triangle} y_t = \underbrace{\sum_{s=0}^{S} \beta_{z,s} z_{t-s}}_{\dot{\triangle} y_t^z} + \underbrace{\sum_{s=0}^{S} \beta_{v,s} v_{t-s}^e}_{\dot{\triangle} y_t^v} + \underbrace{\sum_{s=0}^{S} \beta_{u,s} u_{t-s}^e}_{\dot{\triangle} y_t^u} + \varepsilon_t \tag{1.21}$$

Then the fraction of the variance of $\dot{\triangle} y_t$ explained by each shock is given by: $P^z = \frac{Var(\dot{\triangle} y_t^z)}{Var(\dot{\triangle} y_t)}$, $P^v = \frac{Var(\dot{\triangle} y_t^v)}{Var(\dot{\triangle} y_t)}$, $P^u = \frac{Var(\dot{\triangle} y_t^u)}{Var(\dot{\triangle} y_t)}$. A similar regression to that of (1.21) is run on velocity and inflation and the same shocks to determine its variance decomposition.

It is important to emphasize that unless the shocks z, v and u are orthogonal to each other, the results are sensitive to the ordering adopted. Ingram, Kocherlakota, and Savin (1994) also argue that if the shocks are not orthogonal to each other, then it is impossible to determine exactly the proportion of variance explained by each shock. Should this be the case, this method typically assigns too much variance to the shock ordered first and possibly too little variance to the shock ordered last. To mitigate this problem, we considered all the six possible orderings of the shocks, and then computed the average of the fractions of variance explained by each shock. This way we formed an average of the fractions, computed where each shock has been ordered twice first, twice second and twice last.

By Spectral Frequency

A second step in the analysis is to decompose the variance of the GDP growth, velocity and inflation along another dimension and to show the amount of variance that takes place at short run, business cycle and long run frequencies. Frequencies are defined as in Levy and Dezhbakhsh (2003): the short-run (SR) frequency band corresponds to cycles of 2-3 years, the business cycle (BC) frequency band to cycles of 3-8 years, and the long-run (LR) band to cycles of 8 years and longer.

The proportion of variance of a series due to SR, BC and LR components can be obtained as in Levy and Dezhbakhsh (2003): it amounts to estimating the spectral density of the series, normalizing it by the series variance, and then computing its integral over the corresponding frequency band. If we denote by $f(\omega)$ the spectral density of the series and by σ^2 its variance, then the fraction of variance due to each frequency component is given by

$$H^{SR} = \int_{2\pi/3}^{2\pi/2} f(\omega)/\sigma^2 d\omega, \tag{1.22}$$

$$H^{BC} = \int_{2\pi/8}^{2\pi/3} f(\omega)/\sigma^2 d\omega, \tag{1.23}$$

and

$$H^{LR} = \int_{2\pi/\infty}^{2\pi/8} f(\omega)/\sigma^2 d\omega. \tag{1.24}$$

The frequency bands are determined by the mapping $\omega = 2\pi/p$, where p measures the cycle length (2, 3 or 8 years).

An alternative, equivalent measure for the fractions of variance (suggested also by Levy and Dezhbakhsh (2003)) can also be used. This consists of passing the series through a band-pass filter, estimating the variance of the filtered series and relating it to the variance of the original series. Here the Christiano and Fitzgerald (2003) asymmetric band-pass filter is employed with the aforementioned 2-3, 3-8 and >8 year bands. The asymmetric filter is prefered because it avoids the loss of observations at the end of the samples, which is especially important when we deal with short saples, or when a longer sample is split into shorter subsamples. The other options, the Baxter and King (1999) band-pass filter and the fixed-length symmetric Christiano-Fitzgerald filter would cause severe losses of leads and lags, especially when annual data is analysed.

To assess the fraction of variance explained by each shock in turn at each frequency, we decompose each of the frequency components further, by shocks. The variance decomposition procedure is similar to that described in equation (1.21). The difference consists in pre-filtering the target series and the shock series to extract the adequate frequency component. According to this, the Christiano-Fitzgerald asymmetric band-pass filter with the 2-3, 3-8 and >8 year bands is applied to the output growth, iflation and velocity series, as well as to the productivity, money and credit shock series.

Chapter 2

A Comparison of Exchange Economies within a Monetary Business Cycle

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2.1 Introduction

The contribution of monetary factors to business cycle movements has been studied using the cash-in-advance approach in Cooley and Hansen (1989a), Cooley and Hansen (1995) and Cooley and Hansen (1998), and the shopping time model of Gavin and Kydland (1999). They identify puzzles left unexplained, and how different modeling features help in some areas but not in others. With nominal rigidities, such as in Ohanian, Stockman, and Kilian (1995), the monetary business cycle models can explain features typically associated with a liquidity effect. But imposing such rigidities eliminates the model's ability to generate important inflation tax effects, such as the procyclic movement of labor. This creates a conundrum in which choices have to be made through model selection as to whether inflation tax or liquidity effects are more important to include.

Recent work has brought a rudimentary liquidity effect into otherwise standard exchange-based economies without imposing nominal rigidities. Schabert and Bruckner (2002) establishes special conditions under which there is a liquidity effect in a cash-in-advance economy. Li (2000) expands the cash-in-advance approach by including the production of credit as an alternative to cash for exchange, and then introduces a liquidity effect by requiring that cash injections go through the financial intermediary producing the credit. Schabert and Bruckner (2002) uses a related device for a liquidity effect. These results on a liquidity effect are under special conditions, such are requiring the money injection to be unexpected, but nonetheless show the promise of establishing a broader liquidity effect by requiring the model's cash injection each period (reserves) to go initially to the financial intermediary rather than directly to the agent as in the standard exchange economies now in widespread use.

The approach of extending the cash-in-advance economy by allowing for the production of credit as an alternative to credit has found success in other directions, including the modelling of the velocity of Base, M1, and M2 monetary aggregates (Gillman and Kejak 2004), the explanation of the effect of inflation on growth (Gillman and Kejak 2005) and the specification of a role for financial development within the inflation-growth nexus (Gillman, Harris, and Matyas 2004) and (Gillman and Harris 2004). Using the credit production technology also has shown promise in explaining output movements over the business cycle (Benk, Gillman, and Kejak 2004).

The paper here applies the credit production approach to the business cycle in order to compare this exchange technology extension. By using a financial intermediation that is the same as that found in Li (2000), the approach is consistent with the goal of incorporating a liquidity effect. This is compared to the main alternative standard exchange economies, cash-in-advance and shopping time, which are inflation tax models without a liquidity effect. The device for making the comparison is a novel nested model of the three exchange approaches. The comparison contributes the results that the credit production approach does improve on several margins the ability of the inflation tax models to explain business cycle movements. And these improvements make sense intuitively in that they are related to the addition of another margin, relative to the standard cash-in-advance economy, while bringing into play the a refined version of the margin that is included implicitly in the shopping time approach.

The margin included by the credit approach represents the ability of the agent to tradeoff using cash or credit in exchange, depending on relative costs. Shopping time approaches specify a general transactions cost that induces a margin between using money or time in exchange, and this is can be described as a broad brush approach that the credit approach refines. A distinct advantage of the credit approach relative to shopping time is that credit technology can be shocked in the credit production approach, and calibrated using data from the bank sector, while such a shock to the shopping time is more awkward in its rationale and has not been attempted. In contrast the credit shock in a credit production approach has been identified robustly and shown to explain specific shocks caused by financial deregulation (Benk, Gillman, and Kejak 2005b).

The improvements established in this paper for explaining business cycles rely on the existence of a credit shock. In particular they allow the business model to explain the procyclic movement of inflation at certain times, which the standard models cannot. The intuition of the result is straightforward. When there is a sudden improvement in the productivity of the credit sector, more credit is used relative to cash in exchange since the credit becomes suddenly less expensive. The money supply growth rate has not changed, so the money demand suddenly falls relative to the supply and the inflation rate jumps. Thus, for example, during the financial deregulation of the 1980s in the US and UK, the inflation rate would have been pulsed upwards even while the trend in the inflation rate started to fall. This type of component of the business cycle movements is captured with the credit approach but not the shopping time or standard cash-in-advance models. With an entire era of financial deregulation, such effects can build up, as evidenced in Benk, Gillman, and Kejak (2005b), and be a significant part of business cycle movements.

The paper thus is able to argue that the credit production approach is an extension that, based in microfoundations which allow for calibration, improves the performance of the business cycle model while being consistent with the platform being developed for introducing the liquidity effect into neoclassical business cycle models. The contribution represents an intermediate step towards establishing a fully functional general equilibrium business cycle model that can account for important changes occuring in banking, while capturing both inflation tax and, ultimately, liquidity effect features.

2.2 Exchange-based Business Cycle Models

Three representative agent models are examined, the standard cash-in-advance, a shopping time economy, and the credit production economy. Here a nested model of the three economies is presented. With utility over consumption c_t and leisure x_t given by

$$U = E_0 \sum_{t=0}^{\infty} \beta^t (\log c_t + \Psi \log x_t), \qquad 0 < \beta < 1, \tag{2.1}$$

the consumer faces a minimum of two shocks in all three models: an aggregate output productivity shock, and a money supply growth rate shock. The third shock introduced in the credit economy is to the productivity of credit production.

Current investment i_t plus the depreciated capital from the last period comprise the current capital stock k_t;

$$k_t = (1 - \delta) k_{t-1} + i_t. \tag{2.2}$$

Output y_t is produced by the agent with the previous period capital stock k_{t-1} and current labor n_t via a Cobb-Douglas CRS production function with the productivity shock z_t:

$$y_t = e^{z_t} k_{t-1}^{\alpha} n_t^{1-\alpha}, \tag{2.3}$$

$$z_t = \varphi_z z_{t-1} + \epsilon_{zt}, \qquad \epsilon_{zt} \sim N(0, \sigma_z^2), \quad 0 < \varphi_z < 1. \tag{2.4}$$

Firms maximize their profits $y_t - r_t k_{t-1} - w_t n_t + (1 - \delta) k_{t-1}$, implying the equilibrium real wage rate w_t and the real gross capital rate of return net of depreciation δ, or r_t;

$$w_t = (1 - \alpha) e^{z_t} k_{t-1}^{\alpha} n_t^{-\alpha}, \tag{2.5}$$

$$r_t = \alpha e^{z_t} k_{t-1}^{\alpha-1} n_t^{1-\alpha} + 1 - \delta. \tag{2.6}$$

Current income from labor, capital, and lump-sum transfers of new money T_t are spent on consumption c_t and capital, yielding the change in money stock $M_t - M_{t-1}$. With P_t the nominal price of the consumption good, this gives the period t budget constraint as

$$w_t P_t (1 - x_t - l_{Ft}) + P_t r_t k_{t-1} + T_t - P_t c_t - P_t k_t \geq M_t - M_{t-1}. \tag{2.7}$$

The money supply is subject to shocks. The sequence of nominal transfers satisfy

$$T_t = \Theta_t M_{t-1} = (\Theta^* + e^{u_t} - 1) M_{t-1}, \tag{2.8}$$

where Θ_t is the growth rate of money and Θ^* is the stationary growth rate of money. Shocks to the growth rate of money enter through the e^{u_t} term, where

$$u_t = \varphi_u u_{t-1} + \epsilon_{ut}, \qquad \epsilon_{ut} \ N(0, \sigma_u^2), \quad 0 < \varphi_u < 1. \tag{2.9}$$

The other resource constraint allocates the total time endowment amongst leisure, labor hours in producing the aggregate output, and time spent in exchange activity, denoted by l_{Ft};

$$n_t + x_t + l_{Ft} = 1. \tag{2.10}$$

2.2.1 Exchange

An extended cash-in-advance constraint is specified so that it encompasses three alternative exchange technologies. The general form is

$$M_{t-1} + T_t \geq P_t c_t [B_1 - B_2 c_t^{b_1} \widetilde{A}_{Ft} l_{Ft}^{b_2}], \tag{2.11}$$

where B_1, B_2, b_1, and b_2, are parameters, and $\widetilde{A}_{Ft}$ a variable, specified in the following special cases. The intuition of this generalization is that the second term in brackets shows approximately the amount being purchased without money (this is exact if $B_1 = 1$).

Cash-only

For the standard cash-in-advance economy that uses only cash, let $B_1 = 1$ and $\widetilde{A}_{Ft} = 0$.

Shopping Time

The shopping time case assumes that $\widetilde{A}_{Ft} = 0.0034$, $B_1 = 0$, $B_2 = -1$, $b_1 = 0$, and $b_2 = -1$. This implies that $l_{Ft} = 0.0034 \left(\frac{c_t}{M_t/P_t} \right)$ and this gives the more general form of $l_{Ft} = f\left(c_t, \frac{M_t}{P_t}\right)$ with the particular specification as found in Gavin and Kydland (1999). This specification is justified there and in Lucas (2000) as yielding a constant interest elasticity of money demand equal to -0.5.

Notice that here time in exchange activity is proportional to the consumption velocity of money. And this implies a unitary elasticity of exchange time with respect to velocity; $(\partial l_{Ft}/\partial V_t)\ (V_t/l_{Ft}) = 1$ where $V_t \equiv c_t/(M_t/P_t)$. Or if the elasticity is defined in terms of the ratio of exchange time to consumption, where $\eta \equiv (\partial [l_{Ft}/c_t]/\partial V_t)\ (V_t/[l_{Ft}/c_t])$, then again $\eta = 1$.

Credit production

Here $\widetilde{A}_{Ft} = A_F e^{v_t}$, $B_1 = 1$, $B_2 = 1$, $b_1 = -\gamma$, and $b_2 = \gamma$, where $\gamma = 0.21$, $A_F > 0$, and v_t is a shock that follows an autoregressive process;

$$v_t = \varphi_v v_{t-1} + \epsilon_{vt}, \qquad \epsilon_{vt} \sim N(0, \sigma_v^2), \quad 0 < \varphi_v < 1. \tag{2.12}$$

This is parallel to the specification of the aggregate ouput productivity shock above, except that this is a sectoral productivity shock to credit production. To see this, note that with $a_t \in (0, 1]$ denoting the fraction of consumption goods that are purchased with money, and with $c_t(1-a_t)$ the total amount of goods purchased with credit, then $c_t(1-a_t) = A_F e^{v_t}\left(\frac{l_{Ft}}{c_t}\right)^{\gamma} c_t$ is the production function of the quantity of the total credit used. Its features a diminishing marginal product of labor, normalized by consumption, where the degree of diminishing returns depends on the parameter γ. Note that $\gamma = 0.21$ is found in Gillman and Otto (2003) from the time series estimation of US money demand, as derived from a similar credit production. A value of γ between 0 and 0.5 results in a marginal cost of credit production that is upward sloping and convex, as in the right-hand side of a stand U-shaped marginal cost curve, see Gillman and Kejak (2005).

Note that here the exchange time is not proportional to the consumption velocity of money. And the elasticity of exchange time with respect to velocity is much larger. In particular, $\eta = (\partial[l_{Ft}/c_t]/\partial V_t)\ (V_t/[l_{Ft}/c_t]) = (1/\gamma)(1/[v-1])$. If, for example, $v = 1$ then $\eta \simeq 5$. This means that the exchange time relative to consumption rises much more than proportionally with increases in the velocity. And this is just a standard feature of the production function, that as output rises the labor time ratio can rise by much more. To see this, consider a standard Cobb-Douglas production function of some output, say Y, that depends on some labor quantity L and capital K, as in $Y = L^{\gamma}K^{1-\gamma}$. Then the elasticity of the ratio of labor to capital with respect to the ratio of capital to output, denoted by $\widetilde{\eta}$, is a direct compasion to the η labor elasticity of velocity as defined above; this elasticity is given by $\widetilde{\eta} = 1/\gamma$. With $\gamma = 0.21$, $\widetilde{\eta} \simeq 5$, just as with η when $v = 1$. Thus it is a natural consequence of the exchange production approach to have a more highly elastic time usage.

A related way to summarize the differences amongst the three alternative models in the steady state can be summarized in terms of the interest elasticity of money demand. The cash-only model has a very sluggish interest elasticity of money that rises slightly in magnitude as the inflation rate goes up; it does not allows for exchange time to be used as an alternative to money; and therefore the consumer has no alternative by which to buy goods and only slightly substitutes away from money as inflation rises. The shopping time model has a constant interest elasticity similar to Baumol's model; this can be said to be the result of its assumption of a unitary time elasticity with respect to velocity. And the credit, or banking time, model produces an interest elasticity that rises in magnitude with the inflation rate in a way very similar to the Cagan (1956) model[1]; this is a result of using a standard production function.

2.2.2 Equilibrium

The consumer's exchange constraint can alternatively be written in the nested model as

$$M_{t-1} + T_t \geq a_t P_t c_t, \tag{2.13}$$

where

$$\begin{aligned} a_t &= 1, \tilde{\ } cash-only; \\ &= 1/(0.0034 l_{Ft}), \tilde{\ } shopping-time; \\ &= 1 - A_F e^{v_t}\left(\frac{l_{Ft}}{c_t}\right)^{0.21}, \tilde{\ } credit-production. \end{aligned} \tag{2.14}$$

[1]See Gillman and Kejak (2002).

Or, expressed in terms of l_{Ft}, in each of these cases, gives that

$$\begin{aligned} l_{Ft} &= 0, \tilde{}cash-only; \\ &= 1/(0.0034a_t), \tilde{}shopping-time; \\ &= [(1-a_t)/(A_{Ft}e^{vt})]^{1/0.21}c_t, \tilde{}credit-production. \end{aligned} \tag{2.15}$$

This formulation summarizes the nested model developed above and is convenient for defining the equilibrium and for calibration

The consumer chooses consumption, leisure, capital stock, the fraction goods bought with money, and the real money balances over time, $\{c_t, x_t, k_t, a_t, M_t\}_{t=0}^{\infty}$, to maximize lifetime utility (2.1) subject to the budget constraint (2.7), the cash-in-advance constraint (2.13), and the exchange technology given in equation (2.15) for the three cases:

$$\begin{aligned} L = E\sum_{t=0}^{\infty}\beta^t\{&(\log c_t + \Psi \log x_t) \\ &+ \lambda_t\left[\frac{M_{t-1}+T_t}{P_t} - a_t c_t\right] \\ &+ \mu_t\left[w_t\left(1-x_t-l_{Ft}\right) + r_t k_{t-1} + \frac{M_{t-1}+T_t}{P_t} - c_t - k_t - \frac{M_t}{P_t}\right]\}. \end{aligned} \tag{2.16}$$

A competitive equilibrium for this economy consists of a set of allocations $\{c_t, x_t, l_t, n_t, k_t, a_t, M_t\}_{t=0}^{\infty}$, a set of prices $\{w_t, r_t\}_{t=0}^{\infty}$, exogenous shock processes $\{z_t, v_t, u_t\}_{t=0}^{\infty}$, money supply process and initial conditions k_{-1} and M_{-1} such that given the prices, shocks and government transfers, the allocations solve the consumer's utility maximization problem, solve the firm's profit maximization problem and the goods and labor and money markets clear.

In a stationary deterministic steady state we use the transformation $p_t = \frac{Pt}{Mt}$ (and also denote real money balances by $m_t = \frac{M_t}{P_t}$). There is no uncertainty and time indices can be dropped, denoting by $(*)$ the steady state values and by $R^* = r^*(\Theta^* + 1)$ the steady state interest factor.

2.2.3 Log-linearization and Calibration

The first-order conditions and log-linearization of the model, following Uhlig (1995), is presented in the appendix. This uses the first-order Taylor approximation of the log variables around the steady state and replaces all equations by approximations which are linear functions in the log-deviations of the variables. For example the variable x_t is replaced with $x_t = x^*(1+\hat{x}_t)$, where $\hat{x}_t$ is the percentage deviation (log-deviation) from the steady state, or $\tilde{x}_t \approx d\log x_t$, and x^* is the steady state value of the variable x_t.

The calibration follows the standard by using values that are accepted in the literature.[2] The table in Appendix 2.A.2 presents the values used in all three models.

Figures 2.1, 2.4, 2.2, 2.5, 2.3, 2.6 and 2.7 show the impulse responses for the three models, the cash-only, shopping time, and credit. The first two have just the goods productivity and money shocks, the third in addition has the credit productivity shock.

[2] See the working paper by Benk, Gillman, and Kejak (2004) for calibration references.

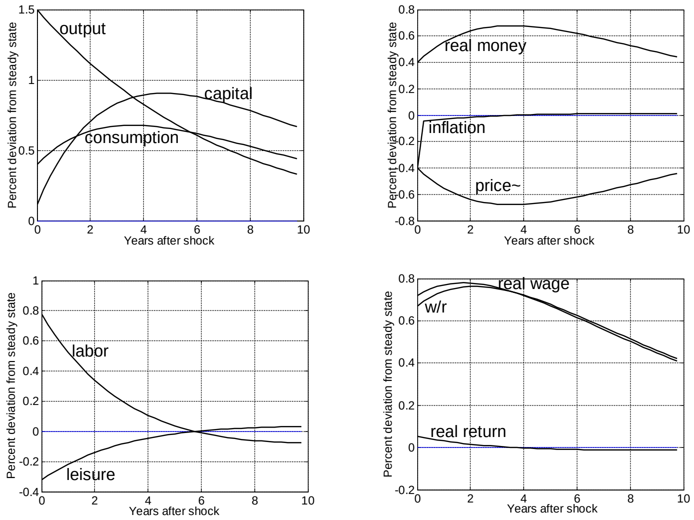

Figure 2.1: Impulse responses to 1 percent productivity shock, Cash-in-Advance model

2.2.4 Goods Productivity Shock

Across the three models, Figures 2.1, 2.2 and 2.3 show that a positive goods productivity shock causes more output, consumption, capital, labor, real wages, real interest and real money, and lower leisure and prices. Shopping time falls slightly while banking time falls a lot, as labor time is more valuable.

2.2.5 Money Shock

Across the three models, a positive shock to the nominal money supply growth rate causes an increase in capital, real wages and prices, and a decrease in output, consumption, labor, the real interest rate and real money. Leisure falls in the shopping time model while increasing in the cash-only and credit models. At the same time, the exchange time in the credit model rises by some ten fold more than the shopping time. Also consumption falls strongly in the cash-only model, less so in the credit model, and hardly at all in the shopping time model. The cash-only and credit models show the typical goods to leisure substitution, but the shopping time model does not. This can be interpreted as the shopping time model having "too much" substitution towards exchange time at low inflation rates, because of the constant -0.5 interest elasticity of money; the credit model in contrast has a near zero interest elasticity of money at very low inflation rates. The credit model's inelastic money demand at low inflation rates causes more substitution from goods to leisure.[3]

[3] See for example Lucas (2000) for a discussion on use of the constant interest elasticity function versus the constant semi-interest elasticity (Cagan, 1956) function at low inflation rates.

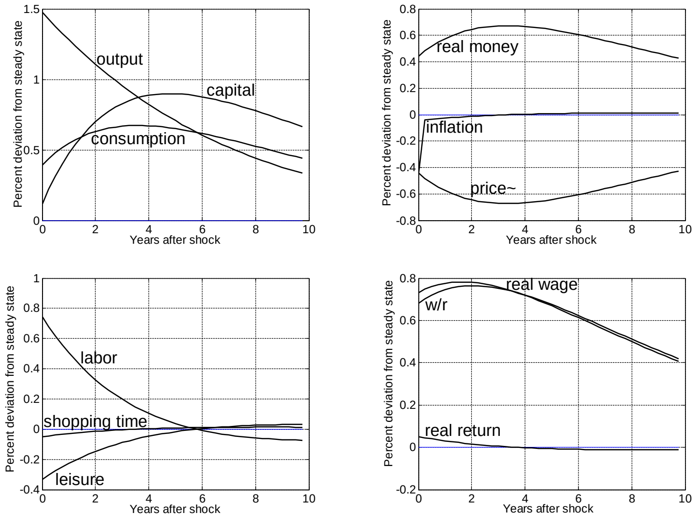

Figure 2.2: Impulse responses to 1 percent productivity shock, Shopping time model

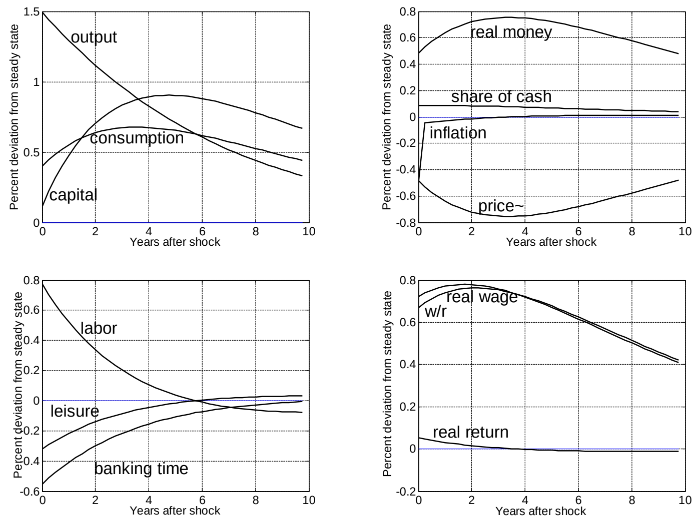

Figure 2.3: Impulse responses to 1 percent productivity shock; Credit model

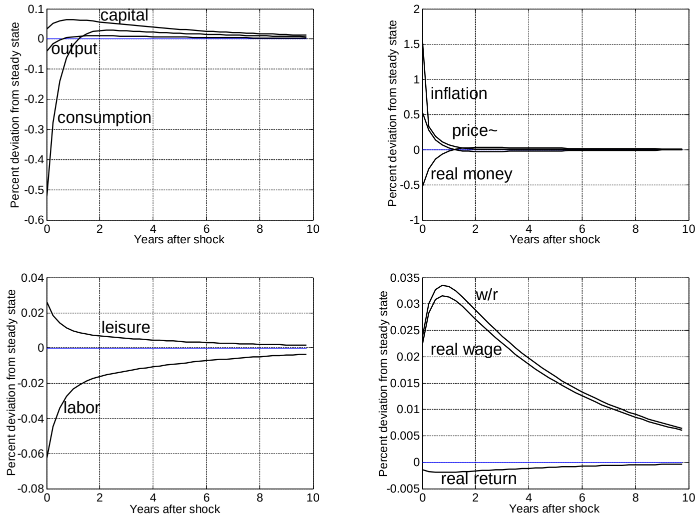

Figure 2.4: Impulse responses to percent money shock, Cash-in-Advance model

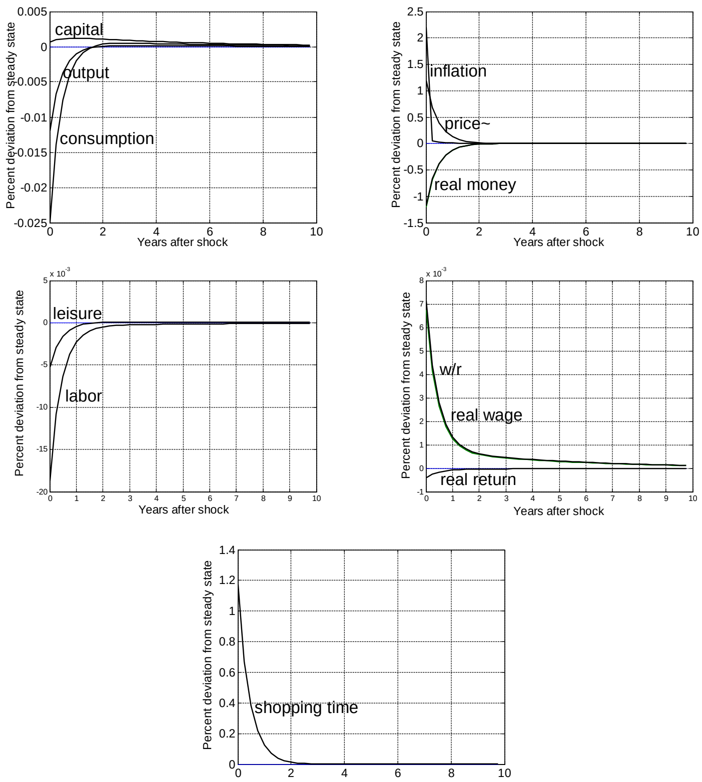

Figure 2.5: Impulse responses to 1 percent money shock, Shopping time model

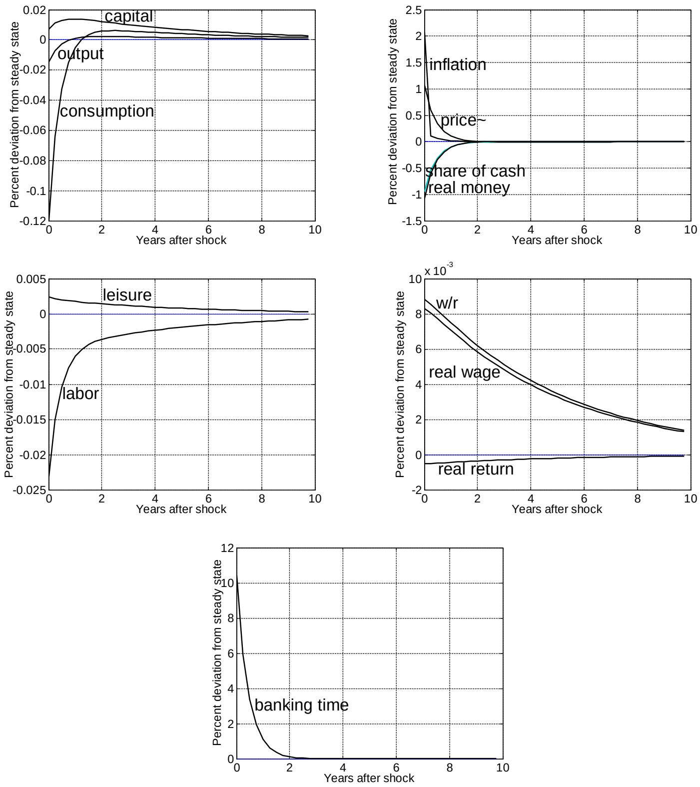

Figure 2.6: Impulse responses to 1 percent money supply shock; Credit model

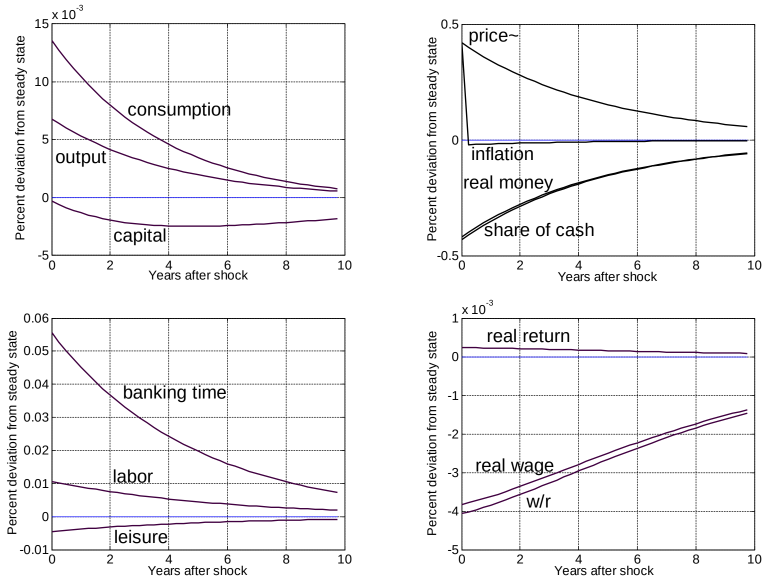

Figure 2.7: Impulse responses to 1 percent credit productivity shock

2.2.6 Credit Productivity Shock

The third shock appears only in the credit model, giving it potentially more explanatory power through this additional dimension. Here the key difference, with a positive credit productivity shock, is that while consumption and output rise, so do prices. In comparison, for a money shock, consumption and ouput fall as prices rise, in all three models. This is the reason why the addtional shock allows for a better explanation of procyclic inflation. And this feature makes sense: an increase in credit productivity during say financial deregulation causes more banking and less money use, with the same money supply growth rate; thus more inflation. If the credit shock also leads to a positive GDP impulse, then inflation moves up at the same time as GDP. This is a feature found in US postwar data, and as elaborated upon next, the impulse responses show that neither the goods productivity or the money shock yield such procyclic inflation.

2.3 Puzzles

Table 2.1 first sets out the actual cyclical behavior of the postwar US economy over the 1959:I -2000:IV period. This updates the facts presented in Kydland and Prescott (1995) and Cooley and Hansen (1995). It shows the standard deviations and the cross-correlations with real GDP and with M1 growth for real and nominal variables.

2.3.1 Simulations

Simulations were conducted for all three models, in order to see how they perform compared to the puzzles in the literature; only the credit model simulations are presented in Table 22.2. This table presents the results of simulating the

Variable	SD %	Corr w/ M grw	Cross correlation of output with: x(-5)	x(-4)	x(-3)	x(-2)	x(-1)	x	x(+1)	x(+2)	x(+3)	x(+4)	x(+5)
Real Output	1.43%	-0.13	0.06	0.26	0.46	0.67	0.86	1.00	0.86	0.67	0.46	0.26	0.06
Consumption	1.47%	0.01	0.42	0.57	0.69	0.80	0.84	0.79	0.62	0.43	0.23	0.04	-0.13
Investment	4.77%	-0.11	0.20	0.37	0.52	0.70	0.83	0.89	0.80	0.63	0.43	0.20	-0.01
Wages	1.16%	0.18	0.43	0.53	0.57	0.60	0.58	0.45	0.29	0.14	-0.02	-0.18	-0.30
Prices (CPI)	1.22%	-0.15	-0.61	-0.68	-0.71	-0.70	-0.64	-0.51	-0.37	-0.22	-0.09	0.04	0.16
Inflation	0.42%	-0.32	-0.33	-0.25	-0.10	0.02	0.20	0.38	0.47	0.47	0.49	0.49	0.41
Money (M1)	3.98%	0.11	0.14	0.15	0.15	0.14	0.11	0.07	0.00	-0.06	-0.09	-0.12	-0.15
Real Money	3.32%	0.20	0.35	0.40	0.43	0.44	0.39	0.30	0.17	0.06	-0.04	-0.13	-0.21
Interest rate (TBill)	1.15%	-0.51	-0.61	-0.50	-0.33	-0.14	0.13	0.36	0.48	0.51	0.50	0.47	0.43
Cons. velocity	2.68%	-0.25	-0.24	-0.21	-0.17	-0.11	-0.02	0.07	0.14	0.18	0.18	0.18	0.17
Income velocity	3.27%	-0.28	-0.38	-0.34	-0.26	-0.16	-0.01	0.15	0.23	0.27	0.27	0.26	0.23

Table 2.1: Cyclical behavior of the US economy: 1959:I -2000:IV

credit model economy 50 times, each simulation being 168 periods long, to match the number of observations underlying the US statistics reported in Table 2.1. Each simulated time series is filtered with the H-P filter; the standard deviations of the key variables are reported as well as their cross-correlation with output.

A comparison with the actual cross correlations in Table 2.1 shows some noteworthy features. While the credit model does not capture the actual output correlation with banking hours, it does do rather well with the inflation rate and the nominal interest rate. The actual data shows a positive correlation of future output with inflation and nominal interest rates, and a negative correlation with lagged output with inflation and nominal interest rates. The credit model simulation shows a similar pattern although it is not exaclty in phase with actual data. For example the actual data shows a positive current output correlation, and in the simulation the correlation turns positive only with the one-period ahead output.

2.3.2 Explanation of Puzzles with Simulations Across Models

The various puzzles from Cooley and Hansen (1989a), Cooley and Hansen (1995),Cooley and Hansen (1998) and Gavin and Kydland (1999) are enumerated in Table 2.3 and 2.4, and organized into Credit, Inflation Tax, Liquidity, and Feedback categories. Columns 1-10 summarize the extent to which the three models, credit, cash-only and shopping time respectively, are able to explain puzzles when faced with productivity shocks (columns 2-4), money supply shocks (columns 5-7) and joint productivity and money shocks (columns 8-10). Columns 11-14 show when the credit shock is also active, applying only to the credit model.

First note that when subject to joint productivity and money shocks, the credit model generates the procyclic monetary aggregates and the money-output phase shift, as found in the actual data. These facts are not replicated by the two alternative models with the joint shocks. This shows some advantage of the credit model using standard shocks.

Credit shocks alone (column 11) generate procyclic monetary aggregates and income velocity as well as the phase shift between money and output, as seen in the data. This simulation also replicate the procyclic inflation and nominal interest rate, with values very close to the data. The other models cannot match the data here. Column 14 presents results of the credit model with all three shocks, as in the simulations presented in Table 2.2. Here the inflation procyclic movement with current output is lost, but as noted above the simulation still matches the correlation of inflation with one-period ahead output.

What emerges primarily from this comparison with the puzzles is that the credit shock can be important in explaining inflation movements. Put differently, when the economy is in a period during which the credit shock is important, such as banking deregulation, the procyclic inflation movement can be explained in this way.

Also notable is that it is clear that none of the three models are able to explain liquidity effects.

Variable	SD %	Corr w/ M grw	Cross correlation of output with:										
			x(-5)	x(-4)	x(-3)	x(-2)	x(-1)	x	x(+1)	x(+2)	x(+3)	x(+4)	x(+5)
Capital	0.40%	0.02	-0.45	-0.39	-0.29	-0.14	0.07	0.36	0.54	0.63	0.66	0.64	0.59
Real money	1.31%	-0.87	-0.10	-0.04	0.01	0.10	0.22	0.37	0.31	0.25	0.21	0.16	0.11
Price	2.79%	0.59	0.05	0.03	0.01	-0.03	-0.08	-0.16	-0.13	-0.11	-0.09	-0.08	-0.07
Consumption	0.47%	-0.25	-0.23	-0.12	0.03	0.24	0.51	0.86	0.73	0.60	0.48	0.37	0.26
Leisure	0.31%	0.04	-0.06	-0.18	-0.32	-0.50	-0.72	-0.98	-0.62	-0.34	-0.13	0.04	0.15
Labor	0.75%	-0.06	0.06	0.18	0.32	0.50	0.72	0.98	0.62	0.34	0.13	-0.04	-0.15
Banking time	11.02%	1.00	0.02	0.01	0.00	-0.01	-0.04	-0.06	-0.05	-0.03	-0.03	-0.02	-0.01
Share of cash	1.09%	-0.92	-0.02	0.00	0.00	0.02	0.05	0.08	0.06	0.04	0.04	0.03	0.02
Real wage	0.72%	-0.01	-0.12	0.00	0.16	0.38	0.65	0.98	0.74	0.54	0.37	0.22	0.10
Real return	0.05%	-0.04	0.10	0.21	0.35	0.52	0.72	0.96	0.59	0.29	0.07	-0.09	-0.20
Inflation	2.00%	0.84	0.00	-0.03	-0.03	-0.05	-0.08	-0.09	0.03	0.03	0.02	0.02	0.02
Output	1.44%	-0.01	-0.03	0.09	0.25	0.45	0.70	1.00	0.70	0.45	0.25	0.09	-0.03
Interest rate	2.00%	0.84	0.00	-0.02	-0.02	-0.03	-0.06	-0.07	0.05	0.04	0.02	0.02	0.02
w/r	0.68%	-0.01	-0.14	-0.02	0.15	0.36	0.63	0.97	0.75	0.55	0.39	0.24	0.12
Income velocity	1.54%	0.73	0.06	0.13	0.22	0.34	0.46	0.60	0.38	0.21	0.06	-0.05	-0.12
Cons.. velocity	1.09%	0.92	0.02	0.00	0.00	-0.02	-0.05	-0.08	-0.06	-0.04	-0.04	-0.03	-0.02
Investment	4.51%	0.09	0.04	0.15	0.30	0.49	0.71	0.99	0.65	0.38	0.17	0.00	-0.11
Money	2.33%	0.23	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.00	-0.01	-0.02
Money growth	1.06%	1.00	0.02	0.01	0.02	0.01	0.00	-0.01	-0.02	-0.01	-0.02	-0.02	-0.02

Table 2.2: Standard deviations in percent and correlations with output of the simulated economy (HP filtered series)

Facts and Puzzles	Productivity shocks			Money shocks			Prod. & money shocks			Credit model with credit shocks			
	Credit model	CIA model	SHT model	Credit model	CIA model	SHT model	Credit model	CIA model	SHT model	CR shock	PR+CR shocks	CR+M shocks	CR+PR+M shocks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
A. Credit													
1. Monetary aggregates are pro-	Yes	Yes	NO	NO	Yes	NO	Yes	NO	NO	**YES**	**YES**	NO -	Yes
cyclical (+0.07; +0.33 in CH 1995)	.55	.33	-.33	-.05	.07	-.22	.03	-.04	0	.26	.05	.05	.01
2. Phase shift in the corr. b/w output and money = lagged money is correlated with present output	NO	Yes	Yes	Yes	Yes	Yes	Yes	NO	NO	**YES**	NO	Yes	Yes
3. Positive correlation between out-	NO	NO	NO	NO	NO	NO	NO	NO	NO	**YES**	NO -	NO -	NO
put and inflation (+0.38)	-.53	-.56	-.52	-.88	-.94	-.85	-.11	-.12	-.08	.39	.39	.79	.09
4. Positive corr. b/w output and	NO	NO	NO	NO	NO	NO	NO	NO	NO	**YES**	NO -	NO -	NO
nominal interest rate (+0.35)	-.42	-.43	-.40	-.88	-.94	-.85	-.08	-.09	-.05	.39	.30	.79	.07
B. Inflation Tax													
1. Income velocity is procyclical	Yes	Yes	Yes	NO	NO	NO	Yes	Yes	Yes	Yes 1	Yes	NO -	**YES**
(+0.15)	.97	.98	.98	-.98	-.97	-1	.63	.88	.61		.90	.73	.60
2. Negative correlation between	N/A	N/A	N/A	Yes	Yes	Yes	**YES**	**YES**	Yes	N/A	N/A	Yes -	Yes
money growth and output (-0.13)				-.98	-.95	-1	-.03	-.05	-.02			.91	.04
3. Negative corr. b/w money	N/A	N/A	N/A	Yes	Yes	Yes	**YES**	**YES**	Yes	N/A	N/A	Yes -	Yes -
growth and hours (-0.15 in CH 1995)				-.98	-.95	-1	-.05	-.10	-.03			.91	.06
4. Negative corr. b/w money	N/A	N/A	N/A	Yes	Yes	Yes	Yes	Yes	**YES**	N/A	N/A	Yes -	**YES**
growth and cons. (-0.1 in CH 1998 but 0.02 in CH 1995, 0.01 here)				-1	-1	-1	-.30	-.79	-.08			.99	-.25
5. Negative correlation between	Yes	Yes	Yes	**YES**	Yes	Yes	Yes	Yes	Yes	NO 1	Yes -	Yes -	Yes -
output and prices (–0.51)	-.91	-.89	-.92	-.44	-.16	-.62	-.15	-.20	-.15		.72	.35	.16

Table 2.3: The extent to which productivity, money or credit shocks can explain the monetary puzzles

Facts and Puzzles	Productivity shocks			Money shocks			Prod. & money shocks			Credit model with credit shocks			
	Credit model	CIA model	SHT model	Credit model	CIA model	SHT model	Credit model	CIA model	SHT model	CR shock	PR+CR shocks	CR+M shocks	CR+PR+M shocks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
C. Liquidity													
1. Weak phase shift in the correlation of money growth with real variables	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Negative correlation between money growth and price level (-0.15)	N/A	N/A	N/A	NO .60	NO .44	NO .63	NO .58	NO .44	NO .63	N/A	N/A	NO .60	NO .59
3. Negative correlation between money growth and inflation (-0.32)	N/A	N/A	N/A	NO .86	NO .94	NO .84	NO .84	NO .92	NO .83	N/A	N/A	NO .83	NO .84
4. Negative correlation between money growth and nominal interest rate (liquidity effect) (-0.50)	N/A	N/A	N/A	NO .86	NO .94	NO .84	NO .85	NO .92	NO .83	N/A	N/A	NO .84	NO .84
5. Negative corr. b/w money growth and investment (-0.10)	N/A	N/A	N/A	NO 1	NO 1	NO 1	NO .05	NO .29	NO 0	N/A	N/A	NO 1	NO .09
6. Negative corr. b/w money growth and income velocity (-0.35 in CH 1998, -0.27 here)	N/A	N/A	N/A	NO 1	NO 1	NO 1	NO .75	NO .43	NO .78	N/A	N/A	NO .93	NO .73
D. Feedback													
1. Much higher money variance than price variance, 3.98% vs. 1.22	NO	NO	NO	NO 2.27% vs. 2.76	NO 2.24% vs. 2.39%	NO 2.22% vs. 2.80%	NO 2.27% vs. 2.79%	NO 2.27% vs. 2.47%	NO 2.28% vs. 2.88%	NO	NO	**YES** 0.32% vs. 0.30%	NO 2.23% vs. 2.79%

Table 2.4: The extent to which productivity, money or credit shocks can explain the monetary puzzles (cont'd)

2.4 Discussion

The impulse responses show that the shopping time model has some differences such as its leisure decrease when the money supply growth rate is shocked upwards. This feature is not found in the other two models and it appears to be related to the assumption of its exchange time moving proportionally with velocity. This may create some lessor performance of the shopping time model to explain some of the inflation tax puzzles. For example the credit model with goods productivity and money shocks seems better at explaining procyclic monetary aggregates.

However the performance differences amongst the three models are somewhat marginal in comparison to the advantage of having the additional credit shock in the credit model. This gives the procyclic inflation rate movements found in the data. Of course a type of shopping time shock could be added to the shopping time framework, but this lacks intuition and has not appeared in the literature. Thus the noticeable advantage of the credit model in terms of the puzzles is this additional shock and its unique ability to capture some of the substitution away from money use during important financial sector innovation periods. Benk, Gillman, and Kejak (2005b) show that such credit shocks could be identified and associated with the specific US banking deregulatory acts that occured in the 1980s and 1990s.

Liquidity effects are another matter. Cooley and Hansen (1995) and Cooley and Hansen (1998) use a Lucas and Stokey (1987) cash-good/credit-good exchange technology instead of the simpler cash-only one found in Cooley and Hansen (1989a). These "inflation tax" models are then modified with nominal rigidities through wage contracts. The short run non-neutralities so introduced cause larger velocity and interest rate volatility that are more close to the facts. However the inflation tax models of Section 2 above better fit for example the negative correlation between current output and the price level. And the nominal rigidity models poorly explain real variable movements, and do not capture money growth and interest rate correlations. Further, the inflation rate correlation is not capture in such rigidity models.

2.5 Conclusions

The paper analyzes three different models of exchange technology. The first two are the standard cash-only and shopping time models and the third is a credit model that is a stochastic version of the Gillman and Kejak (2005) economy. The credit model allows for an additional shock to the usual goods productivity and money shocks. It finds that this addition allows inflation's comovement with output at different points in the phase of the business cycle to be captured well. Impulse responses confirm this feature in the credit model that is not available in the cash-only and shopping time models.

The comparison also finds that leisure decreases in the shopping time model when there is a money shock, while it increases in the other two models. This shows an unusual lack of the goods to leisure substitution that appears apparently when the substitution effect towards more leisure in these models dominates any negative income effect that may induce less leisure. Here it appears that the shopping time model generates too much increased shopping and a strong negative income effect of this lost time that is spent in exchange activity. The paper explains this result in terms of the interest elasticity of money being perhaps to high in magnitude at low inflation rates in the shopping time model. This may also be why the credit model does a bit better on some monetary puzzles than the shopping time model, even when there are only the two shocks on goods productivity and money.

The major caveat is that none of these "inflation tax" models can capture liquidity effects apparently existing in the data. Beyond the comparison made here, the contribution of the paper is that it finds advantages with respect to the non-liquidity related puzzles, especially the comovement of inflation, in a model that has been used in an extended form to introduce liquidity effects, as found in Li (2000). This suggests that further development of the monetary business cycle with the credit production approach may yield a model more encompassing of the features in the data without introducing rigidities. For example, as speculation, it suggests requiring the money transfer from the government to pass through the financial intermediary so as to generate a temporary, phased, increase in financial capital that causes the real interest rate to fall temporarily.

2.A Appendix

2.A.1 First-order Conditions and Log-linearization

The first-order conditions with respect to c_t, x_t, k_t, a_t, M_t are

$$\frac{1}{c_t} - \lambda_t a_t - \mu_t w_t \left(\frac{1-a_t}{A_F e^{v_t}} \right)^{\frac{1}{\gamma}} - \mu_t = 0, \tag{2.17}$$

$$\frac{\Psi}{x_t} - \mu_t w_t = 0, \tag{2.18}$$

$$-\mu_t + \beta E_t \left\{ \mu_{t+1} r_{t+1} \right\} = 0, \tag{2.19}$$

$$-\lambda_t c_t + \mu_t w_t c_t \frac{1}{\gamma A_F e^{v_t}} \left(\frac{1-a_t}{A_F e^{v_t}} \right)^{\frac{1}{\gamma}-1} = 0, \tag{2.20}$$

$$\frac{-\mu_t}{P_t} + \beta E_t \left\{ \frac{\lambda_{t+1} + \mu_{t+1}}{P_{t+1}} \right\} = 0. \tag{2.21}$$

In equilibrium these can be simplified to:

$$R^* - 1 = \frac{w^*}{\gamma^* A_F^*} \left(\frac{1-a^*}{A_F^*} \right)^{\frac{1}{\gamma}-1}, \tag{2.22}$$

$$\frac{x_t}{\Psi c_t} = \frac{1 + a^*(R^*-1) + w^* \left(\frac{1-a^*}{A_F^*} \right)^{\frac{1}{\gamma}}}{w^*}, \tag{2.23}$$

$$r^* = \frac{1}{\beta}. \tag{2.24}$$

The log-linearized system of equilibrium conditions includes the consumer's firstorder conditions

$$(\lambda^* a^* c^* + \mu^* c^*)\hat{c}_t + \lambda^* a^* c^* \hat{a}_t + \mu^* w^* l_F^* \hat{w}_t + \mu^* w^* l_F^* \hat{l}_{Ft} + \lambda^* a^* c^* \hat{\lambda}_t + (\mu^* w^* l_F^* + \mu^* c^*)\hat{\mu}_t = 0, \tag{2.25}$$

$$\hat{x}_t + \hat{\mu}_t + \hat{w}_t = 0, \tag{2.26}$$

$$-\hat{\mu}_t + E_t\hat{\mu}_{t+1} + E_t\hat{r}_{t+1} = 0, \tag{2.27}$$

$$-\hat{\lambda}_t + \hat{\mu}_t + \hat{w}_t + (1-\gamma)\hat{l}_{Ft} - (1-\gamma)\hat{c}_t - v_t = 0, \tag{2.28}$$

$$-\hat{\mu}_t + \hat{p}_t + E_t\left\{\frac{\lambda^*}{\lambda^*+\mu^*}\hat{\lambda}_{t+1} + \frac{\mu^*}{\lambda^*+\mu^*}\hat{\mu}_{t+1} - \hat{p}_{t+1} - u_{t+1}\right\} = 0, \tag{2.29}$$

the firm's equilibrium conditions

$$-\hat{w}_t + z_t + \alpha\hat{k}_{t-1} - \alpha\hat{n}_t = 0, \tag{2.30}$$

$$-\hat{r}_t + [1-\beta(1-\delta)]z_t + (\alpha-1)[1-\beta(1-\delta)]\hat{k}_{t-1} + (1-\alpha)[1-\beta(1-\delta)]\hat{n}_t = 0, \tag{2.31}$$

$$-\hat{y}_t + z_t + \alpha\hat{k}_{t-1} + (1-\alpha)\hat{n}_t = 0, \tag{2.32}$$

and the resource and money market constraints

$$-\hat{l}_{Ft} + \frac{a^*}{\gamma(a^*-1)}\hat{a}_t + \hat{c}_t - \frac{1}{\gamma}v_t = 0, \tag{2.33}$$

$$l_F^*\hat{l}_{Ft} + x^*\hat{x}_t + n^*\hat{n}_t = 0, \tag{2.34}$$

$$\hat{p}_t + \hat{a}_t + \hat{c}_t = 0, \tag{2.35}$$

$$-w^*n^*\hat{w}_t - w^*n^*\hat{n}_t - r^*k^*\hat{r}_t - r^*k^*\hat{k}_{t-1} + c^*\hat{c}_t + k^*\hat{k}_t = 0, \tag{2.36}$$

$$\hat{p}_t - \hat{p}_{t-1} - \hat{\pi}_t + u_t = 0. \tag{2.37}$$

Equations (2.25)–(2.37), together with the three shock processes for good-sproductivity, money supply and credit productivity form a system of linear stochastic difference equations in the endogenous state variable $\hat{k}_t$, exogenous state variables z_t, v_t, u_t, endogenous control variables: $\hat{c}_t$, $\hat{x}_t$, $\hat{n}_t$, $\hat{l}_{Ft}$, $\hat{a}_t$, $\hat{w}_t$, $\hat{r}_t$, $\hat{y}_t$, $\hat{p}_t$ and shadow prices $\hat{\lambda}_t$, $\hat{\mu}_t$.

2.A.2 Calibration

	Credit	Cash Only	Shopping Time
α	0.36	0.36	0.36
δ	0.05	0.05	0.05
β	0.99	0.99	0.99
A_F	1.422	N/A	N/A
Ψ	2.03	2.03	1.876
Θ	0.0125	0.0125	0.0125
γ	0.21	N/A	N/A
φ_z	0.95	0.95	0.95
σ_z	0.0075	0.0075	0.0075
φ_v	0.95	N/A	N/A
σ_v	0.0075	N/A	N/A
φ_u	0.57	0.57	0.57
σ_u	0.01	0.01	0.01
c	0.8098	0.8072	0.8463
x	0.7055	0.7069	0.6847
n	0.2940	0.2930	0.3072
l_F	0.00049	N/A	0.0080
a	0.7002	N/A	N/A
w	2.3706	2.3706	2.3706
r	1.0101	1.0101	1.0101
π	1.0125	1.0125	1.0125
y	1.0891	1.0855	1.1381
k	11.1695	11.1333	11.6725
m	0.5670	0.8072	0.3598

Chapter 3

Credit Shocks in the Financial Deregulatory Era. Not the Usual Suspects

Joint with Max Gillman and Michal Kejak

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3.1 Introduction

Identifying the sources of shocks that influence the real business cycle has become the focus of recent research. Chari, Kehoe, and McGrattan (2003) and Kehoe and Prescott (2002) consider how policy may explain capital, labor and goods distortions that contribute to business cycle fluctuations. Uhlig (2003) in contrast takes an atheoretical approach to decomposing fluctuations into certain candidate shocks, finding that a medium range output productivity shock and a shorter range less discernible shock together explain a good portion of the fluctuations. Meanwhile, Espino and Hintermaier (2004) extend Kocherlakota's (2000) formulation of the Kiyotaki and Moore (1997) intertemporal credit shock by constructing a real business cycle with credit constraints.

A credit shock may make a viable candidate for causing some of the output fluctuations, although this still remains little explored within the business cycle framework. One alternative to intertemporal credit is the use of credit for exchange purposes, where the credit is produced in a banking sector using real resources. With this production of credit approach, Einarsson and Marquis (2001) examine the movements of credit aggregates in a monetary business cycle model with banking, while Li (2000) presents a credit model that exhibits some of the classic liquidity effects when open market operations must pass through financial intermediaries. While neither of the latter two papers introduce a shock to the credit sector, there is a separate literature on banking as a source of innovations. This includes Berger (2003), who documents technological progress in the banking sector, and Strahan (2003), who presents econometric evidence of how US bank deregulation has acted as a positive shock that has contributed to GDP increases. Strahan (2003) estimates how asset structures in the banking industry changed significantly after branching and interstate banking deregulations, how the bank profit rate became sharply more correlated with its subsequent asset growth following the 1980s deregulation, and how US state panel data show that the states's growth rate of personal income accelerated by 0.56 percentage points following branching deregulation.[1] Thus bank law deregulations have been specifically linked to structural change in the banking industry and US output growth rate increases.

The paper here contributes a study of how credit shocks affect output in a credit production framework. The model includes credit as an alternative to money in a stochastic exogenous growth version of Gillman and Kejak (2005), with shocks to the productivity of credit along with the more traditional shocks to output productivity and to money supply. From the solution to the monetary business cycle model, the credit shock is constructed each year using data as in Parkin (1988), Ingram, Kocherlakota, and Savin (1994), and Ingram, Kocherlakota, and Savin (1997). Then the contribution of the shock to GDP changes is estimated. Further the paper follows the spirit of Kehoe and Prescott (2002) by attributing the source of the shocks to changes in legislation, specifically banking legislation. The shocks are compared to the major law changes during the national US financial deregulation that occurred in the 1980s and 1990s. A significant ability to correlate the shock-induced GDP movements with the deregulation is found.

The model's recursive solution is used along with US data to construct the shocks in a robust fashion. The profile of the credit shock is found to be stable under some six different ways of estimating it. Along with the model's solution, at least three variables need to be assigned values with time series data in order to minimally identify the three shocks. Five such variables are found to be available and all are used for the baseline, by employing an estimation procedure to identify the three shocks from five equations. Alternative constructions are also made for robustness; it is found that the nearly identical shock profile results in all cases when variables associated with sectors in which the three shocks occur in the model are included in the construction. And this includes two cases in which there is exact identification of the shocks.[2]

As an added characterization of the credit shock, its contribution to the variance of the output is also presented. This variance is found to vary widely, a verification of the Ingram, Kocherlakota, and Savin (1994) finding that the contribution of an individual shock to variance can have a wide range of values, depending for example on its ordering in the VAR. However, since the shock construction procedure uses only the autocorrelation coefficients of the shock processes, this uncertain variance decomposition does not affect the construction. Further, the estimated autocorrelation that results from the time series for the constructed credit shock is close in value to the assumed value used in the construction, a feature that adds validation.

[1] This updates a previous study by Jayaratne and Strahan (1996) that finds that the states's growth rate accelerated by 0.5 to 1 percentage points following deregulation during the 1972 to 1992 period.

[2] Kocherlakota Ingram and Savin (1994) describe how the identification of a model's shock can differ depending on which equilibrium conditions are selected to solve for the shock in combination with the data. Here, rather than using an arbitrary selection of equilibrium conditions, the approach is to use the recursive solution to the model which embodies the entire set of equilibrium conditions.

The paper therefore presents a rigorous testing of the hypothesis that shocks to credit technology may play a role in explaining the output fluctuations during certain historical episodes. Although it does not go as far as to combine an intertemporal credit role with the exchange credit function in the model, the paper shows that the exchange credit function itself may be important during periods when the use of credit for exchange is significantly shocked. For example, consider the lifting of Regulation Q. The unrestricted ability to write checks on money market mutual funds that are invested in short term government treasury securities allowed the consumer a greater chance to earn interest during the period while purchasing goods with credit, instead of using cash. Such an efficiency increase can induce the investment of more funds during each period rather than keeping them idle as cash, and cause a jolt to GDP.

The approach of linking a change in policies with the source of shocks is consistent with a growing literature on decomposing total factor productivity changes. Examples are found in Hopenhayn and Neumeyer (2002), Cole and Ohanian (2002) and Kehoe and Prescott (2002). And finally the paper is able to show that several of the features of Uhlig's (2003) second, unidentified, shorter term shock are satisfied by the credit shock of our model. Taken together, the construction of the shock and its effect on GDP, the link of the shock to certain policy changes, and its partial conformity with the atheoretical shock identified by Uhlig (2003), allows the conclusion that the credit shock is a viable, previously unidentified, candidate shock that can significantly affect output during certain periods.

3.2 The Credit Model

The representative agent self produces credit with labor only and buys the aggregate consumption good with a combination of money and credit, whereby the marginal cost of money (the nominal interest rate) equals the marginal cost of credit (the real wage divided by the marginal product of labor in credit production). The credit production exhibits a rising marginal cost as the share of credit used in exchange goes up. The particular form of the credit production function is equivalent to the assumption that the value-added from the credit service is proportional to the cost of production.

With an explicit price for the credit service as in Gillman and Kejak (2004), it can be shown that this assumption implies that the total revenue from selling the credit service (the value-added) is proportional to the wage cost, leaving a constant rate of profit. This proportionality of the value added with the total cost implies that as total consumption rises, so must the labor input into credit services in order to keep constant the share of credit in exchange. Then the implied production function can be written simply in terms of the share of credit being equal to a diminishing function of the ratio of labor in credit production relative to the total good consumption.

The credit production specification allows for an additional productivity shock. Instead of just good productivity and money shocks, there are three shocks also including one to the productivity of credit.

Consider a representative consumer that maximizes over an infinite horizon its expected lifetime utility over consumption c_t and leisure x_t. Utility is given by:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t (\log c_t + \Psi \log x_t) \qquad 0 < \beta < 1. \tag{3.1}$$

The consumer can purchase the goods by using either money or credit services. Let $a_t \in (0,1]$ denote the fraction of consumption goods that are purchased with money. Then the consumer's cash-in-advance constraint will have the form:

$$M_{t-1} + T_t \geq a_t P_t c_t, \tag{3.2}$$

where $M_{t-1}$is the money stock carried from the previous period, T_t is the nominal lump-sum money transfer received from the government and P_t denotes the current price level. It is assumed that the government policy includes sequences of nominal transfers which satisfy:

$$T_t = \Theta_t M_{t-1} = (\Theta^* + e^{u_t} - 1) M_{t-1}, \tag{3.3}$$

where Θ_t is the growth rate of money and Θ^* is the stationary growth rate of money. Transfer is subject to random shocks u_t which follow the autoregressive process:

$$u_t = \varphi_u u_{t-1} + \epsilon_{ut}, \qquad \epsilon_{ut} \sim N(0, \sigma^2_{\epsilon u}), \quad 0 < \varphi_u < 1. \tag{3.4}$$

The amount of credit used is equal to $c_t(1 - a_t)$. The production function for this amount of credit is given by

$$c_t(1 - a_t) = A_F e^{v_t} \left(\frac{l_{Ft}}{c_t} \right)^{\gamma} c_t, \qquad A_F > 0, \quad \gamma \in (0,1).$$

This can be written as

$$1 - a_t = A_F e^{v_t} \left(\frac{l_{Ft}}{c_t} \right)^{\gamma}, \tag{3.5}$$

where $1 - a_t$ is the share of goods bought with credit, $A_F e^{v_t}$ is the productivity shift parameter and l_{Ft} is the labor time spent in producing credit services. There exists productivity shocks that follow an autocorrelated process:

$$v_t = \varphi_v v_{t-1} + \epsilon_{vt}, \qquad \epsilon_{vt} \sim N(0, \sigma^2_{\epsilon v}), \quad 0 < \varphi_v < 1. \tag{3.6}$$

Assume a total time endowment of 1, which is divided among time spent working, leisure and time spent in credit service production:

$$n_t + x_t + l_{Ft} = 1. \tag{3.7}$$

Output y_t is produced by the agent, acting in part as the representative firm, from capital accumulated in the previous period k_{t-1} and current labor n_t using a Cobb-Douglas CRS production function which is subject to technology shocks z_t:

$$y_t = e^{z_t} k^{\alpha}_{t-1} n^{1-\alpha}_t, \tag{3.8}$$

$$z_t = \varphi_z z_{t-1} + \epsilon_{zt}, \qquad \epsilon_{zt} \sim N(0, \sigma^2_{\epsilon v}), \quad 0 < \varphi_z < 1. \tag{3.9}$$

The part of output that is not consumed is invested in physical capital. Current investment i_t together with depreciated capital form the capital stock used for production in the next period:

$$k_t = (1 - \delta) k_{t-1} + i_t. \tag{3.10}$$

Firms maximize their profits $y_t - r_t k_{t-1} - w_t n_t + (1-\delta)k_{t-1}$, which yield the following functions for w_t, the real wage rate and r_t, the gross real rate of return, net of depreciation δ:

$$w_t = (1-\alpha)e^{z_t} k_{t-1}^{\alpha} n_t^{-\alpha}, \tag{3.11}$$

$$r_t = \alpha e^{z_t} k_{t-1}^{\alpha-1} n_t^{1-\alpha} + 1 - \delta. \tag{3.12}$$

Current income from labor, capital, money balances and lump-sum transfers are spent on consumption, new capital formation and the accumulation of real balances. The period t budget constraint of the representative consumer is given by:

$$w_t P_t (1 - x_t - l_{Ft}) + P_t r_t k_{t-1} + T_t + M_{t-1} \geq P_t c_t + P_t k_t + M_t. \tag{3.13}$$

The consumer chooses consumption, leisure, time spent in credit service production, capital stock, credit service purchase and money balance path $\{c_t, x_t, l_{Ft}, k_t, a_t, M_t\}_{t=0}^{\infty}$ to maximize lifetime utility (3.1) subject to the cash-in-advance constraint (3.2), budget constraint (3.13) and credit service technology (3.5).

3.2.1 Equilibrium

Dividing equations (3.2) and (3.13) by the price level and substituting l_{Ft} expressed from (3.5), the Lagrangian of the maximization problem of the household is

$$\begin{aligned} L = E \sum_{t=0}^{\infty} \beta^t \{ & (\log c_t + \Psi \log x_t) \\ & + \lambda_t \left[\frac{M_{t-1} + T_t}{P_t} - a_t c_t \right] \\ & + \mu_t \left[w_t \left(1 - x_t - \left(\frac{1-a_t}{A_F e^{v_t}} \right)^{\frac{1}{\gamma}} c_t \right) + r_t k_{t-1} + \frac{M_{t-1} + T_t}{P_t} - c_t - k_t - \frac{M_t}{P_t} \right] \}. \end{aligned} \tag{3.14}$$

The first-order conditions with respect to c_t, x_t, k_t, a_t, M_t are

$$\frac{1}{c_t} - \lambda_t a_t - \mu_t w_t \left(\frac{1-a_t}{A_F e^{v_t}} \right)^{\frac{1}{\gamma}} - \mu_t = 0, \tag{3.15}$$

$$\frac{\Psi}{x_t} - \mu_t w_t = 0, \tag{3.16}$$

$$-\mu_t + \beta E_t \left\{ \mu_{t+1} r_{t+1} \right\} = 0, \tag{3.17}$$

$$-\lambda_t c_t + \mu_t w_t c_t \frac{1}{\gamma A_F e^{v_t}} \left(\frac{1-a_t}{A_F e^{v_t}} \right)^{\frac{1}{\gamma}-1} = 0, \tag{3.18}$$

$$\frac{-\mu_t}{P_t} + \beta E_t \left\{ \frac{\lambda_{t+1} + \mu_{t+1}}{P_{t+1}} \right\} = 0. \tag{3.19}$$

A competitive equilibrium for this economy consists of a set of allocations $\{c_t, x_t, l_t, n_t, k_t, a_t, M_t\}_{t=0}^{\infty}$, a set of prices $\{w_t, r_t\}_{t=0}^{\infty}$, exogenous shock processes $\{z_t, v_t, u_t\}_{t=0}^{\infty}$, money supply process and initial conditions k_{-1} and M_{-1} such that given the prices, shocks and government transfers, the allocations solve the consumer's utility maximization problem, solve the firm's profit maximization problem and the goods and labor and money markets clear.

In a stationary deterministic steady state we use the transformation $p_t = \frac{Pt}{Mt}$ (and also denote real money balances by $m_t = \frac{M_t}{P_t}$). There is no uncertainty and time indices can be dropped, denoting by $(*)$ the steady state values and by $R^* = r^*(\Theta^* + 1)$ the steady state interest factor. In the equilibrium, inflation equals the growth rate of the money supply. The first order conditions (3.15)-(3.19) can be simplified to:

$$R^* - 1 = \frac{w^*}{\gamma^* A_F^*} \left(\frac{1 - a^*}{A_F^*} \right)^{\frac{1}{\gamma} - 1}, \tag{3.20}$$

$$\frac{x_t}{\Psi c_t} = \frac{1 + a^*(R^* - 1) + w^* \left(\frac{1 - a^*}{A_F^*} \right)^{\frac{1}{\gamma}}}{w^*}, \tag{3.21}$$

$$r^* = \frac{1}{\beta}. \tag{3.22}$$

Equations (3.20)-(3.22) together with the steady-state versions of equations (3.2)-(6) and (3.11)-(13) define the steady state of the system.

3.2.2 Calibration and Numerical Dynamics Solution

The model is solved by using the log-linearization technique of King, Plosser, and Rebelo (1987), Campbell (1994) and Uhlig (1995). A first-order Taylor approximation of the log variables around the steady state results in 12 equations for the first-order conditions of the consumer and firm, and the constraints, together with the productivity and money supply shocks processes (3.4), (3.6) and (3.9).[3] This gives a system of linear stochastic difference equations in the log-linearized endogenous state variable $\hat{k}_t$, the exogenous state variables z_t, v_t, u_t, and the log-linearized endogenous control variables, $\hat{c}_t$, $\hat{x}_t$, $\hat{n}_t$, $\hat{l}_{Ft}$, $\hat{a}_t$, $\hat{w}_t$, $\hat{r}_t$, $\hat{y}_t$, $\hat{p}_t$ and shadow prices $\hat{\lambda}_t$, $\hat{\mu}_t$.

Solving the stochastic difference equations system above means determining a recursive equilibrium law of motion of the endogenous variable $\mathbf{X}_t^{'} = [\hat{k}_t]$ and $\mathbf{Y}_t^{'} = [\hat{c}_t \quad \hat{x}_t \quad \hat{n}_t \quad \hat{l}_{Ft} \quad \hat{a}_t \quad \hat{w}_t \quad \hat{r}_t \quad \hat{y}_t \quad \hat{p}_t]$ on the lagged values of the endogenous state variable $\mathbf{X}_{t-1}^{'} = [\hat{k}_{t-1}]$ and on the current values of the exogenous state variables $\mathbf{Z}_t^{'} = [z_t \quad v_t \quad u_t]$. The solution has the form:

$$\mathbf{X}_t = PP\ \mathbf{X}_{t-1} + QQ\ \mathbf{Z}_t, \tag{3.23}$$

$$\mathbf{Y}_t = RR\ \mathbf{X}_{t-1} + SS\ \mathbf{Z}_t, \tag{3.24}$$

where PP, QQ, RR, SS are coefficient matrixes.

The US economy is the benchmark for calibration of parameters, which are chosen as close as possible to the values in the literature (Cooley and Hansen (1989a), Cooley and Hansen (1995), Gillman and Kejak (2005)). The length of a period is assumed to be one quarter. The quarterly discount factor is assumed to be $\beta = 0.99$. This implies through equation (3.22) a quarterly net real return

[3] The details of the log-linearization can be found in Benk, Gillman, and Kejak (2004).

of 1%. The depreciation rate is set equal to $\delta = 0.025$ and the share of capital input is set equal to $\alpha = 0.36$.

Regarding the parameters of the exchange technology, the degree of diminishing return in the credit sector is set to $\gamma = 0.21$, which is Gillman and Otto's (2003) time series estimate of γ in a related model for the US (values of $\gamma \in (0, 0.5)$ give a convex, upward-sloping, marginal cost curve). The share of cash purchases is fixed at $a = 0.7$ as in Gillman and Kejak (2005). With a baseline nominal interest rate of 2.25%, explained below, the productivity parameter A_F is then implied to be 1.422.

The baseline proportion of time allocated to leisure is set at $x_t = 0.7055$, similar to the 0.7 in Gillman and Kejak (2005) and the 0.69 in Jones, Rodolfo, and Rossi (1993). Then, the steady-state first order conditions imply the amount of hours spent in credit services production, $l_F = 0.00049$. This quarterly value when annualized is close in value to the annual value of 0.0014 in Gillman and Kejak (2005).

For the shock processes, the standard deviations and autocorrelations need values. The standard deviation of disturbances to the goods production technology is calibrated so that the standard deviation of the simulated output series is near to the standard deviation of the US output, giving $\sigma_{\epsilon z} = 0.0075$ (as compared to 0.00721 in Cooley and Hansen (1989a)). Persistence is set equal to $\varphi_z = 0.95$, as is common.

The money supply process is calibrated so that the money supply varies in a way that is consistent with the US experience between 1959-2000. Following Cooley and Hansen (1989a) and Cooley and Hansen (1995) the persistence and the variance of the money supply is estimated from the following regression for the money supply growth (standard errors in parentheses):

$$\Delta log M_t = \underset{(0.0011)}{0.005139} + \underset{(0.065)}{0.576748} \Delta log M_{t-1} + \epsilon_t, \quad \sigma_\epsilon = 0.010022. \tag{3.25}$$

This implies $\varphi_u = 0.58$, $\sigma_{\epsilon u} = 0.01$, close to Cooley and Hansen (1995) estimates of 0.49 and 0.0089 for the period 1954-1991. The regression above also implies an average growth rate of money ($E \, \Delta \log M_t$) of 1.23% per quarter, which is around 5% per year. And a 1.23% quarterly inflation rate plus a 1% real interest rate implies a 2.25% quarterly nominal interest rate.

Finally, values for the credit shock generation process are required. While the persistence of the aggregate output is typically estimated from the Solow residual, this is more difficult to do for a specific sector, such as the credit sector. Instead, it is assumed that the credit shock process has the same standard deviation and autocorrelation as in the aggregate goods sector, or that $\sigma_{\epsilon v} = 0.0075$ and $\varphi_v = 0.95$. This assumption proves reasonable as is seen below in that the estimated autocorrelation is close to the assumed value.

Given the values for the parameters and the steady state variables, the recursive system of linear stochastic difference equations is solved using the methods of Uhlig (1995). Here the MATLAB program provided online by Uhlig is adapted for our model, and the solution given by equations (3.23) and (3.24) takes the form

$$\hat{k}_t = 0.953 \hat{k}_{t-1} + 0.117 z_t - 0.0003 v_t + 0.007 u_t, \tag{3.26}$$

$$\begin{bmatrix} \hat{c}_t \\ \hat{x}_t \\ \hat{n}_t \\ \hat{l}_{Ft} \\ \hat{a}_t \\ \hat{w}_t \\ \hat{r}_t \\ \hat{p}_t \\ \hat{y}_t \end{bmatrix} = \begin{bmatrix} 0.564 \\ 0.110 \\ -0.265 \\ 0.100 \\ 0.042 \\ 0.456 \\ -0.028 \\ -0.606 \\ 0.190 \end{bmatrix} \begin{bmatrix} \hat{k}_{t-1} \end{bmatrix} + \begin{bmatrix} 0.399 & 0.014 & -0.120 \\ -0.321 & -0.005 & 0.002 \\ 0.772 & 0.011 & -0.023 \\ -0.551 & 0.056 & 10.430 \\ 0.085 & -0.432 & -0.949 \\ 0.722 & -0.004 & 0.008 \\ 0.052 & 0.0002 & -0.001 \\ -0.485 & 0.4184 & 1.068 \\ 1.494 & 0.007 & -0.015 \end{bmatrix} \begin{bmatrix} z_t \\ v_t \\ u_t \end{bmatrix}. \tag{3.27}$$

3.2.3 Impulse Responses of the Credit Shock

The recursive equilibrium laws of motion determined in the previous section permit computation of the impulse responses of shocks on the variables of the model. Figure 3.1 illustrates the impulse responses of the credit economy when faced with a 1% shock to the productivity of the banking sector. Intuitively, financial innovation and productivity growth in the banking sector decreases the cost of using credit relative to cash, inducing an increase in demand for credit and a decrease in the demand for cash. The share of cash purchases falls by 0.43% while the real money demand drops by 0.42%, this drop being equivalent with an immediate upward jump in the nominal price level. The price level jumps up, given that there is the same money supply and less money demand, and adjusts back to its long-run growth path after the shock. This causes inflation to converge from below to its long-run level.

The fall in the cost of credit lowers the shadow exchange cost of consumption goods relative to leisure and induces substitution consumption from leisure. This involves an increase in consumption of 0.014% and a decrease in leisure of 0.005%. With more efficient labor in the credit sector, and less leisure, labor in the goods sector increases by 0.01%. The modestly increased labor supply somewhat lowers the real wage and the input price ratio (w/r) by about 0.004%. This results in a decrease in the capital to labor ratio, in contrast to a Tobin (1965) type effect. The time spent in the banking sector increases by 0.056%. However note that if the credit productivity parameter is calibrated to be large enough, then the time spent in banking can potentially decrease. This results when there is a large enough shift out in the credit services output, from the productivity boost, that less labor is required in the end.

In sum, a positive credit productivity shock sees the economy have increased work, consumption, output, prices and banking, with less leisure, capital, and real money use.

3.3 Results: The Construction of Credit shocks

The effects of the changes in banking laws on the business cycle can be studied by identifying the magnitude of the credit shocks, and their effects on output, and then by comparing these effects with the chronology of the deregulation. First is the construction of the three shocks, z_t, v_t and u_t, in each period from 1972:1 to 2000:4. This is done by assigning values to certain control and state variables, using US quarterly data, substituting the values back into the solution

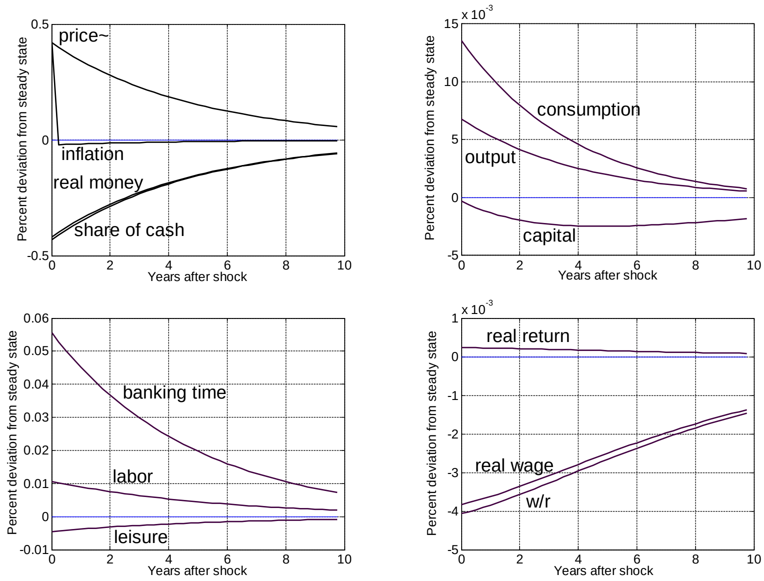

Table 3.1: Impulse responses to 1 percent credit productivity shock

to the recursive equilibrium system given in equation (3.26) and (3.27), and then solving for z_t, v_t and u_t. The choice of the control variables that are assigned values using data is made on the simple basis of using as many variables for which there is reliable data, while trying to include key variables like labor hours in banking. The banking hours is the limiting factor in the data range, beginning only in 1972. The result is five variables: output, consumption, investment, banking hours and real money.[4] Having five equations in the three unknown shocks gives an overidentification of the shocks, while in contrast with only three equations there would be an exact identification. Overidentification still allows for a unique determination of the three shocks through an estimation procedure. This is done with ordinary least squares as described below.

Given the five control variables with values from US data, the log-deviations of these variables $\hat{y}_t$, $\hat{c}_t$, $\hat{\imath}_t$, $\hat{l}_{Ft}$ and $\hat{m}_t$ are defined as the percentage deviations of the variables in each period relative to their H-P filtered trend. Next is the construction of the state variable, the capital stock. Following Chari, Kehoe, and McGrattan (2003), this variable is constructed by using the capital accumulation equation, the investment data, and an assumed value for the initial capital stock. With the data on investment used to compute $\hat{\imath}_t$, the cyclical component of the H-P filtered series, the initial value choice of the log-linearized capital stock $\hat{k}_{-1}$ is set equal to 0. Then the log-linearization of the capital accumulation equation (3.10) is used to generate $\hat{k}_t$.

The five equations with the now given values for $\hat{y}_t$, $\hat{c}_t$, $\hat{\imath}_t$, $\hat{l}_{Ft}$, $\hat{m}_t$, and $\hat{k}_t$, allow for the ordinary least squares estimation of the three unknown shocks, z_t,

[4] The data sources is the IMF online IFS database for all variables except the hours in banking, which is from the online Bureau of Labor Statistics. For this series, the Commercial Banks sector is used, where the hour series is the product of the two series, "average weekly hours of production workers" and "production workers, thousands". This data is at a monthly frequency, and it is converted to a quarterly basis using a simple three month average.

v_t and u_t. To illustrate this, rewrite equation (3.27) in matrix form as

$$X_t = A[\hat{k}_{t-1}] + BE_t,$$

where A and B are the coefficient matrices from equation (3.27), and

$$\begin{aligned} X_t &= [\hat{y}_t \quad \hat{c}_t \quad \hat{\imath}_t \quad \hat{l}_{Ft} \quad \hat{m}_t]', \\ E_t &= [z_t \quad v_t \quad u_t]'. \end{aligned}$$

For this system of five linear equations in three unknowns, for each t the ordinary least squares estimate of $\tilde{E}_t$ is found from the formula:

$$\tilde{E}_t = (B'B)^{-1}B'(X_t - A[\hat{k}_{t-1}]). \tag{3.28}$$

The magnitudes of the shocks are plotted in Figure 3.1. The estimated

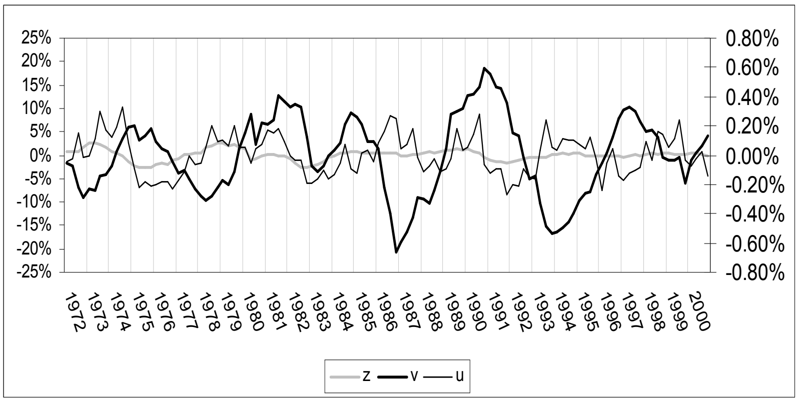

Figure 3.1: Evolution of productivity (z), credit (v) and money (u) shocks (u on the right axis)

autocorrelation coefficients, with ρ denoting estimated values, are $\rho_z = 0.9203$, $\rho_v = 0.9362$, and $\rho_u = 0.6564$, which are found by fitting an AR(1) model to the shocks and which compare well to the assumed values of $\varphi_z = 0.95$, $\varphi_v = 0.95$, and $\varphi_u = 0.57$. The variance of credit shocks appears to be larger than the variance of the productivity shocks, while the assumption is that they are the same. The difference can be because the aggregation of the sectoral shocks into a cumulative shock z_t results in the smoothing of idiosyncratic sectoral shocks, and a smaller variance relative to some individual sectors such as the credit sector. Using the larger estimated variance for the credit shock in simulations results in somewhat altered correlations amongst variables, but does not affect the construction of the magnitude of the shock or its effect on GDP.

3.3.1 Effect of the Credit Shock on Output

Given the construction of v_t, two measures can be determined that help illustrate how the credit shock effects the economy. These are the period-by-period innovations to the credit shock process (ϵ_{vt}), and a measure of the effect of the credit shock on GDP. The innovations are computed directly from equation (3.6) by substituting in the values for v_t and the estimated value for the autocorrelation parameter, $\rho_v = 0.9362$. These are graphed in Figure 3.2, plotted on the left axis, along with the v_t themselves.

Second, consider defining a measure of the effect of credit shocks on GDP that uses the ratio of the actual GDP to the simulated GDP when it is assumed that the credit shocks v_t are each equal to zero. Taking this ratio and subtracting one gives the percentage deviation of actual GDP from the simulated GDP with no credit shocks, or $\frac{GDP_{actual}}{GDP|_{v=0}} - 1$. The result is a measure of how much higher GDP was during the period as a result of the credit shocks taking on the values that are estimated in equation (3.28). This is graphed also in Figure 3.2, plotted on the right axis. The graphs show that the individual credit shock innovations tend to bunch up in positive and negative directions and so cumulate to create the shocks v_t and the cyclical changes in output with some lag.

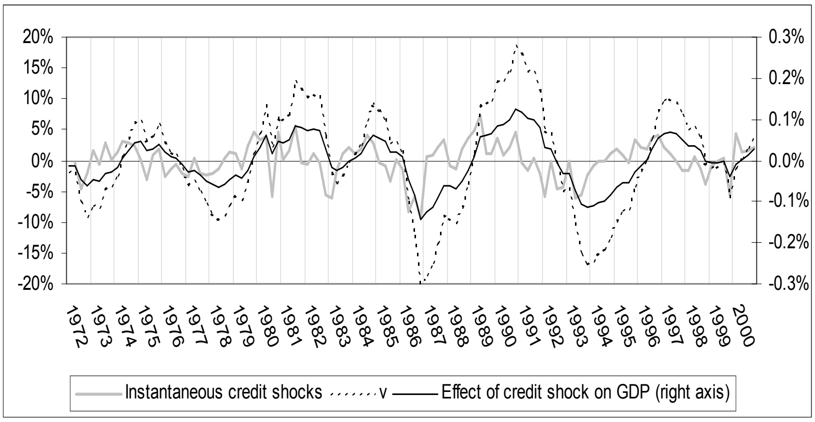

Figure 3.2: Credit innovations ($\hat{\epsilon}_{vt}$), the credit shock (v_t), and the effect of credit shocks on GDP ($\frac{GDP_{actual}}{GDP|_{v=0}} - 1$)

3.3.2 Robustness of the Credit Shock Construction

The construction of the economy's three shocks uses five variables in the baseline calculation. Alternatively the combinations of five variables taken four at a time, and five taken three at a time, allow for 15 more possible ways to construct the credit shock v_t. All fifteen of these were computed, and Figure 3.3 graphs six of these along with the baseline. The results show that all variable combinations that include real money, labor hours in banking, and either output or investment, generate nearly the same figure. The other combination presented in Figure 3.3 is money, banking hours and consumption, which shows conformity in the second part of the period but appears rather random in the first part of the period. Other combinations show such randomness and a lack of conformity for the whole period.

The interpretation of these results is that as long as the variables are included that correspond to the model's sectors in which the three shocks occur,

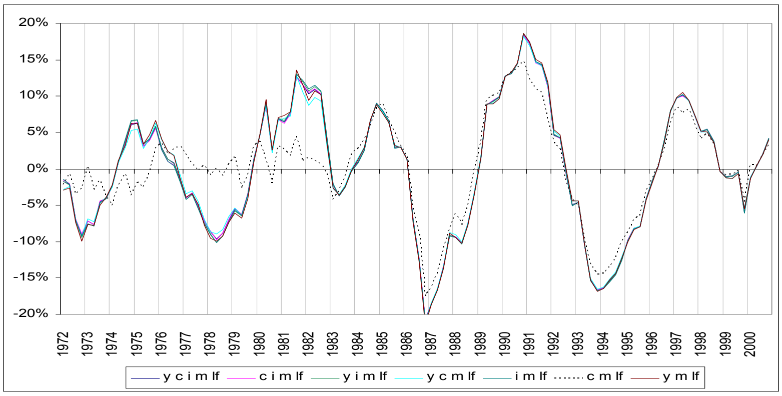

Figure 3.3: The Credit Shock under Alternative Identifications

then the results have a non-random form that allow for further interpretation. In particular, the real money, banking hours and output variables correspond directly to the sectors in which the money, credit and output shocks occur. As a qualification, the investment variable instead of output gives similar results. Given the standard business cycle evidence of how investment reflects well the goods sector productivity shock, this substitutability of investment for output is not surprising. Further, because it is also well known that the consumption series does not reflect as well the output productivity shock, it is not surprising that substitution of consumption for both output and investment gives a more random result.

Thus the construction is robust within six different alternatives for variable combinations, these being $\hat{y}_t$, $\hat{c}_t$, $\hat{\imath}_t$, $\hat{l}_{Ft}$, $\hat{m}_t$; $\hat{y}_t$, $\hat{c}_t$, $\hat{l}_{Ft}$, $\hat{m}_t$; $\hat{y}_t$, $\hat{\imath}_t$, $\hat{l}_{Ft}$, $\hat{m}_t$; $\hat{c}_t$, $\hat{\imath}_t$, $\hat{l}_{Ft}$, $\hat{m}_t$; $\hat{y}_t$, $\hat{l}_{Ft}$, $\hat{m}_t$; and $\hat{\imath}_t$, $\hat{l}_{Ft}$, $\hat{m}_t$. The latter two constructions are exact identifications that are made without estimation.

3.3.3 Variance Decomposition

The construction of the credit shock makes use of the autocorrelation coefficient φ_v, for the credit shock process given in equation (3.6), when it uses the recursive equilibrium solution found in equations (3.26 and 3.27). This coefficient is then estimated from an AR(1) process for the resulting credit shock series v_t. And then the shock innovations ϵ_{vt} are computed with the time series v_t and its estimated autocorrelation. The closeness in value between the autocorrelation coefficient that is assumed in the construction ($\varphi_v = 0.95$) and its estimated value using the constructed shock ($\rho_v = 0.9362$) is in a sense a further check on the consistency of the credit shock construction.

The standard deviation of the shock processes is not used in the shock construction, although it is used in simulations of the economy for the impulse responses. As an additional step to characterize the credit shock process, the results are presented here of a study of the contribution of the shocks to the variance of the output. Ingram, Kocherlakota, and Savin (1994) show that the contribution to the variance of output from a particular shock can vary widely depending on its VAR ordering. Results for the Section 2.2 economy confirm this. Alternative variance decompositions of the three shocks were made using all possible alternative constructions of the shocks, and under all possible VAR orderings. The distribution of these variances varies significantly with each of the three possible VAR orderings. The distributions presented in Figure3.4 are for the credit shock when ordered first (left-hand side) and second, using the alternative constructions with all possible combinations of the five variables ($\hat{y}_t$, $\hat{c}_t$, $\hat{\imath}_t$, $\hat{l}_{Ft}$, $\hat{m}_t$) that contain at least the real money, banking hours and either output and investment (a total of 12 observations for each VAR ordering). The credit shock shows some bunching around 10%.

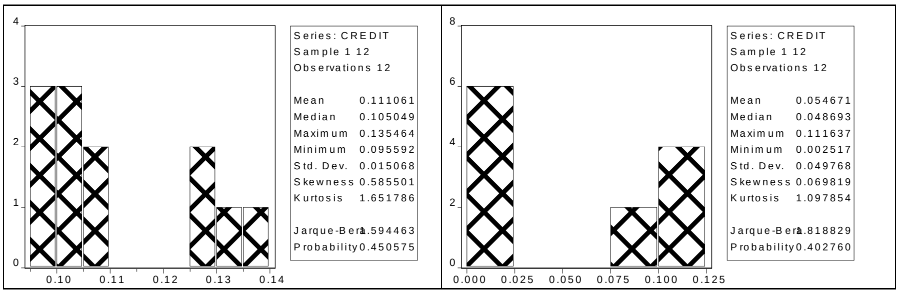

Figure 3.4: Distribution of the Variance Decompositions of the Credit Shock, with 1st and 2nd Orderings.

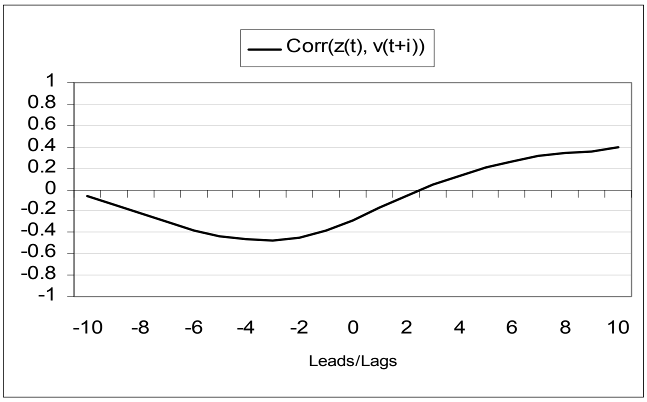

Figure 3.5: Cross-correlations between the output sector and credit sector shocks.

Ingram, Kocherlakota, and Savin (1994) point out that only when shocks are completely uncorrelated with each other will the variance decomposition be unique. Figure 3.5 illustrates for example the non-zero correlations between the output and credit sector shocks for the baseline construction. They range from positive to negative, over the one-period lag and one-period lead. This is the correlation that gives rise to the variation in the variance decomposition. However, despite finding such variation in the fraction of the variance of output explained by the credit shock, it is important to note that the credit shock construction remains unaffected by this variation.

3.4 Credit Shocks and Banking Deregulation

The credit shock innovations and their effect on GDP, graphed in Figure 3.1, appear to have some significant chronological conformity to the timing of banking reform legislation during the period. To see this, consider first an outline of the deregulatory era and its major acts, the timing of the business cycles during the period, how the acts fall within the cycles, and finally the degree to which the credit shocks appear to coincide with the acts.

3.4.1 Legislative Events

The US banking crises of the 1930s in the US led to regulations designed to increase the soundness of the banking system. This restricted the scope of banking geographically and vertically, while prohibiting the payment of interest on demand deposits and putting a ceiling on interest rates payable on time deposits (The Banking Acts of 1933 and 1935, Regulation Q). High inflation during the 1960s and 1970s caused interest rates to rise above the ceilings, made it difficult for banks to compete for deposit funds, and led to the expansion of unregulated money market funds. This created pressure to deregulate.

There were five major acts during this period, with a sixth falling at the end of the period under study. The Depository Institutions Deregulation and Monetary Control Act (DIDMCA) of 1980 phased out the deposit interest rate ceilings and allowed checkable deposits that paid a market interest rate. A second major step in the deregulatory process was the Garn-St Germain Act of 1982, which authorized banks and other depository institutions to offer money market deposit accounts that could compete with money market mutual funds[5].

The end of the 1980s brought a crisis to the savings and loan sector in the US, apparently a fall-out of the innovation in the other parts of the banking sector and of the 1986 repeal of highly favorable tax write-offs for real estate limited partnerships that were enacted in the major tax act of 1981. The Financial Institutions Reform, Recovery and Enforcement Act of 1989 (FIRREA) and the Federal Deposit Insurance Corporation Improvement Act of 1991 (FDICIA) provided for a restructuring of the savings and loan sector that enabled it to compete anew on a more level basis with the rest of the financial industry. The FIRREA created the Resolution Trust Company (RTC) which made closure easier, equalized rules for savings and loans relative to banks, extended FDIC insurance to savings and loans, and the facilitated the conversion of savings and loans to banks. The FDICIA in contrast increased the cost of deposit insurance with risk-based premiums and allowed savings and loans to fail more easily by discouraging bail-outs.[6]

The 1990s saw the elimination of most of the remaining restrictions from the 1930s regulatory acts. The Riegle-Neal Interstate Banking and Branching Efficiency Act of 1994 repealed the McFadden Act and allowed interstate bank branching and consolidation. The Gramm-Leach-Bliley Act of 1999 repealed

[5] For more detailed explanations regarding banking legislation see Mishkin (1997).

[6] See Hanc (1998) for a detailed analysis.

	US avg.	1973:IV↘ 1975:I↗	1980:I↘ 1980:III↗	1981:III↘ 1982:III↗	1990:II↘ 1991:I↗
Duration					
Peak↘Trough	3.17	5	2	4	3
Trough↗Peak	24	20	4	31	39
Amplitude					
Peak↘Trough	-2.02	-3.40	-2.19	-2.86	-1.49
Trough↗Peak	28.87	23.66	4.26	37.04	39.39
Cumulation					
Peak↘Trough	-2.65	-5.06	-2.04	-6.40	-1.19
Trough↗Peak	423.79	252.43	8.57	603.20	668.06
Excess					
Peak↘Trough	-0.58	-1.04	-0.62	-0.19	-0.60
Trough↗Peak	1.02	-0.20	0.51	-0.34	3.07

Table 3.2: Cycle characteristics: post-war averages, and individual cycle values

the Glass-Steagall Act and allowed mergers between commercial banks, insurance companies and investment banks. Together these Acts evidently increased competition, generated greater efficiencies and increased the productivity in the banking sector[7].

3.4.2 Correlation of Shock-induced GDP movements with Law Changes

The effect of the deregulatory acts can be viewed within the business cycle framework. Consider first a definition of the cycles during the period 1972:1 to 2000:4, using the Bry and Boschan (1971) technique, and their brief characterization. Table 3.2 reports the duration (quarters) and amplitude (percent of GDP) of the cycles, as well as Harding and Pagan (2002) measures of the cumulative movements (total gain/loss during the cycle, in percent) and excess movements (the deviation of the cumulative movements from its approximation by a triangle, in percent). The first column reports the averages of these measures for the postwar US data, and the other column report the particular values for the cycles of the period. The results show for example a longer than average duration, a higher than average amplitude, and a greater cumulative total for the expansions starting in 1982 and in 1991, during which time most of the major financial deregulations occurred. Also in evidence is a stronger expansion (more cumulative GDP increase) for the short one starting in 1980:III and the longer one starting in 1982:III, as implied by a lower excess measure as compared to the average.

The dating of the cycles and their characterization are consistent with the possibility that the major financial deregulations of the early 1980s and early to mid 1990s helped boost output. Analysis of the credit shock innovations strengthens the evidence that the banking legislation contributed to the source of the increases in GDP during these expansions. Figure 3.1 shows a positive

[7] See Guzman (2003) for details on financial deregulations in the 90s. Strahan documents other US changes. Cetorelli (2004) finds evidence of greater competition in banking in the EU following deregulation of the finance sector.

credit shock lasting from 1980 to 1983, and another from 1983 to 1986; the innovations to the credit shocks show spikes that correspond to the period following the introduction of the two early 1980s deregulatory acts. Similar positive innovation spikes and credit shocks follow the 1989 and 1994 acts. Thus these four acts coincide closely with the four positive credit shocks that increased GDP during this period. The 1999 act also correlates closely to an innovation spike seen to occur at the end of the period.

Also of interest are the negative effects of the credit shocks on GDP. There are three larger such effects, occurring from 1976 to 1980, 1986 to 1989, and from 1992 to 1996, caused by innovations somewhat preceding these periods. In terms of the acts, the enactment of the 1991 FDICIA act is followed by some negative spikes that caused the 1986 to 1989 negative effect of the credit shock. The 1991 act increased costs to the savings and loans, while allowing for easier closures, and there was a significant consolidation of the savings and loans sector following this act, involving the many closures; these effects may have caused an initially negative effect on output.

The negative shock of 1976 to 1980 is interpreted as being a result of the banks bumping up against restrictive financial industry regulation. In particular, in 1976 to 1980 banks faced binding constraints from Regulation Q, as the inflation rate shot up, that suddenly inhibited their intermediation ability. This could have created the negative spikes at that time. The negative credit shock from 1986 to 1989 conceivably is related to the ending in 1986 of a highly favorable tax treatment for the real estate industry. The Tax Reform Act of 1986 repealed the limited partnership write-offs for real estate investments through which limited partners could get (from unused write-offs of general partners) up to eight times the value of their investment in write-offs that directly reduced their taxable income. This allowed for economically unattractive investment projects to be attractive nonetheless because of the tax law. The 1986 act was viewed as "bursting a bubble" in real estate investment. With the savings and loans's returns propped up by assets weighted heavily in such real estate, this 1986 reform may have triggered the collapse of the savings and loans and its subsequent reform and deregulation. In evidence in 1986 is a strong negative credit shock innovation that preceded the 1986 to 1989 negative effect on GDP of the credit shock, and that coincides in time to the 1986 law change.

3.5 Discussion

Uhlig (2003), taking an atheoretical approach, finds two main shocks which are able to explain more than 90% of the movements in US GDP. He interprets these shocks in terms of a list of the "prime suspects" of business cycle propagation. One of these is a medium-run shock that is found to be similar to the typical output productivity shock. The other is a shorter term shock that he finds does not fit well the characteristics of any of the shocks on his list of candidate shocks. A comparison shows that the credit shock of our model has several similar features of Uhlig's (2003) short-term shock.

In particular, the real side of the economy compares closely while the nominal side shows less congruence. On the real side, the impulse responses of output, consumption, labor hours are similar for the Section 2.2 model's credit shock and for Uhlig's (2003) short-term shock. The real wage rate response to the credit shock can be compared to the labor productivity response for the short term shock in Uhlig (2003). Both fall after the shock and then gradually adjust back; the pattern of the credit shock is especially similar in the decomposition case in Uhlig (2003) for which θ is equal to 150. Note however that while the credit shock impulse responses die out by construction, there is some persistence evident in the Uhlig (2003) short term shock.

On the nominal side, the model's inflation rate response matches the short term shock response of Uhlig (2003) to some degree. The pattern of the model's inflation rate from the second period on is very similar to that of Uhlig's (2003) PPI inflation. And the pattern of the model's inflation rate impulse response to the credit shock is similar to the Uhlig (2003) CPI inflation impulse response in that in both there is a positive jump that then turns negative. However in the model the jump is immediate and in Uhlig (2003) it is gradual, possibly explained by a lack of price stickiness in the credit model; and the model's nominal interest rate response compares less well with the federal funds response in Uhlig (2003), possibly for a related reason.

3.6 Conclusions

The paper analyzes a stochastic version of the Gillman and Kejak (2005) monetary economy with a payments technology for exchange credit. Deterministically this credit technology has been useful in explaining the effect of inflation on growth (Gillman and Kejak 2005), the role of financial development in the inflation-growth evidence (Gillman, Harris, and Matyas 2004), and in explaining Tobin (1965) evidence (Gillman and Nakov 2003), as well as for allowing for a liquidity effect to be postulated (Li 2000). Applied to the business cycle, a shock to credit productivity allows for a new focus on shocks besides the goods productivity and money supply shocks. The paper constructs the credit shock by solving the recursive equilibrium system, substituting in data for the endogenous variables in the equilibrium solution, and then either estimating or solving for each of the three shocks, in a procedure related to Parkin (1988), Ingram, Kocherlakota, and Savin (1994), and Ingram, Kocherlakota, and Savin (1997). The construction is found to be robust to the use of several different data sets, with the condition that data for variables from the sectors being shocked needs to be included in the construction. The credit shock innovations show congruence with change in US banking laws during the financial deregulatory era of the 1980s and 1990s. The idea that a credit shock can affect aggregate productivity and be linked to changes in government policy is not inconsistent with the conclusions of Kehoe and Prescott (2002) that depressions across the world have resulted from shocks to productivity related to government policy changes. Indeed it would be interesting to apply the analysis of the paper to the US 1930s depression period, although data on the bank sector may be a constraining factor.

The credit shock also shows similar features to a key shock identified by Uhlig (2003). He finds that two shocks explain the majority of the movements in GNP: a medium-run one similar to the goods productivity shock, and another shorter term one that lacks similarities with the candidate shocks that Uhlig (2003) considers. The credit shock of this model parallels the effect of this second shorter term shock on the real side of the economy. This strengthens the case for considering the credit shock as a potentially important candidate shock that can contribute significantly to business cycle movements.

Another approach in the business cycle literature is that of Chari, Kehoe, and McGrattan (2003) who decompose the shocks into different sources of marginal distortions. How the credit shock identified here may fit into their productivity, labor tax, and capital tax wedges may be worth further study. Since their labor tax distorts the leisure-labor margin in a way similar to the inflation tax in a monetary model, and both the cost of credit and the cost of money affect this margin in the model of this paper, the credit shocks might partly be accounted for through this wedge.

Chapter 4

Money Velocity in an Endogenous Growth Business Cycle with Credit Shocks

Joint with Max Gillman and Michal Kejak

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4.1 Introduction

Explaining velocity at business cycle frequencies involves a rich literature. Freeman and Kydland (2000), Hodrick, Kocherlakota, and Lucas (1991) and Cooley and Hansen (1995) endogenize money velocity in models with shocks to the goods sector productivity and the money supply. Cooley and Hansen call the procyclic behavior of US velocity "one of the most compelling features of aggregate data"(p.179). Their model reproduces this but its correlation of velocity with output is high compared to data. Here the goods sector productivity shock drives velocity changes, in a way similar to Friedman and Schwartz's (1963b) velocity theory as based on the application of the permanent income hypothesis to money demand (p.44). A positive temporary output shock (productivity) causes income to rise temporarily while money demand depends on consumption demand and is not much affected by the temporary income increase; a procyclic velocity results. However the most common explanation of velocity, that it depends on monetary-induced inflation effects on the nominal interest rate, as in McGrattan (1998), has no role in explaining velocity at business cycle frequencies, as Wang and Shi (2006) note in their alternative search-theoretic approach to velocity. Also missing is a role for financial sector shocks (King and Plosser 1984), financial innovation (Ireland 1991), technological progress (Berger 2003), or deregulation (Stiroh and Strahan 2003).

The paper explains 75% of the variability of velocity seen in 1972-2003 US quarterly data, by confronting the problems of velocity movements that are too procyclic, that are little affected by money shocks, and that have no role for financial sector shocks. In particular, it adds shocks to the productivity of providing exchange credit, which is introduced instead of the trips-to-the-bank approach of Freeman and Kydland (2000) or the cash-good, credit-good framework in Hodrick et al (2006) and Cooley and Hansen (1995), and uses an endogenous growth framework instead of an exogenous growth one (Section 4.2). Money and credit shocks both positively affect velocity but affect growth in opposite ways (Section 4.3). This allows both shocks to get picked up by the shock construction process (Appendix), thereby inducing a large role for the shocks in the velocity variation and a subsequently less procyclic velocity as the goods productivity shock is relatively less important. The velocity variance decomposition for post-1972 data show all three shocks playing large roles that vary by subperiod. Money shocks have the largest effect during the high inflation period of 1972-1982, as might be expected; credit shocks are relatively more important during the financial deregulatory period of 1983-1995, also as expected (Section 4.4). The results are discussed relative to other velocity studies (Section 4.5), with conclusions (Section 4.6).

4.2 Endogenous Growth with Credit

The representative agent economy is an endogenous growth extension of Benk, Gillman, and Kejak (2005a), with a Lucas (1988) human capital investment technology causing growth. The agent allocates resources amongst three sectors: goods production, human capital investment, and exchange credit production as a means to avoid the inflation tax. There are three random shocks at the beginning of the period, observed by the consumer before the decision process, which follow a vector first-order autoregressive process for goods sector productivity, z_t, the money supply growth rate, u_t, and credit sector productivity, v_t :

$$Z_t = \Phi_Z Z_{t-1} + \varepsilon_{Zt} \tag{4.1}$$

where the shocks are $Z_t = [z_t \; u_t \; v_t]'$, the autocorrelation matrix is $\Phi_Z = diag\{\varphi_z, \varphi_u, \varphi_v\}$ and $\varphi_z, \varphi_u, \varphi_v \in (0,1)$ are autocorrelation parameters, and the shock innovations are $\varepsilon_{Zt} = [\epsilon_{zt} \; \epsilon_{ut} \; \epsilon_{vt}]' \sim N(\mathbf{0}, \mathbf{\Sigma})$. The general structure of the second-order moments is assumed to be given by the variance-covariance matrix $\mathbf{\Sigma}$. These shocks affect the economy as described below.

The representative agent's period t utility over consumption c_t and leisure x_t is $\frac{(c_t x_t^{\Psi})^{1-\theta}}{1-\theta}$, with $\theta \geq 0$ and $\Psi > 0$. Output of goods (y_t) is produced with physical capital (k_t) that depreciates at the rate δ_k and with effective labor, through Cobb-Douglas production functions. Investment (i_t) is given by the accumulation equation $k_{t+1} = (1-\delta_k)k_t + i_t$. A unit of time is divided amongst leisure (x_t) and work in goods production (l_t), human capital investment (n_t), and exchange credit production (f_t):

$$1 = x_t + l_t + n_t + f_t. \tag{4.2}$$

With h_t denoting human capital, the effective labor employed across sectors is $l_t h_t$, $n_t h_t$, and $f_t h_t$ respectively. Given $A_H > 0$, $\delta_h \geq 0$, human capital accumulates with a labor-only technology (Lucas 1988):

$$h_{t+1} = (1-\delta_h)h_t + A_H n_t h_t. \tag{4.3}$$

Let $a_t \in (0,1]$ denote the fraction of consumption goods that are purchased with money (M_t); then the exchange constraint can be expressed as

$$M_t + T_t \geq a_t P_t c_t, \tag{4.4}$$

where M_t is the money stock carried from the previous period and T_t is the nominal lump-sum money transfer received from the government at the beginning of the current period. Exchange credit (q_t) is produced by the consumer acting in part as a bank to provide a means to pay for the rest of the purchases, without having to hold cash in advance of trading, and instead paying off the debt at the end of the period; this gives that

$$q_t = c_t\,(1 - a_t)\,. \tag{4.5}$$

The consumer deposits all income that is not invested, of $y_t - i_t = c_t$, in its bank, makes purchases of goods c_t with the cash and credit taken out of deposits d_t, where $d_t = [(M_t + T_t)/P_t] + q_t = a_t c_t + (1 - a_t)\,c_t = c_t$. As a bank, the consumer uses a case of the now-standard Clark (1984) financial services technology to produce the exchange credit q_t. Clark assumes a constant returns to scale function in labor, physical capital, and financial capital that equals deposited funds.[1] Here for simplicity no physical capital enters; with $A_F > 0$ and $\gamma \in (0,1)$, the CRS production technology is $q_t = A_F e^{v_t}\,(f_t h_t)^{\gamma}\,d_t^{1-\gamma}$, where v_t is the shock to factor productivity; since deposits equal consumption, this can be written as

$$q_t = A_F e^{v_t}\,(f_t h_t)^{\gamma}\,c_t^{1-\gamma}. \tag{4.6}$$

Solving for q_t/c_t from equation (4.6), substituting this into the relation $a_t = 1-(q_t/c_t)$ from equation (4.5), and substituting this relation for a_t back into the exchange constraint (4.4), yields an exchange constraint analogous to a shopping time constraint as extended to endogenous growth:[2]

$$M_t + T_t \geq [1 - A_F e^{v_t}\,(f_t h_t/c_t)^{\gamma}]\,P_t c_t. \tag{4.7}$$

Let w_t and r_t denote competitive wage and rental rates. Nominal wages ($P_t w_t l_t h_t$) and rents ($P_t r_t k_t$) plus any unspent cash ($M_t + T_t - a_t P_t c_t$), make up the consumer's income, while set-aside cash (M_{t+1}) plus end-of-period credit debt payments $[c_t\,(1 - a_t)]$, and investment (i_t) are expenditures:

$$P_t w_t l_t h_t + P_t r_t k_t + T_t + M_t - M_{t+1} - P_t c_t - P_t k_{t+1} + P_t(1-\delta_k)k_t \geq 0. \tag{4.8}$$

The government transfers a random amount T_t given by

$$\frac{T_t}{M_t} = \Theta_t = \Theta^* + e^{u_t} - 1 = \frac{M_{t+1}}{M_t} - 1, \tag{4.9}$$

so that Θ^* is the stationary gross growth rate of money.

[1] Many studies have empirically verified this CRS specification including deposits as the third factor, and this specification has become dominant in current work, for example Wheelock and Wilson (2006).

[2] Solve $f_t h = g(c_t, M_{t+1}/P_t)$. Then the main shopping time restrictions follow: that $g_1 \geq 0$ and $g_2 \leq 0$, as shown in Gillman and Yerokhin (2005); but here the specification of $f_t h$ results from the credit technology rather than a pre-determined interest elasticity of money demand as in shopping time models.

The competitive firm maximizes profit given by $y_t - w_t l_t h_t - r_t k_t$, with production technology $y_t = A_G e^{z_t} k_t{}^{1-\alpha}(l_t h_t)^{\alpha}$. Then

$$w_t = \alpha A_G e^{z_t} \left(\frac{k_t}{l_t h_t}\right)^{1-\alpha}; \tag{4.10}$$

$$r_t = (1-\alpha) A_G e^{z_t} \left(\frac{k_t}{l_t h_t}\right)^{-\alpha}. \tag{4.11}$$

Definition of Equilibrium Denoting the state of the economy by $s = (k, h, M, z, u, v)$, and with $\beta \in (0,1)$, the representative agent's optimization problem can be written in a recursive form as:

$$V(s) = \max_{c,x,l,n,f,k',h',M'} \left\{ \frac{(cx^{\Psi})^{1-\theta}}{1-\theta} + \beta EV(s') \right\} \tag{4.12}$$

subject to the conditions (4.2), (4.3), (4.7) and (4.8). Define the competitive equilibrium as a set of policy functions $c(s)$, $x(s)$, $l(s)$, $n(s)$, $f(s)$, $k'(s)$, $h'(s)$, $M'(s)$, pricing functions $P(s)$, $w(s)$, $r(s)$ and the value function $V(s)$, such that (i) households maximize utility $V(s)$, given the pricing functions and that the policy function $V(s)$ solves the functional equation (4.12); (ii) firms maximize profits, with the functions w and r given by (4.10) and (4.11); (iii) the goods and money markets clear, in equations (4.8) and (4.9).

Description of Equilibrium Here the focus is on the effects of shocks on velocity, the output growth rate, and the capital to effective labor ratio across sectors. Equilibrium money demand, and its velocity, is solved primarily from the first-order condition with respect to the choice of hours employed in credit production, this being the additional condition compared to a cash-only economy. Combined with equations (4.4) to (4.7), and other conditions to determine the constraint multipliers, the consumption-normalized money demand is given by

$$\frac{M_{t+1}}{P_t c_t} = a_t = 1 - (A_F e^{v_t})^{1/(1-\gamma)} \left(\frac{\gamma R_t}{w_t}\right)^{\gamma/(1-\gamma)}. \tag{4.13}$$

A positive money supply growth rate shock increases R_t through its inflation rate component and lowers normalized money demand (raises consumption velocity). A positive credit productivity shock v_t reduces money demand directly (raises consumption velocity). A positive goods productivity shock increases w_t and R_t through equations (4.10) and (4.11), and the Fisher equation of interest rates, by which the real interest rate r_t affects the nominal interest rate R_t; the net effect on R_t/w_t is small since there is no effect of this shock on r_t/w_t.

The interest elasticity magnitude (denoted η, where w_t is held constant) is $\eta = [\gamma/(1-\gamma)](1-a_t)/a_t$; this rises with R_t as in the Cagan (1956) model; $\partial\eta/\partial R = \frac{\eta\gamma}{aR(1-\gamma)} > 0$. With the baseline calibration values of $a = 0.224$, and $\gamma = 0.13$, then at $R = 0.10$, the interest elasticity is -0.52. The importance of the elasticity can be seen by considering that there is a bigger increase in velocity from an interest rate increase, the higher is the interest rate (and elasticity); $\partial^2(1/a)/\partial R^2 = \frac{\eta}{(aR)^2}\frac{2\gamma-a}{1-\gamma} > 0$ for $a < 2\gamma = 0.26$, and w constant. And also a credit shock causes a bigger change in velocity the higher is the interest rate (and elasticity); with w and R constant, $\partial(1/a)/\partial v_t = \frac{\eta}{\gamma a} > 0$ for $R > 0$; and with w constant, $\partial^2(1/a)/\left(\partial R \partial v_t\right) > 0$ for $R > 0$. This can explain, for example, why there would be a large response to the model's velocity from deregulation in the early 1980s when interest rates were higher: nominal interest rates fell rapidly after 1981 but velocity stayed high as deregulation began.

Note that in Cooley and Hansen (1995), the comparable normalized money demand is equal to $\phi / \left[1 + R\left(1 - \phi\right)\right]$, where ϕ is a preference parameter for cash goods. A positive money supply shock and goods productivity shock both increase R and reduce the money demand; but with their calibrated value of $\phi = 0.84$, and say $R = 0.10$, the interest elasticity of the normalized money demand is -0.016, compared to -0.52 in our model.

The total effect on income velocity depends not only on $\frac{M_{t+1}}{P_t c_t}$ but also on the income-consumption ratio: $V_t \equiv \frac{y_t}{M_{t+1}/P_t} = \left(\frac{P_t c_t}{M_{t+1}}\right)\frac{y_t}{c_t}$. To the extent that income rises temporarily from a goods productivity shock, y_t/c_t will increase, increasing velocity as in Cooley and Hansen (1995) and Friedman and Schwartz (1963b).[3] With the impact of credit and money shocks on $\frac{P_t c_t}{M_{t+1}}$, the temporary income channel can be of relatively less importance.

Shocks to velocity effect the growth rate (g) through the effect on the percent of labor employed $(1-x)$; this can be seen intuitively by deriving the balanced-path growth rate as $1 + g = \left(\beta\left[1 + A_H\left(1 - x\right) - \delta_h\right]\right)^{1/\theta}$ and the marginal rate of substitution between goods and leisure as $\frac{x}{\Psi c} = \frac{1 + aR + (1-a)\gamma R}{wh}$. A positive money shock increases R and the goods shadow price $\left[1 + aR + \left(1 - a\right)\gamma R\right]$ relative to the leisure shadow price w, induces substitution from goods (c/h) towards leisure (x), and decreases the growth rate; a positive credit shock in reverse decreases the cost of exchange, induces substitution from x towards c/h, increases the employment rate $(1-x)$ and g.

Shocks to velocity also involve a Tobin effect on input price and quantity ratios (see Gillman and Kejak (2005)). A positive money shock causes more leisure, an increase in w/r, and an increase in the capital to effective labor ratio $\frac{k}{lh}$; since it is also true that $1 + g = \left[\beta\left(1 + r - \delta_k\right)\right]^{1/\theta}$, the fall in r goes in tandem with the fall in the marginal product of human capital, $A_H(1-x)$. A positive credit shock conversely decreases w/r and $\frac{k}{lh}$, and increases g. A goods productivity shock directly increases r and g.

4.3 Impulse Responses and Simulations

Standard solution techniques can be applied once growing real variables are normalized by the stock of human capital so that all variables in the deterministic version of the model converge to a constant steady state. We define $\tilde{c} \equiv c/h$, $\tilde{i} \equiv i/h$, $\tilde{k} \equiv k/h$, $\tilde{m} \equiv M/Ph$ and $\tilde{s} \equiv (\tilde{k}, 1, 1, z, u, v)$, log-linearize the equilibrium conditions of the transformed model around its deterministic steady state, and use standard numerical solution methods.

The calibration uses standard parameters for the goods production labor share of $\alpha = 0.6$, a factor productivity normalized at $A_G = 1$, capital depreciation of $\delta_k = 0.012$ and $\delta_h = 0.012$, leisure preference of $\Psi = 3.2$, consumption

[3] Such an effect from y_t/c_t on velocity is included econometrically for US data in Gillman, Siklos, and Silver (1997).

elasticity of $\theta = 2$, and time preference of $\beta = 0.99$. The human capital sector is labor only, with factor productivity of $A_H = 0.12$. Time division at baseline is that leisure's share is 0.70, goods production time 0.16, and human capital investment time 0.14; labor in credit production is 0.0008, or 0.0008/0.3=0.27% of total productive time.

For nominal factors, the consumption velocity of money is set to the 1972-2003 average of the consumption velocity of M1, at 4.5 ($a = 0.224$). Shock characteristics are set to estimated values from the constructed shocks: persistences of $\varphi_z = 0.86$, $\varphi_u = 0.93$, $\varphi_v = 0.93$, standard deviations of $\sigma_{\varepsilon_z} = 2.39$, $\sigma_{\varepsilon_u} = 0.85$, $\sigma_{\varepsilon_v} = 1.9$, and correlations of $corr(\varepsilon_z, \varepsilon_u) = -0.03$, $corr(\varepsilon_z, \varepsilon_v) = -0.24$, $corr(\varepsilon_u, \varepsilon_v) = 0.85$. The credit sector productivity parameter is set at $A_F = 1.86$, and its Cobb-Douglas parameter γ is calibrated using financial industry data at $\gamma = 0.13$. The γ is calibrated by first noting that the Cobb-Douglas function implies a decentralized bank sector profit of $Rq\,(1-\gamma)$: since R is the unit credit equilibrium price (equal to the real wage divided by the marginal product of labor in credit production, or the marginal cost), profit equals $Rq - wfh$ subject to $q = A_F\,(fh)^{\gamma}\,d^{1-\gamma}$; by the CRS technology property, $\gamma Rq = wfh$; so $Rq(1-\gamma)$ is profit returned to the consumer (interest dividend on deposits); and γRq is the resource cost of the credit. Per unit of credit this is γR, so γ is the per unit cost of credit divided by R. Now, since credit is given by $q = c - m$, and $m = ac$, then $q = c(1-a)$ (equation 4.5). With the calibration of $a = 0.224$ then $q = c(1-0.224) = c(0.776)$. Then γ=(per unit credit cost)/$Rc(0.776)$. The estimate of 100 is used as the average annual cost over the data period at 2005 prices of an exchange credit card (American Express) and it is assumed to reflect the total interest costs of using the annual exchange credit (not roll-over intertemporal credit) for a single person (other ad-on charges such as penalties are not included). Then $\gamma = 100/Rc(0.776)$. Using US annual average data for 1972-2003, with $c = 15780$ at 2006 prices, being per capita consumption expenditure, and $R = 0.0627$ the 3-month Treasury Bill interest rate (annual basis), then $\gamma = 100/[(0.0627)15780(0.776) \simeq 0.13$.

Sensitivity to alternative values of γ affect mainly the relative effect of money versus credit shocks on velocity. A larger γ makes the interest elasticity of money demand higher, causes money shocks to affect velocity more, credit shocks to affect velocity less, and thereby increases the importance of the money shock relative to the credit shock. Our low calibrated value of γ thus could be viewed as on the conservative side of the importance of money shocks. And note that a value of γ greater than 0.5 is less plausible as this gives a concave marginal cost curve per unit of credit produced, rather than a convex marginal cost that applies for $\gamma < 0.5$ (Gillman and Kejak 2005).

The impulse responses (Figure 14.1show the effects of the shocks over time, and illustrate the discussion of the effects of shocks on the equilibrium in Section 4.2. A positive money shock (M) increases velocity (vel), causes an output growth rate (gY) decrease that persists for more than 50 periods, and an increase in the investment to output ratio, as in a positive Tobin effect. Opposite effects occur for a positive credit shock (CR) on the growth rate and investment ratio, with a positive effect on velocity. The productivity shock (PR) increases velocity, the output growth rate, and the investment ratio for a substantial time before the effect turns slightly negative and dies out.

Simulations show that the relative volatility of the output velocity of money, of 1.40, is 75% of the actual 1972-2003 average for the output velocity of M1,

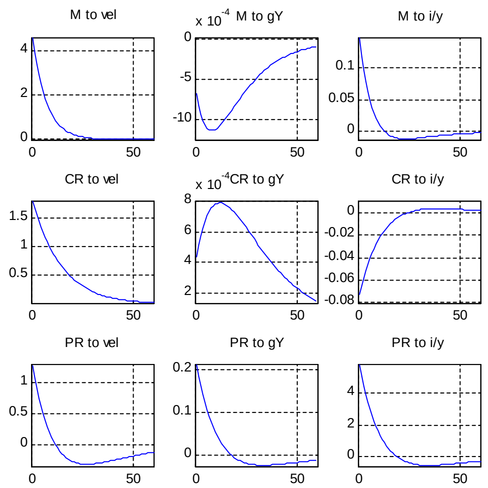

Figure 4.1: Impulse Responses: Velocity, Output Growth, Investment Ratio

of 1.88; this 75% substantially improves on previous work, such as less than 50% in Benk, Gillman, and Kejak (2005a), and 57% for the comparable case (of a relative risk aversion coefficient of 2 in Table 3) in Wang and Shi (2006). The model's contemporaneous correlation of velocity with the output ratio y/h is 0.07, lower that the comparable 0.24 found in the data (where data for h is described in the Appendix), rather than too high as in Cooley and Hansen (0.95 compared to 0.37 in their data sample). Also, Freeman and Kydland's (2000) simulation shows a real M1 correlation with real output of 0.98 compared to 0.26 in their 1979-1995 subsample. We have a 0.53 output correlation of m/h compared to the data's $(M1/P)/h$ output correlation of 0.31 for the 1972-2003 sample; plus, a 1.67 relative volatility of m/h versus 2.14 in data; a 0.85 correlation of c/h with output versus 0.79 in data; and a 0.59 relative volatility of c/h versus 1.03 in data. With only the goods productivity shock active, the c/h relative volatility is the same, but the velocity relative volatility drops by more than half to 0.56 and m/h volatility drops in half to 0.83; the model's ability to come close to the data for velocity and m/h depends on the money and credit shocks being operative.

4.4 Variance Decomposition Of Velocity

From the shock construction (see Appendix), a standard variance decomposition of velocity is conducted, similar to the variance decomposition for output described in Benk, Gillman, and Kejak (2005b) for an exogenous growth case. The endogenous and exogenous growth results are compared in Table 4.1, for the baseline (five-variable) case of the shock construction, with six possible orderings of the shocks, and for US quarterly data from 1972-2003; here the exogenous growth case used for comparison is the economy set out in Benk, Gillman, and Kejak (2005b). For the whole period, the table shows an average effect of 4%

Shock ordering			Endogenous model			Exogenous model		
CR	PR	M	79%	18%	3%	84%	16%	0%
CR	M	PR	84%	8%	8%	88%	5%	7%
PR	CR	M	5%	92%	3%	5%	95%	0%
M	CR	PR	84%	8%	8%	2%	88%	10%
M	PR	CR	84%	11%	5%	2%	16%	82%
PR	M	CR	5%	89%	6%	5%	14%	81%
Average			**PR**	**M**	**CR**	**PR**	**M**	**CR**
1972-2003			9%	45%	46%	10%	4%	86%
1972-1982			30%	50%	20%	29%	11%	60%
1983-1996			4%	48%	48%	7%	10%	83%
1997-2003			32%	31%	37%	33%	8%	59%

Table 4.1: Velocity Variance Decomposition, with Different Shock Orderings

for the money shock in exogenous growth but 45% for the endogenous growth model. The credit shock effect on velocity drops from 86% for the exogenous growth results to 46% in endogenous growth. The productivity shock explains an average of 9% of the variance in endogenous growth.

The table also breaks the period into subperiods of 1972-1982, 1983-1996, and 1997-2003. The first subperiod is when the high accelerating inflation rate took place, and credit was restrained by financial sector regulations. The money shock shows a 50% average share, more than twice that of the 20% for credit, while the productivity share is at 30%. In the next subperiod, when financial deregulation was taking place and the inflation rate was much lower but still variable, credit shocks had their highest effect at 48%; money shocks also had a 48% share. In the last subperiod, with a lower, more stable, inflation rate and a significantly deregulated financial market, the money and credit shocks had lower effects, and the goods shock a high of 32%.

The variance decompositions vary with the definition of the subperiod. For example, if the period of 1983-2003 is considered without further subperiods, the goods productivity share is 6% while money and credit shares are 47% and 47% respectively. This masks the fact that the goods productivity played a much bigger role in the latter part of the subperiod, with a share of 32% from 1997-2003, compared to 4% during 1983-1996.

What emerges is that the productivity shock, and the permanent income theory of velocity, takes on more importance during the latter subperiod when there are less episodes of large credit and money shocks. Money shocks are relatively important during the inflation acceleration and deceleration of the 1970s and 1980s; credit is relatively important during financial deregulation.

4.5 Discussion

Prescott (1987) presents a goods continuum with an exogenous division between cash and credit that Freeman and Kydland (2000) and Gillman (1993) make endogenous, resulting in an endogenous velocity. These models involve general transaction costs and a goods continuum that can be cumbersome relative to a more standard single-good model. Alternatively, the Section 4.2 model has a single good with a credit industry production function from banking microfoundations, allowing plausible credit shocks to sectoral productivity to be identified. This uses the producer side of banking rather than the consumer-side shopping time or trips-to-the bank: consider that with internet banking, shifting funds from savings to current accounts is nearly costless to consumers, and getting hold of cash is simple with ubiquitous cash machines or with debit cards at point of purchase, neither of which requires trips to the bank. However, the costs on the production side are real and measurable.

Hodrick, Kocherlakota, and Lucas (1991) use the cash-good, credit good, economy and find that velocity variability, coming from substitution between cash and credit goods, and from the precautionary demand for money when the exchange constraint is not binding, is not fit well relative to evidence for reasonable parameter values. In our model, the exchange constraint always binds, the shocks drive velocity variability, the velocity volatility is within 75% of actual, while the average velocity is matched exactly and parameter specifications are standard except for the credit sector. However a fitness-of-model comparison using the Hodrick et al. approach is not conducted and would be useful.[4]

Ireland (1996) specifies exogenous velocity shocks and productivity shocks, and shows how to maintain the Friedman optimum in the face of such shocks using various money supply regimes. In our model, with an endogenous velocity that is affected by various shocks, it would be interesting to derive how the effects on velocity could be offset through money supply rules in order to establish the optimum or, more topically, an inflation target.

4.6 Conclusion

The paper extends a standard monetary real business cycle by setting it within endogenous growth and adding credit sector shocks. A large portion of the variability of velocity found in the data is simulated in the model, an advance for the neoclassical exchange model. While the standard explanation focuses on the goods productivity shock only in explaining velocity in an exchange economy, here two other factors combine together to play an important role. Shocks to the money supply growth rate have a significant impact on velocity, especially during the high inflation period; credit shocks, found to have an important impact on GDP during the deregulatory era, for example in Benk, Gillman, and Kejak (2005a), also effect velocity strongly during this period. Thus while temporary income deviations can be dominant, as in Friedman and Schwartz's (1963b) permanent income hypothesis explanation of velocity, during times when money supply growth rates and credit markets are significantly shocked, these other factors can dominate swings in velocity.

The results suggest for example that episodes in monetary regimes could cause different degrees of money supply shocks. This can help explain why there might be higher inflation persistence in the 1970s and 1980s, and less such persistence during the inflation targeting period, a possible topic for future work. It might also be a useful extension of this methodology to examine jointly the effects of the shocks on GDP as well as on velocity with a view towards explaining whether having the credit outlet to increase velocity can take pressure off GDP volatility. If so this could be viewed as part of the Jermann and Quadrini (2006) thesis that financial deregulation and increases in finance

[4] See Basu and Dua (1996) for and Hamilton (1989) for other empirical considerations in testing velocity in related cash-good/credit-good models.

activity contributed to the post 1983 moderation in GDP, or even to moderations in GDP experienced in the 1930s and 1950s. Another extension could be to examine money and credit shocks in countries outside of the US. Transition countries, with large inflations post-1989 and subsequent banking deregulations, might also reveal significant roles for money and credit influences. Extension of the model to include intertemporal credit that is intermediated through a costly process similar to that of exchange credit would allow for financial shocks that are more of the banking crisis genre.

4.A Appendix: Construction of shocks

Based on the solution of the model from section 2, the log-deviations of the model variables be written as linear functions of the state $\widehat{s} = (\widehat{\tilde{k}}, z, u, v)$. By stacking the equations, the solution can be written in matrix form as $X_t = A\left[\begin{array}{c}\widehat{\tilde{k}}_t\end{array}\right] + B\left[\begin{array}{ccc} z_t & u_t & v_t \end{array}\right]'$, where $X = \left[\begin{array}{ccccccc}\widehat{\tilde{c}} & \hat{x} & \hat{l} & \hat{f} & \hat{a} & \widehat{\tilde{m}} & \widehat{\tilde{k}}' \end{array}\right]'$. Given the solution for matrices A and B, the series of shocks $\left[\begin{array}{ccc} z_t & u_t & v_t \end{array}\right]$ are constructed using data on at least three variables in X_t plus data for $\widehat{\tilde{k}}_t$, and then backing-out the solution for the shocks in each period. Identification of the three series of shocks requires at least three variables from X_t. More variables can be used, with the aim of finding robust solutions for the shocks; in this over-indentified case a least-square procedure is used. To do this, we use data for the state variable $\widehat{\tilde{k}}$, plus the normalized variables of $\widehat{c/y}$, $\widehat{i/y}$, $\widehat{m/y}$, $\hat{f}$ and $\widehat{mplb}$. Then we let $XX_t = AA\left[\begin{array}{c}\widehat{\tilde{k}}_t\end{array}\right] + BB\left[\begin{array}{ccc} z_t & u_t & v_t \end{array}\right]'$,where $XX = \left[\begin{array}{ccccc}\widehat{c/y} & \widehat{i/y} & \widehat{m/y} & \widehat{f} & \widehat{mplb}\end{array}\right]'$ and the rows of the matrices AA and BB result from the linear combinations of the corresponding rows of matrices A and B, where $mplb$ represents the marginal product of labor in banking from equation (4.6). Then the baseline estimated three shocks (est) are given by least squares as $est\left[\begin{array}{ccc} z_t & u_t & v_t \end{array}\right]'_t = (BB'BB)^{-1}BB'(XX_t - AA\left[\begin{array}{c}\widehat{\tilde{k}}_t\end{array}\right])$.

Here the data series on $\widehat{\tilde{k}}$, where $\tilde{k} = k/h$, and $\widehat{\tilde{k}}$ is its log deviation, is constructed with the capital accumulation equation and data on investment, giving $\widehat{\tilde{\imath}}_t$ (with $\widehat{\tilde{k}}_{-1} = 0$), and with the human capital series of Jorgenson and Stiroh (2000), extrapolated forward until 2003. We also use data on labor hours f from the Finance, Insurance and Real Estate sector (FIR), and the wage rate in FIR for the marginal product ($mplb$).

A crosscheck of the model calibration is to estimate the shock persistence parameters φ_z, φ_u and φ_v from the constructed shock series. For this reason we estimate a system from equation (4.1) by the method of seemingly unrelated regressions (SUR). The resulting estimates of the autocorrelation parameters are 0.86 (0.04), 0.93 (0.03) and 0.93 (0.03) respectively (with standard errors in parentheses), which equal the assumed values and thereby show internal consistency of the calibration. From this estimation, the cross-correlations and variances of the error terms are used in the model simulation in Section 3. The corresponding variance-covariance matrix $\mathbf{\Sigma}$ for equation (4.1) contains the following elements: $var(\epsilon_{zt}) = 5.698$, $var(\epsilon_{ut}) = 0.720$, $var(\epsilon_{vt}) = 3.617$; and $cov(\epsilon_{zt}, \epsilon_{ut}) = -0.056$, $cov(\epsilon_{zt}, \epsilon_{vt}) = -1.106$, $cov(\epsilon_{ut}, \epsilon_{vt}) = 1.376$.

Chapter 5

Volatility Cycles of Output and Inflation, 1919-2004: A Money and Banking Approach to a Puzzle

Joint with Max Gillman and Michal Kejak

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5.1 Introduction

Explaining changes in real output and in inflation has been done by focusing on short run factors. For example the standard is to estimate the effect of current monetary policy shocks with the shock restricted to be only in the short run. Yet studies continue to find that trend inflation is Granger caused by money, such as in Crowder (1998) for the US, and Assenmacher-Wesche and Gerlach (2008) for the Euro area in which the inflation-money causality is found for the medium and longer run. Econometric studies find a long run negative effect of inflation on growth, such as Fountas, Karanasos, and Kim (2006), who find this for the US, UK and Japan with Granger causality from inflation to growth. This suggests that money shocks may well have persistence that affects real variables over long periods of time. And as Muller and Watson (2008) conclude:

> Most macroeconomic series and relationships thus exhibit pronounced non-trivial dynamics below business-cycle frequencies...this underlies the importance of understanding the sources and implications of such low frequency volatility changes (p.1008).

Ignoring the long run impact of monetary policy also excludes a reputable inflation tax literature that starts with Bailey, 1956, and goes up to the inflation-induced goods to leisure substitution that decreases the endogenous output growth rate (Gomme 1993, Gillman and Kejak 2005). Benk, Gillman, and

Kejak (2008) apply these Lucas (1988) -based growth extensions to Cooley and Hansen (1989b) so as to include key likely shocks that affect the fluctuations of velocity: goods productivity, money supply, and credit shocks as in Benk, Gillman, and Kejak (2005b).

This paper includes long run features of the data and applies the Benk, Gillman, and Kejak (2008) framework to explain a puzzle: why the annual US volatility of inflation and output diverged downwards after 1983 away from the volatilities of velocity and money supply growth which moved upwards post-1983, after all four of these volatilities had moved together historically from 1919-1983 (Section 5.2). Rather than filtering out long run features of the shocks on the basis that they are unimportant to volatility, a minimal 86 year Christiano and Fitzgerald (2003) filter is used to obtain stationarity series, with windows for the short run, business cycle and long run as defined in Levy and Dezhbakhsh (2003), at 0-2 years, 3-8 years, and 8+ years respectively; the latter window is similar to the long run of Muller and Watson (2008).

Money shocks are found to have a significant effect on the volatility of endogenous growth rate of output and of inflation, as are the credit and goods productivity shocks, across the full frequency spectrum (Section 5.5). As in Ingram, Kocherlakota, and Savin (1994) and Benk, Gillman, and Kejak (2008), the parsimonious set of shocks are constructed from the equilibrium solution of the economy and from actual filtered data on equilibrium variables, including the state variable. These shocks are found to explain, on average across the four subperiods covering 1919-2004, about 50% of the output growth variability and 72% of the inflation variability, and with variation taking place in all three frequencies.

The explanation of the puzzle is that the model's implied credit shock volatility rose at the same time as velocity and money supply volatilities, suggesting that a greater volatility of credit during the financially deregulated period insulated the economy from inflation and GDP volatility. As a corollary, in contrast during the Depression period when credit was constrained by virtue of the bank failures, inflation and velocity variability were much higher than credit variability and monetary shocks could more easily translate into inflation and GDP shocks.

The puzzle's explanation is supported by simulation results that show a good ability of the model in explaining RBC and monetary relative volatilities and correlations, as compared to the data over the period (Section 5.4). Also supportive is that the model's credit shock correlation with the goods productivity shock changes from an historically negative sign, during the subperiods occurring from 1919-1983, to a positive sign during the Great Moderation subperiod of 1984-2004. And the standard deviation of the money shock is found to vary little across the four subperiods of the two cycles, indicating that indeed the money supply shock process can be viewed historically as part of a continuous monetary policy process in which shocks arise as part of a stable variance structure (Section 5.6).

The financial deregulation approach to the puzzle is not inconsistent with role of finance contributing to the Great Moderation as in Jermann and Quadrini (2006) or Perri and Quadrini (2008). And the long run contribution of the money shock to volatility is consistent with what Chari, Kehoe, and McGrattan (2008) argue needs to be a part of the monetary policy process in order to explain interest rate empirics. Ignoring this component, as well as ignoring the distortions along the labor-leisure margin, they argue result in a "dubiously" specified set of shocks with non-robust policy prognoses. In our economy, with the money supply as part of the shocks of the economy, and with credit productivity shocks associated with changes in banking laws, these shocks can affect the long run inflation rate, nominal interest rate and the leisure-labor margin as well as provide potentially a policy-related way in which important volatilities can rise and fall. Fluctuations in money-induced inflation taxes and in implicit taxes from banking regulation can affect the economy's margins.

5.2 Historical Trends

Viewing the historical volatility cycles reveals a volatility puzzle. US GDP and inflation rate volatilities rose steadily from the 1950s through the mid-1980s, and then subsequently decreased during the "Great Moderation", thereby creating a full volatility cycle. Preceding this volatility cycle was a larger rise and decline in these two volatilities in the period from 1919-1954, encompassing the Great Depression and WWII. Figures 1-4 show that inflation, its volatility, the money supply growth rate, money velocity volatility and GDP volatility all moved roughly together from 1919-1983. Post-1983, inflation and GDP volatility moved downwards together while money supply growth and velocity volatility diverged upwards.[1]

1) The absolute value of the inflation rate level and its volatility move together, as can be seen in Figure 5.1. That inflation is positively related to inflation uncertainty is supported in Fountas and Karanasos (2007) for the G7 countries.

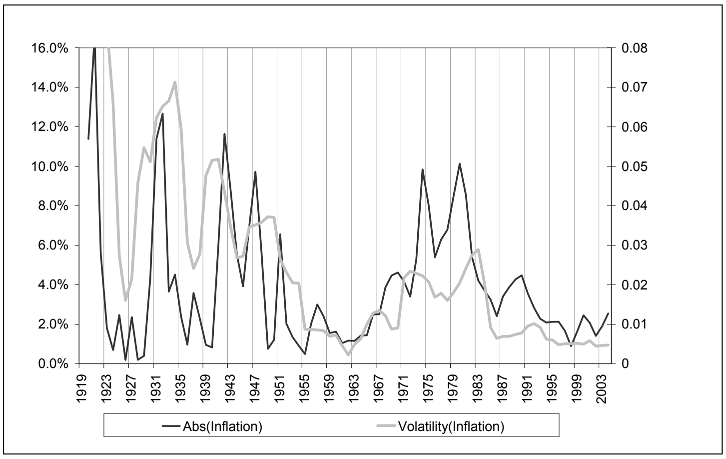

Figure 5.1: Absolute Value of Inflation and its Volatility, 1919-2004

2) The M1 money supply growth rate tracts inflation, as seen in Figure 5.2, although with prominent deviations post 1983. Here a 5-year moving average is used for money growth so as to focus on the trend.

[1] Volatility is calculated as the standard deviation of the variable over a certain window. For annual data it is a 7 year window; the formula is
$volatility(x_t) = SD(x_{t-k}, x_{t-k+1}, ...x_t, ..., x_{t+k-1}, x_{t+k})$, where $k = 3$.

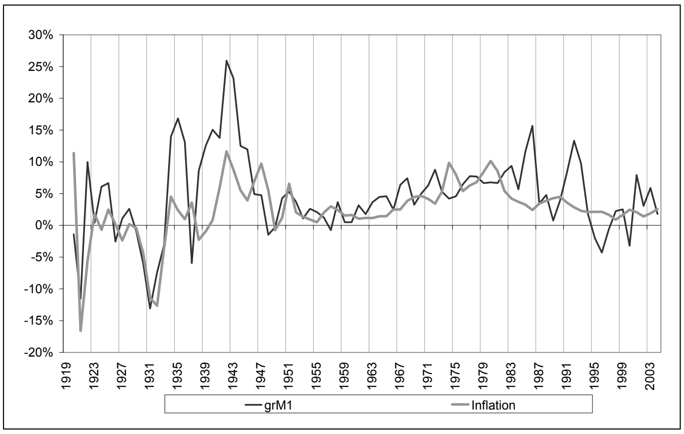

Figure 5.2: M1 Money Supply Growth (5-Yr MA) and Inflation, 1919-2004

3) Inflation volatility, GDP volatility, and GDP growth rate volatility moved together closely (except WWII); see Figure 3. There was a volatility cycle after WWI, that went up and down from the 1920s to the 1950s (with a double hump for GDP including WWII); there is another lower magnitude cycle, up and down, from the 1950s to 2000.[2]

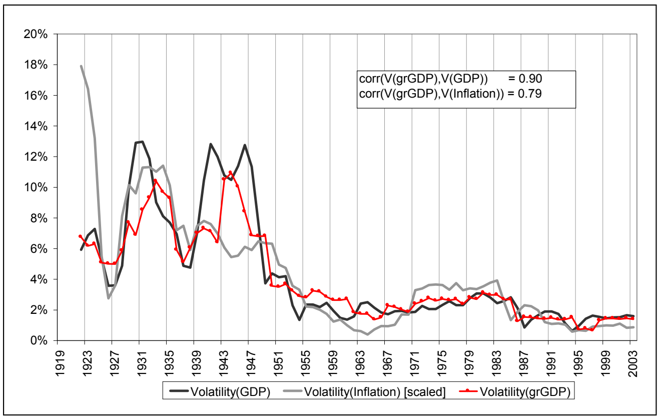

Figure 5.3: Volatilites of Inflation, GDP, and GDP Growth, 1919-2004

4) Lessor known, money velocity volatility and M1 growth rate volatility moved together and broadly followed inflation and GDP volatility up until 1983, when they together sharply diverged from the other two (Figure 5.4).

Together these facts suggest as historically plausible a priori the proposition that the money supply growth may partly cause inflation and its volatility, which is correlated with GDP volatility, while allowing for the possibility that

[2]Inflation volatility in Figures 5.3 and 5.4 is scaled by multiplying it by the average proportion difference between it and the GDP volatility for the 1919-2004 period. Standard data is used for GDP (described in Appendix 5.A.1); alternative experimentation with the Miron and Romer (1990) data found a larger volatility of GDP during the 1919-1939 period.

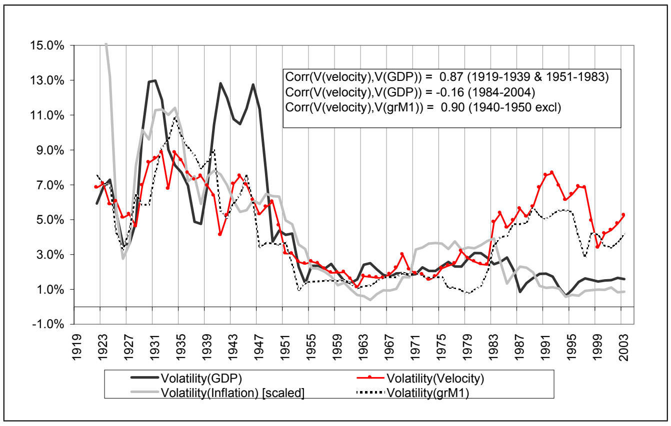

Figure 5.4: Volatilities of GDP, Inflation, Velocity and M1 Growth 1919-2004

the puzzling divergent increase in the volatility of money supply growth and money velocity post-1983 could be entangled with new credit instruments that enabled facile inflation avoidance after financial deregulation.

5.3 Stochastic Endogenous Growth with Banking

The representative agent economy is extended from Benk, Gillman, and Kejak (2008) by decentralizing the bank sector that produces credit. By combining the business cycle with endogenous growth, stationary inflation lowers the output growth rate as supported empirically for example in Gillman, Harris, and Matyas (2004) and Fountas, Karanasos, and Kim (2006). Over the business cycle, shocks cause changes in growth rates and in stationary ratios. The shocks to the goods sector productivity and the money supply growth rate are standard, while the third shock to the credit sector productivity exists by virtue of the model's endogeneity of money velocity via a micro-based production of exchange credit.

The shocks occur at the beginning of the period, observed by the consumer before the decision process, and follow a vector first-order autoregressive process. For goods sector productivity, z_t, the money supply growth rate, u_t, and bank sector productivity, v_t :

$$Z_t = \Phi_Z Z_{t-1} + \varepsilon_{Zt}, \tag{5.1}$$

where the shocks are $Z_t = [z_t \; u_t \; v_t]'$, the autocorrelation matrix is $\Phi_Z = diag\{\varphi_z, \varphi_u, \varphi_v\}$ and $\varphi_z, \varphi_u, \varphi_v \in (0,1)$ are autocorrelation parameters, and the shock innovations are $\varepsilon_{Zt} = [\epsilon_{zt} \; \epsilon_{ut} \; \epsilon_{vt}]' \sim N(\mathbf{0}, \mathbf{\Sigma})$. The general structure of the second-order moments is assumed to be given by the variance-covariance matrix $\mathbf{\Sigma}$. These shocks affect the economy as described below.

5.3.1 Consumer Problem

A representative consumer has expected lifetime utility from consumption of goods, c_t, and leisure, x_t; with $\beta \in (0,1)$ and $\theta > 0$, this is given by

$$U = E_0 \sum_{t=0}^{\infty} \beta \frac{(c_t x_t^{\Psi})^{1-\theta}}{1-\theta}. \tag{5.2}$$

Output of goods, y_t, and increases in human capital, are produced with physical capital and effective labor each in Cobb-Douglas fashion; the bank sector produces exchange credit using labor and deposits as inputs. Let s_{Gt} and s_{Ht} denote the fractions of physical capital that the agent uses in the goods production (G) and human capital investment (H), whereby

$$s_{Gt} + s_{Ht} = 1. \tag{5.3}$$

The agent allocates a time endowment of one amongst leisure, x_t, labor in goods production, l_t, time spent investing in the stock of human capital, n_t, and time spent working in the bank sector, denoted by f_t:

$$l_t + n_t + f_t + x_t = 1. \tag{5.4}$$

Output of goods can be converted into physical capital, k_t, without cost and so is divided between consumption goods and investment, denoted by i_t, net of capital depreciation. Thus, the capital stock used for production in the next period is given by:

$$k_{t+1} = (1-\delta_k)k_t + i_t = (1-\delta_k)k_t + y_t - c_t. \tag{5.5}$$

The human capital investment is produced using capital $s_{Ht}k_t$ and effective labor $n_t h_t$ (King and Rebelo 1990):

$$H(s_{Ht}k_t, n_t h_t) = A_H (s_{Ht}k_t)^{1-\eta}(n_t h_t)^{\eta}. \tag{5.6}$$

And the human capital flow constraint is:

$$h_{t+1} = (1-\delta_h)h_t + H(s_{Ht}k_t, n_t h_t). \tag{5.7}$$

With w_t and r_t denoting the real wage and real interest rate, the consumer receives nominal income of wages and rents, $P_t w_t (l_t + f_t) h_t$ and $P_t r_t (s_{Gt} + s_{Qt}) k_t$, a nominal transfer from the government, T_t, and dividends from the bank.

The consumer buys shares in the bank by making deposits of income at the bank. Each dollar deposited buys one share at a fixed price of one, and the consumer receives the residual profit of the bank as dividend income in proportion to the number of shares (deposits) owned. Denoting the real quantity of deposits by d_t, and the dividend per unit of deposits as R_{Qt}, the consumer receives a nominal dividend income of $P_t R_{Qt} d_t$. The consumer also pays to the bank a fee for credit services, whereby one unit of credit service is required for each unit of credit that the bank supplies the consumer for use in buying goods. With P_{Qt} denoting the nominal price of each unit of credit, and q_t the real quantity of credit that the consumer can use in exchange, the consumer pays $P_{Qt} q_t$ in credit fees.

With other expenditures on goods, of $P_t c_t$, and physical capital investment, $P_t k_{t+1} - P_t(1-\delta_k)k_t$, and on investment in cash for purchases, of $M_{t+1} - M_t$, the consumer's budget constraint is

$$\begin{aligned} & P_t w_t (l_t + f_t) h_t + P_t r_t s_{Gt} k_t + P_t R_{Qt} d_t + T_t \\ \geq \quad & P_{Qt} q_t + P_t c_t + P_t k_{t+1} - P_t(1-\delta_k)k_t + M_{t+1} - M_t. \end{aligned} \tag{5.8}$$

The consumer can purchase the goods by using either money M_t or credit services. With the lump sum transfer of cash T_t coming from the government at the beginning of the period, and with money and credit equally usable to buys goods, the consumer's exchange technology is

$$M_t + T_t + P_t q_t \geq P_t c_t. \tag{5.9}$$

Since all cash comes out of deposits at the bank, and credit purchases are paid off at the end of the period out of the same deposits, the total deposits are equal to consumption. This gives the constraint that

$$d_t = c_t. \tag{5.10}$$

Given k_0, h_0, and the evolution of M_t $(t \geq 0)$ as given by the exogenous monetary policy in equation (5.18) below, the consumer maximizes utility subject to the budget,exchange and deposit constraints (5.8)-(5.10).

5.3.2 Banking Firm Problem

The bank produces credit that is available for exchange at the point of purchase. The bank determines the amount of such credit by maximizing its dividend profit subject to the labor and deposit costs of producing the credit. The production of credit uses a constant returns to scale technology with effective labor and deposited funds as inputs. This follows the "financial intermediation approach" (Matthews and Thompson 2008) that is dominant in the banking literature, which was started by Clark (1984) and Hancock (1985). In particular, with $A_F > 0$ and $\gamma \in (0,1)$,

$$q_t = A_F e^{v_t} (f_t h_t)^{\gamma} d_t^{1-\gamma}, \tag{5.11}$$

where $A_F e^{v_t}$ is the stochastic factor productivity. [3]

Subject to the production function in equation (5.11), the bank maximizes profit Π_{Qt} with respect to the labor f_t and deposits d_t:

$$\Pi_{Qt} = P_{Qt} q_t - P_t w_t f_t h_t - P_t R_{Qt} d_t. \tag{5.12}$$

[3] This "banking time" model can be interpreted as a special case of the shopping time model: substituting q_t from equation (5.11) into equation (5.9), and for d_t from equation (5.10), and solving for the effective banking time as $f_t h_t = \left(\frac{c_t - m_t}{A_F e^{v_t} c_t^{1-\gamma}} \right)^{1/\gamma}$, with $(M_t + T_t)/P_t \equiv m_t$, then $f_t h_t = g(m_t, c_t)$, with $g_1 < 0$ and $g_2 > 0$, as in a shopping time model. However there is no Feenstra (1986) equivalence to a standard money-in-the-utility function model because then h_t would enter the utility function, as seen by solving for the raw bank time $f_t = \hat{g}(m_t, c_t) h_t$, substituting for f_t in the allocation of time constraint (5.4), solving for x_t from this time constraint and substituting into the utility function.

Equilibrium implies that

$$\left(\frac{P_{Qt}}{P_t}\right)\gamma A_F e^{v_t}\left(\frac{f_t h_t}{d_t}\right)^{\gamma-1} = w_t; \tag{5.13}$$

$$\left(\frac{P_{Qt}}{P_t}\right)(1-\gamma)\,A_F e^{v_t}\left(\frac{f_t h_t}{d_t}\right)^{\gamma} = R_{Qt}. \tag{5.14}$$

These indicate that the marginal cost of credit, $\left(\frac{P_{Qt}}{P_t}\right)$, is equal to the marginal factor price divided by the marginal factor product, or $\frac{w_t}{\gamma A_F e^{v_t}\left(\frac{f_t h_t}{d_t}\right)^{\gamma-1}}$, and that the zero profit dividend yield paid on deposits is equal to the fraction of the marginal cost given by $\left(\frac{P_{Qt}}{P_t}\right)(1-\gamma)\left(\frac{q_t}{d_t}\right)$.

5.3.3 Goods Producer Problem

The firm maximizes profit given by $y_t - w_t l_t h_t - r_t s_{Gt} k_t$, subject to a standard Cobb-Douglas production function in effective labor and capital:

$$y_t = A_G e^{z_t}(s_{Gt}k_t)^{1-\alpha}(l_t h_t)^{\alpha}. \tag{5.15}$$

The first order conditions for the firm's problem yield the following expressions for the wage rate and the rental rate of capital:

$$w_t = \alpha A_G e^{z_t}\left(\frac{s_{Gt}k_t}{l_t h_t}\right)^{1-\alpha}, \tag{5.16}$$

$$r_t = (1-\alpha)A_G e^{z_t}\left(\frac{s_{Gt}k_t}{l_t h_t}\right)^{-\alpha}. \tag{5.17}$$

5.3.4 Government Money Supply

It is assumed that the government policy includes sequences of nominal transfers which satisfy:

$$T_t = \Theta_t M_t = (\Theta^* + e^{u_t} - 1)M_t, \qquad \Theta_t = [M_t - M_{t-1}]/M_{t-1}. \tag{5.18}$$

where Θ_t is the growth rate of money and Θ^* is the stationary gross growth rate of money.

5.3.5 Definition of Competitive Equilibrium

The representative agent's optimization problem can be written recursively as:

$$V(s) = \max_{c,x,l,n,f,s_G,q,d,k',h',M'}\left\{\frac{(c_t x_t^{\Psi})^{1-\theta}}{1-\theta} + \beta EV(s')\right\} \tag{5.19}$$

subject to the conditions (5.3) to (5.10), where the state of the economy is denoted by $s = (k, h, M, z, u, v)$ and a prime (') indicates the next-period values. A competitive equilibrium consists of a set of policy functions $c(s)$, $x(s)$, $l(s)$, $n(s)$, $f(s)$, $s_G(s)$, $s_H(s)$, $q(s)$, $d(s)$, $k'(s)$, $h'(s)$, $M'(s)$, pricing functions $P(s)$, $w(s)$, $r(s)$, $R_Q(s)$, $P_Q(s)$ and a value function $V(s)$, such that:

(i) the consumer maximize utility, given the pricing functions and the policy functions, so that $V(s)$ solves the functional equation (5.19);

(ii) the bank firm maximizes profit similarly in equation (5.12) subject to the technology of equation (5.11)

(iii) the goods producer maximizes profit similarly, with the resulting functions for w and r being given by equations (5.16) and (5.17);

(iv) the goods, money and credit markets clear, in equations (5.11), (5.15) and (5.18).

5.3.6 Balanced-Growth Path Equilibrium

As derived from the equilibrium above, a partial set of equilibrium conditions along the balanced-growth path (BGP) are given here to describe the deterministic balanced-growth path equilibrium, and how inflation affects it. The balanced-growth rate is denoted by g, and dropping time subscripts on stationary variables the BGP conditions are

$$\left(\frac{P_{Qt}}{P_t}\right) = R; \tag{5.20}$$

$$1 + R = (1+\pi)\left(1 + r - \delta_k\right); \tag{5.21}$$

$$\frac{x}{\alpha c_t} = \frac{1+\tilde{R}}{wh_t}; \tag{5.22}$$

$$\tilde{R} = \left(1 - \frac{q_t}{d_t}\right) R + \left(\frac{q_t}{d_t}\right)\gamma R; \tag{5.23}$$

$$\frac{q_t}{d_t} = 1 - \left(A_F e^{v_t}\right)^{\frac{1}{1-\gamma}} \left(\frac{\gamma R}{w}\right)^{\frac{\gamma}{1-\gamma}}; \tag{5.24}$$

$$r_H \equiv \varepsilon A_H \left(\frac{s_H k_t}{l_H h_t}\right)^{(1-\varepsilon)} (1-x); \tag{5.25}$$

$$(1+g)^{\theta} = \frac{1 + r_H - \delta_H}{1+\rho} = \frac{1 + r - \delta_K}{1+\rho}. \tag{5.26}$$

The relative price of credit is its marginal cost and by equation (5.20) this is equal to the nominal interest rate. At the optimum, the nominal interest R of equation (5.21) equals zero and no credit is used. But as inflation rises, the agent substitutes from goods towards leisure while equalizing the margin of the ratio of the shadow price of goods to leisure, $x/(\alpha c_t) = \left[1 + \tilde{R}\right] / (wh_t)$, in equation (5.22). Here $\tilde{R}$, as given in equation (5.23), is the average exchange cost per unit of output; this equals the average cost of using cash, R, weighted by $1 - \frac{q_t}{d_t}$ and the average cost of using credit, γR, weighted by $\frac{q_t}{d_t}$. That γR_t is an average cost can be verified by dividing the total cost of credit production by the total output of credit production. And this total exchange cost determines how much substitution there is from money to credit, and from goods to leisure. The solution for consumption-normalized money demand, $1 - \frac{q_t}{c_t}$, is derived from equation (5.9), (5.10) and (5.24); from here it is clear that the consumption velocity of money, denoted by $v_t \equiv \frac{c_t}{\frac{M_t}{P_t}}$, rises at an increasing rate as the nominal interest rate rises (see Gillman and Kejak, 2005).

Inflation-induced substitution towards leisure causes a fall in the human capital return of $r_H \equiv \varepsilon A_H (s_H k_t / l_H h)^{(1-\varepsilon)}(1-x)$, given in equation (5.25). The marginal product of physical capital r, in equation (5.17), also falls, while the real wage w in equation (5.16) rises. This causes a Tobin (1965)-type substitution from labor to capital across both goods and human capital investment sectors in response to the higher real wage to real interest rate ratio; the Tobin (1965) like rise in $s_H k_t / l_H h_t$ mitigates but does not reverse the fall in the return to human capital r_H caused by the increase in leisure. The growth rate, in equation (5.26), falls as R rises since both r_H and r fall. But as the inflation rate continues to rise, the credit substitution channel allows the growth rate to decline at a decreasing rate, as increasingly more credit and less leisure are used as the substitute for the inflation-taxed good (Gillman and Kejak 2005).

5.4 Model Simulation

5.4.1 Calibration

Table 5.1 presents the parameters for the calibration which are chosen in order to match the Table 5.2 target values of certain variables; the targets are the average annual values from US time series for 1919-2004. These values reflect issues raised by Gomme and Rupert (2007), in their study of the two sector real business cycle model, in that our human capital sector is a second sector with some comparison to the household sector in Gomme and Rupert.

The capital share in the goods sector is set at $1 - \alpha = 0.36$ as in Jones, Manuelli, and Siu (2005), the annual discount factor is set at $\beta = 0.96$, and log-utility is assumed so that $\theta = 1$. The US average annual output growth rate g is set at 2.4% as in the data. The baseline investment to output ratio target value is $i/y = 0.26$. For comparison this is 0.13 in Gomme, Ravikumar, and Rupert (2006) for postwar market structures, equipment and software. But also including consumer durables in Gomme, Ravikumar, and Rupert (2006) adds 0.10, and housing adds another 0.056, for a postwar total of 0.29. Our education sector will include some of this investment, causing a rate less than 0.29. However, there are alternative ways to measure i/y as discussed in Gomme and Ruppert. The 0.26 value implies that the annual depreciation rate of capital is $\delta_K = 0.031$. In turn this gives the goods sector capital to effective labor ratio and the real interest rate net of depreciation of $r - \delta_K = 0.067$.

The rate of depreciation of human capital is set at $\delta_H = 0.025$ as in Jones, Manuelli, and Siu (2005) and Jorgenson and Fraumeni (1989). The allocation of time is similar to Gomme and Rupert (2007), with the working time set at $l = 0.24$ and leisure at $x = 0.55$. Time in human capital investment is set at $n = 0.2$. Given n, g, and δ_H and equation (5.7) implies the capital to effective labor ratio in the human capital sector and so the value of the capital share in the education sector, which is $\varepsilon = 0.83$. The chosen values imply $A_H = 0.21$, with the weight on the leisure in the utility function given by $\psi = 1.84$.

In the banking sector we set the value of the inverse of the consumption velocity of money, m/c, equal to the average annual value for the period 1919-2004, which is 0.38. The average annual inflation rate, π, over the same period is 2.6% which implies that the annual money growth, σ, is equal to 5%. Using an approximate cost of an exchange credit card (American Express) at \$100,

Preferences		
θ	1	Relative risk aversion parameter
ψ	1.84	Leisure weight
β	0.96	Discount factor
Goods Production		
α	0.64	Labor share in goods production
δ_K	0.031	Depreciation rate of goods sector
A_G	1	Goods productivity parameter
Human Capital Production		
ε	0.83	Labor share in human capital production
δ_H	0.025	Depreciation rate of human capital sector
A_H	0.21	Human capital productivity parameter
Banking Sector		
γ	0.11	Labor share in credit production
A_F	1.1	Banking productivity parameter
Government		
σ	0.05	Money growth rate
Shocks processes		
	Autocorrelation parameters	
φ_z	0.84	Production productivity
φ_u	0.74	Money growth rate
φ_v	0.73	Banking productivity
	Variances	
σ_z	0.77	Production productivity
σ_u	0.50	Money growth rate
σ_v	1.16	Banking productivity

Table 5.1: Parameters of Calibration

and the per capita annual consumption expenditure, $c = \$15780$, both at 2006 prices, the share of the labor in the banking sector is $\gamma = 100/[R(1-[m/c])c] = 0.11$ (for further details see the calibration in Benk, Gillman, and Kejak (2008)).

Table 5.1 also includes the parameters characterizing the shock processes of equation (5.1); these are chosen through an iterative process by which the assumed shock parameters converge with the actual shock parameters that are in turn estimated from the constructed shock processes described in Appendix A3. In particular, estimated parameters are inputed back into the model, shocks are re-constructed and parameters re-estimated until convergence is achieved in the parameter structure.

5.4.2 Effects of Shocks on Output Growth and Inflation

In order to solve the model, we log-linearize the equilibrium conditions of the model around its deterministic steady state, with variables that grow along the balanced-path normalized to stationary variables by dividing them by the human capital stock h_t. The impulse responses of the shocks are given in the Appendix in Figures 13-18. The initial impact of the shocks in the first period involves no change in the capital stocks, so that starting from the BGP equilibrium the changes in levels go in the same direction as the changes in growth

g	0.024	Avg. annual output growth rate
π	0.026	Avg. annual inflation rate
l	0.248	Labor used in goods sector
n	0.20	Labor used in human capital sector
f	0.0018	Labor used in banking sector
i/y	0.26	Investment-output ratio in goods sector
m/c	0.38	Share of money transactions

Table 5.2: Target Values of Calibration

rates. And the percentage changes of non-state variables like consumption are equal to the changes of the related normalized values. Indicating the percentage deviation from the balanced growth path by $\widehat{\ }$, then for example this means that $\widehat{c_t} = \widehat{(c_t/h_t)}$.

A positive money growth shock, $u_t > 0$, causes the inflation rate and nominal interest rate to deviate upwards; $\widehat{\pi_t} > 0$, $\widehat{R_t} > 0$. Consumption declines on impact of the shock, so that $\widehat{c_t} < 0$, because of the increased shadow price $\widehat{\tilde{R}_t} > 0$. Investment drops some; $\widehat{i_t} < 0$. And so output drops as both consumption and investment decrease; $\widehat{y_t} < 0$. Thus the growth rate of output declines from a money shock. Another perspective of the output decrease is that the return to physical capital falls: by log-linearizing (5.17), $\widehat{r_t} \approx -\beta \left(\widehat{s_{Gt}} - \widehat{l_t} + \widehat{(k_t/h_t)} \right)$, or since the capital stock is constant at impact, $\widehat{r_t} \approx -\beta \left(\widehat{s_{Gt}} - \widehat{l_t} \right)$. It results that $\widehat{r_t} < 0$, so that $\left| \widehat{l_t} \right| > |\widehat{s_{Gt}}|$. Since the share of labor and capital in goods production both decrease it follows that $\widehat{y_t} \approx (1-\beta)\, \widehat{s_{Gt}} + \beta \widehat{l_t} < 0$. So output also falls by that route. The related effect on the output of human capital and its return is revealed from the change in the real wage: by log-linearizing (5.16), $\widehat{w_t} \approx (1-\beta) \left(\widehat{s_{Gt}} - \widehat{l_t} \right) > 0$. This implies that the shares in human capital output go up, so that $\widehat{s_{Ht}} > 0$ and $\widehat{l_{Ht}} > 0$ and output in human capital increases as does its output growth rate: $\widehat{g_{Ht}} > 0$. And because $\widehat{w_t} - \widehat{\tilde{R}_t} \left(\tilde{R} / \left(1 + \tilde{R} \right) \right) < 0$, the consumption shadow price increases relative to the leisure shadow price, inducing substitution from consumption towards leisure, so that $\widehat{x_t} > 0$. This leisure increase causes a lower return to human capital (see equation 5.25) and a consequent lower growth rate of consumption, denoted by $\widehat{g_{ct}} < 0$.

A positive credit shock, $v_t > 0$, on the contrary leads to a decreased cost of exchange, and works in reverse as compared to a monetary shock. A goods productivity shock, $z_t > 0$, directly increases the interest rate, $\widehat{r_t} > 0$, and the wage rate, $\widehat{w_t} > 0$. Since the return to physical capital is larger than the return to human capital, resources move into the goods sector so that $\widehat{s_{Gt}} > 0$, $\widehat{l_t} > 0$ and $\widehat{y_t} > 0$. Increased consumption and real money demand cause a decrease in the inflation rate; $\widehat{\pi_t} < 0$. So a positive goods productivity shock causes an increase in output growth and a decrease in the inflation rate.

The effect of shocks on inflation can also be seen from by log-linearizing equations (5.9) and (5.18):

$$\widehat{\pi_t} = \widehat{g_{Vt}} - \widehat{g_{ct}} + u_t \tag{5.27}$$

where u_t is monetary supply growth rate shock and g_{Vt} is the growth rate of consumption velocity V_t defined as $V_t = P_t c_t / M_{t+1}$. A positive money shock directly causes inflation to deviate upwards; $\widehat{\pi}_t > 0$. And since this shock causes velocity to rise and consumption growth to fall ($\widehat{g_{Vt}} > 0$ and $\widehat{g_{ct}} < 0$), these other factors both go in the same direction so as to further amplify the inflation rate increase. If the shock effects on $\widehat{g_{ct}}$ and $\widehat{g_{Vt}}$ are small, then $\widehat{\pi}_t \simeq u_t$. However, the other shocks can be important, such as the shift up on velocity when credit was deregulated in the early 1980s; this would have raised inflation sharply above the level of the money supply growth rate, which is broadly consistent with the "missing money" at that time. A positive credit shock causes both velocity and consumption growth to rise ($\widehat{g_{Vt}} > 0$ and $\widehat{g_{ct}} > 0$), resulting in opposing effects. A positive shock to goods productivity causes consumption velocity to be somewhat affected (Benk, Gillman, and Kejak (2008)) while making $\widehat{g_{ct}} > 0$ so that inflation decreases; $\widehat{\pi}_t < 0$.

5.4.3 Simulation Results

Table 3 presents US data stylized facts and simulations of the model, in terms of moments of a set of variables for the period 1919-2004; Tables 4 and 5 present the same for the 1919-1954 and 1955-2004 subperiods. The data series have been detrended using the Christiano and Fitzgerald (2003) asymmetric frequency filter with a band of 2-86 years (where 86 is the sample size). And the covariance matrix is separately computed for each of the two subperiods and for the whole period.

Results are divided into the real side, or RBC, and the more monetary side, or Monetary. On the real side, consumption, investment and output growth volatilities relative to output volatility, along with output and output growth correlations are simulated rather well in the full sample and both subsamples. However, simulated investment has an output correlation above the data in 1919-1954; simulated consumption volatility is low relative to data in the second volatility cycle of 1955-2004; and simulated consumption correlation with output growth is too high. Employment, defined as labor hours in the goods and banking sector or $l_t + f_t$, has a simulated relative volatility that is right on the data.

Monetary results show that simulated velocity volatilities are close to data; and there is at most a 0.17 difference between simulated velocity correlation with output and output growth in the three samples. The simulated real money (normalized by human capital) gets the relative volatility very close to the data, with output and output growth rate correlations close in the full sample but less close in the 1955-2004 period.

While the inflation correlation with output is not well captured, in contrast the correct signs of the inflation correlation with output growth are well captured. And even though the sign of the inflation correlation with output growth changes across prewar and postwar subperiods, the model captures this. And this can be seen as support for the model's central feature of the inflation tax effect on output growth. Figure 5 shows the inflation rate and the GDP growth rate over the whole sample: both the positive correlation between these variables in the first half of the sample, before 1955, and the negative correlation between these variables apparent in after 1955, is captured in the 1919-1954 and the 1955-2004 simulation results.

Simulation Results Data: 1919-2004	RELATIVE VOLATILITY		OUTPUT CORRELATION		OUTPUT GROWTH RATE CORRELATION	
	Simulated	Data	Simulated	Data	Simulated	Data
RBC						
Consumption	0.51	0.64	0.71	0.56	0.30	0.01
Investment	2.97	4.09	0.94	0.53	0.31	0.17
Output Growth Rate	0.29	0.48	0.35	0.20	1.00	1.00
Employment	0.73	0.75	0.84	0.91	0.26	0.30
Monetary						
Income Velocity of Money	1.21	1.39	-0.03	0.06	-0.05	0.01
Normalized Real Money	1.60	1.61	0.65	0.47	0.26	0.14
Inflation Rate	0.81	0.44	-0.44	0.40	0.10	0.32

Note: See Appendix for data sources. All data series represent the cyclical component of the data filtered with the Christiano and Fitzgerald (2003) asymmetric frequency filter with a band of 2-86 years (86=sample size). Series are in logs except those that represent rates. Relative volatility is measured as the ratio of standard deviation of the series to the standard deviation of GDP

Table 5.3: US Business Cycle Facts, 1919-2004, and Simulations

Simulation Results Data: 1919-1954	RELATIVE VOLATILITY		OUTPUT CORRELATION		OUTPUT GROWTH RATE CORRELATION	
	Simulated	Data	Simulated	Data	Simulated	Data
RBC						
Consumption	0.47	0.61	0.66	0.52	0.29	0.01
Investment	3.11	4.05	0.95	0.49	0.22	0.19
Output Growth Rate	0.32	0.48	0.28	0.23	1.00	1.00
Employment	0.76	0.75	0.87	0.95	0.17	0.33
Monetary						
Income Velocity of Money	0.96	1.22	0.10	-0.03	-0.07	0.05
Normalized Real Money	1.32	1.54	0.69	0.57	0.27	0.13
Inflation Rate	0.73	0.42	-0.48	0.38	0.16	0.45

Note: See Appendix for data sources. All data series represent the cyclical component of the data filtered with the Christiano and Fitzgerald (2003) asymmetric frequency filter with a band of 2-86 years (86=sample size). Series are in logs except those that represent rates. Relative volatility is measured as the ratio of standard deviation of the series to the standard deviation of GDP

Table 5.4: US Business Cycle Facts, 1919-1954, and Simulations

Simulation Results Data: 1955-2004	RELATIVE VOLATILITY		OUTPUT CORRELATION		OUTPUT GROWTH RATE CORRELATION	
	Simulated	Data	Simulated	Data	Simulated	Data
RBC						
Consumption	0.49	0.94	0.70	0.85	0.30	0.03
Investment	3.01	3.87	0.95	0.86	0.22	0.14
Output Growth Rate	0.31	0.59	0.28	0.04	1.00	1.00
Employment	0.76	0.72	0.86	0.41	0.18	0.06
Monetary						
Income Velocity of Money	2.86	2.55	0.24	0.40	0.05	-0.12
Normalized Real Money	2.79	2.28	0.11	-0.03	0.06	0.17
Inflation Rate	1.31	0.59	-0.01	0.39	-0.08	-0.50

Note: See Appendix for data sources. All data series represent the cyclical component of the data filtered with the Christiano and Fitzgerald (2003) asymmetric frequency filter with a band of 2-86 years (86=sample size). Series are in logs except those that represent rates. Relative volatility is measured as the ratio of standard deviation of the series to the standard deviation of GDP

Table 5.5: US Business Cycle Facts, 1955-2004, and Simulations

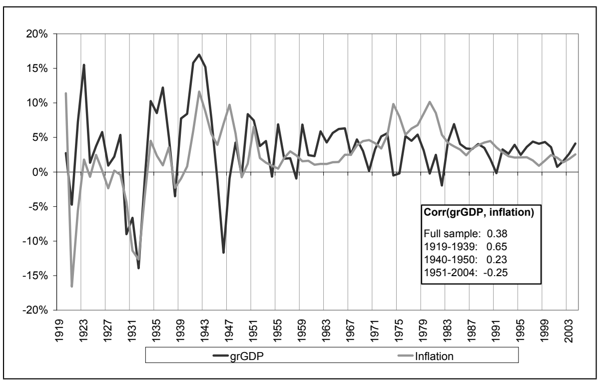

Figure 5.5: GDP Growth Rate and the Inflation Rate, 1919-2004

5.5 Shocks and Volatilities

The money shocks, u_t, and the productivity shocks in credit and goods production, v_t and z_t, are recovered by a least squares procedure using the equilibrium solution of the model and data series for six of the unknown variables of the model. This process is described in Appendix A.1, as in Benk, Gillman, and Kejak (2005b) and Benk, Gillman, and Kejak (2008). The actual constructed shocks both under endogenous and exogenous growth are found below. One difference from previous work is that we use a band pass filter that takes out only the 86 year trend from the data, a minimalist filter desirable for leaving in the longer run features, along with business cycle and short run features (see Section 5.1 for the filter).

5.5.1 Band Pass Filters

Figure 5.6 shows the band pass filters of the three shocks at the different frequencies across the whole sample period. A result is that the short run fluctuations of all three shocks (the righthand panels) are much more apparent in the first volatility cycle period than in the second. Fluctuations at the business cycle frequency (middle panels) are larger during the depression and WWII. The long run fluctuations (lefthand panels) are more severe for the productivity shock during the first volatility cycle period, but rather equal across both cycle periods for the money shock. This last result is apparently due to the large inflation build-up during the 1960s and 1970s that rivaled the deflation of the depression in terms of the amplitude of the fluctuation. In sum, all three frequencies indicate non-trivial and plausible aspects of the shocks.

5.5.2 Variance Decompositions

A variance decomposition of output growth and inflation is presented for both endogenous and exogenous growth versions of the model.[4] Tables 5.6 and 5.7 show how much of the total variance in the data is explained within each subperiod by each of the model's shocks: the productivity (PR), money (M) and credit (CR) shocks. Variance is further decomposed by frequencies, across the various subperiods. The short-run (SR) frequency band corresponds to cycles of 2-3 years, the business cycle (BC) frequency band to cycles of 3-8 years, and the long-run (LR) band to cycles of 8 years and longer; the spectral density of the series is normalized by the series variance, and then its integral is computed over the corresponding frequency band. This gives a 9 element, three-by-three, submatrix within the two tables for each subperiod. The fourth and eighth columns are marked FREQ and these show the total variance found within each frequency by the respective endogenous and exogenous growth models; the sum of the columns in contrast is the amount of variation within each frequency of the data that is explained by the model.

The results are reported for the entire 1919-2004 period, and for 1919-1935, 1936-1954, 1955-1982, and 1983-2004, corresponding approximately to the rise and fall of the two volatility cycles. Note that in Figure 5.4, inflation volatility peaks in the first volatility cycle around 1935, but the GDP volatility continues

[4] The parameters for the exogenous growth model are the same as for the endogenous growth model parameters of Table 5.1, except for the lack of human capital parameters.

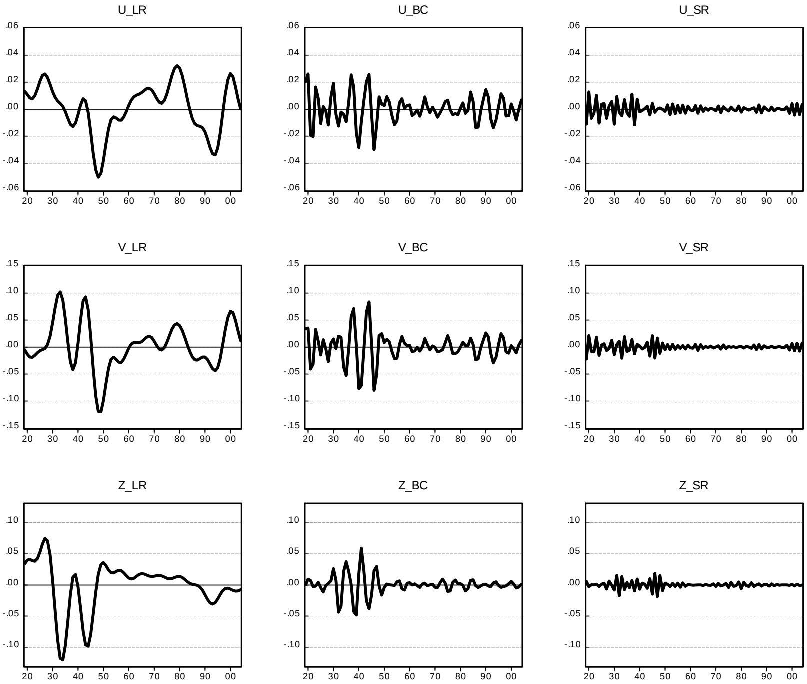

Figure 5.6: The decomposition of money (u), credit (v) and productivity (z) shocks into their long run (LR), business cycle (BC) and short run (SR) components

to have another double peak during WWII and only then recedes. So this 1935 date is based more on the inflation peak and other dates could be used. For the second volatility cycle, Figure 5.4 shows that GDP volatility troughs in 1954 (when the Korean War was over, with an armistice signed on July 27, 1953), but GDP growth and inflation troughed in 1963 (on August 7, 1964 the US approved the use of military force in the Vietnam War, without declaring war, through the Gulf of Tonkin Resolution); so the 1954 dividing point might alternatively be substituted by 1963.

For GDP growth volatility, Table 5.6 shows that consistently more than double the total simulated variation takes place in the long run than in the SR and BC frequencies, for the endogenous growth versus the exogenous growth models, as seen by comparing the FREQ columns. But how do the models perform in terms of explaining the data's volatility? For the entire period of 1919-2004, the last three rows show that the endogenous growth model explains only a total of 22% (the sum of the 9 three-by-three elements) of the total variation versus 46% for exogenous growth. But looking at the subperiods gives a different story. Overall, the endogenous growth model explains 65% of the Great Depression subperiod, 44%, 47% and 49% for the other subperiods, versus 64%, 48%, 59% and 26% for the exogenous growth model. Even though the average subperiod explained volatility is comparable at 51% for the endogenous growth and 49% for the exogenous growth models, the Great Moderation subperiod is the standout difference, with the endogenous growth model explaining almost double the volatility.

More particularly, productivity shocks explain between 7 and 21% of the variation across the four subperiods, with more explained during the volatility upswings than the downswings. The average for productivity shocks is 16% of the variation each subperiod, with the average for money and credit shocks being 20% and 16%. Money shocks explain 29% of the variation during the Great Depression subperiod, with much of this in the LR spectrum. However credit shocks explain relatively the most during the Great Moderation subperiod (19% of the variation).

For inflation, Table 5.7 shows the endogenous growth and exogenous growth give many similar results, with an across-subperiod average of 72% of the data's variation explained in endogenous growth and 80% in exogenous growth, and with a substantial amount of this in the LR spectrum. The total explained variation by subperiod is 98%, 88%, 54% and 50% of the volatility for endogenous growth, and 87%, 90%, 58% and 84% for exogenous growth; in the entire period sample this is 70% versus 61% for endogenous and exogenous growth. The average explained variance by shock in the endogenous growth model, for PR, M and CR, is 19%, 25% and 27% and in exogenous growth, 20%, 32% and 16%. With endogenous growth, money and credit shocks explain most of the inflation variation during the Great Depression subperiod, while in the Great Moderation the goods productivity PR shock explains the most total variation, with a equal split in the total contribution of the M and CR shocks.

The effects of the shocks on output and inflation can also be graphically illustrated using the regression estimation methodology of Benk, Gillman, and Kejak (2005b). Figure 5.7 shows that the productivity shock caused the depression era drop in output, as expected, and that the money shock also contributed to the depressionary output drop. But even more prolonged was the negative effect of the money shock on GDP during the Great Inflation period of the 1970s,

		Endogenous				Exogenous			
		PR	M	CR	FREQ	PR	M	CR	FREQ
1919-1935									
	SR	7%	7%	7%	25%	13%	11%	3%	37%
	BC	9%	4%	5%	38%	16%	1%	7%	45%
	LR	2%	18%	6%	37%	3%	3%	7%	18%
1936-1954									
	SR	0%	7%	7%	28%	1%	15%	16%	38%
	BC	3%	6%	6%	41%	4%	18%	2%	48%
	LR	4%	7%	4%	31%	2%	0%	0%	14%
1955-1982									
	SR	8%	2%	2%	18%	18%	4%	2%	36%
	BC	12%	1%	1%	33%	19%	1%	12%	44%
	LR	1%	11%	9%	49%	1%	0%	2%	20%
1983-2004									
	SR	3%	3%	3%	15%	7%	0%	0%	35%
	BC	4%	10%	11%	30%	9%	0%	0%	44%
	LR	5%	5%	5%	55%	1%	8%	1%	21%
1919-2004									
	SR	2%	4%	4%	19%	6%	14%	4%	34%
	BC	5%	2%	3%	34%	8%	7%	4%	46%
	LR	0%	1%	1%	47%	0%	0%	3%	20%

Table 5.6: Decomposition of Variance of GDP growth by Frequency, 1919-2004

		Endogenous				Exogenous			
		PR	M	CR	FREQ	PR	M	CR	FREQ
1919-1935									
	SR	1%	16%	21%	37%	2%	22%	9%	36%
	BC	4%	15%	23%	45%	7%	26%	1%	45%
	LR	5%	11%	3%	18%	9%	1%	10%	19%
1936-1954									
	SR	4%	14%	15%	33%	5%	21%	4%	33%
	BC	18%	4%	5%	43%	15%	5%	11%	39%
	LR	24%	2%	2%	23%	28%	0%	1%	28%
1955-1982									
	SR	0%	9%	8%	32%	0%	2%	1%	28%
	BC	1%	8%	8%	40%	1%	21%	10%	40%
	LR	0%	9%	11%	27%	1%	8%	14%	33%
1983-2004									
	SR	10%	5%	6%	32%	7%	3%	2%	25%
	BC	0%	4%	4%	41%	0%	8%	5%	35%
	LR	12%	5%	4%	27%	7%	13%	39%	39%
1919-2004									
	SR	1%	15%	19%	34%	1%	20%	6%	33%
	BC	7%	10%	13%	43%	7%	14%	4%	38%
	LR	0%	3%	3%	23%	0%	8%	1%	29%

Table 5.7: Decomposition of Variance of Inflation by Frequency, 1919-2004

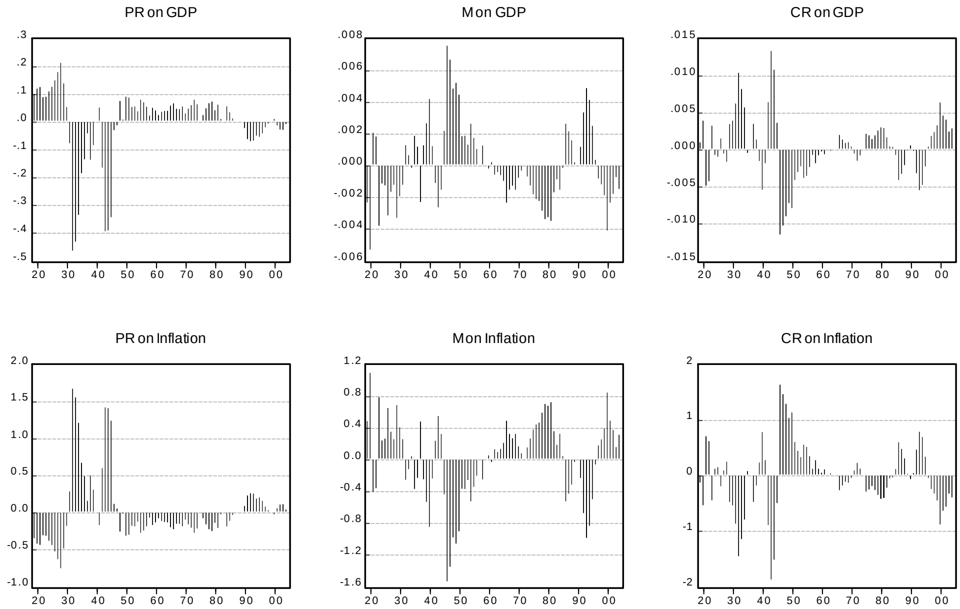

Figure 5.7: Effect of shocks on GDP and Inflation

during which time the productivity shock had only positive effects. The credit shock helped GDP to increase during the 1933 banking reorganization and the start of federal deposit insurance; and there is a positive CR effect on GDP during the financial deregulation in the early 1980s. The money shock effect on inflation is in evidence during the 1930s deflation, and the 1970s and 1980s inflation. The credit shock lowered inflation during the depression and the late 1970s and early 1980s.

5.6 Discussion

A comparison of the model's results can be made to the empirical literature on the Great Moderation, such as the succinct summary and extension by Giannone, Lenza, and Reichlin (2008). They find that the larger the VAR model, the more of the Great Moderation that is explained by a change in the structure of the shock process ("good policy"), and the less by a change in the variation of the shock process ("good luck"). Giannone et al. also emphasize that missing information biases estimates of the shock variance, an omitted variable bias. They suggest that covariance between GDP and other variables like inflation can increase predictability, and that estimates of the shocks must take into account such multivariate information.

Our equilibrium involves a large number of equations, and the shocks of our model are derived from these equilibrium conditions and time series variables. The covariance is estimated from the shocks, while taking into account the

		StdDev	Correlation PR	M	CR
1919-1935					
	PR	**0.074**	1.00	0.50	-0.72
	M	**0.020**	0.50	1.00	0.18
	CR	**0.053**	-0.72	0.18	1.00
1936-1954					
	PR	**0.053**	1.00	-0.54	-0.82
	M	**0.026**	-0.54	1.00	0.92
	CR	**0.085**	-0.82	0.92	1.00
1955-1982					
	PR	**0.007**	1.00	0.00	-0.23
	M	**0.013**	0.00	1.00	0.97
	CR	**0.021**	-0.23	0.97	1.00
1983-2004					
	PR	**0.011**	1.00	0.54	0.30
	M	**0.021**	0.54	1.00	0.96
	CR	**0.040**	0.30	0.96	1.00
1919-2004					
	PR	**0.043**	1.00	0.17	-0.51
	M	**0.023**	0.17	1.00	0.75
	CR	**0.053**	-0.51	0.75	1.00

Table 5.8: Correlation Matrix of Shocks Across Subperiods, and Whole Period

way in which, for example, money supply growth affects output by causing inflation to rise and output growth to decrease. Table 5.8 presents the covariance structure of the shocks across the different subperiods and for the whole period.

The covariance matrices across subperiod give several results:

1. Standard Deviation (SD): The SD of the goods productivity shock (z) is much greater in the first than the second volatility cycle, as expected (a change in "luck"). The SD of the money shock (u) is historically similar across subperiods, except that it is lower during the Great Inflation subperiod. This suggests the contribution of the monetary shocks was more in terms of "policy"; or looking at the Great Moderation compared to the previous subperiod, the "luck" was even a bit worse. The SD of the credit shock (v) is less stable but again lowest during the Great Inflation subperiod.

2. Covariances: The credit shock is negatively correlated with the goods productivity shock in the first three subperiods, but positively correlated in the Great Moderation. And it is highly correlated with the money shock in the last three subperiods, but negatively correlated in the Great Depression subperiod.

One interpretation is that in the Great Depression, credit was constrained by the collapse of the banking sector, leading to the negative correlation of credit shocks with goods productivity shocks. Restrictions on credit may have similarly produced a like negative correlation between CR and PR in the next two subperiods. In the Great Moderation subperiod, credit was liberalized with financial deregulation, leading to a positive correlation of CR with PR. This credit deregulation would have allowed the economy to be more insulated from the inflation tax, which in turn allowed credit to take up an historically different, positive, role of helping output growth in part by insulating the economy from money shocks.

Figure 5.8 presents the volatility of the constructed credit shock in comparison to that of GDP. The volatilities moved together everywhere except especially in 1927-1938 and 1983-2004 (as well as in WWII). When credit was repressed by banking failure in the Great Depression, GDP volatility went way up while credit shock volatility did not rise as much. And when deregulation began in 1981, credit volatility rose while GDP volatility fell. This suggests that the high velocity volatility and M1 money volatility after 1983 (Figure 5.4), along with the high credit volatility in Figure 5.8, reflect the financial deregulation effect and explain how velocity and M1 volatility could rise even while inflation volatility fell.

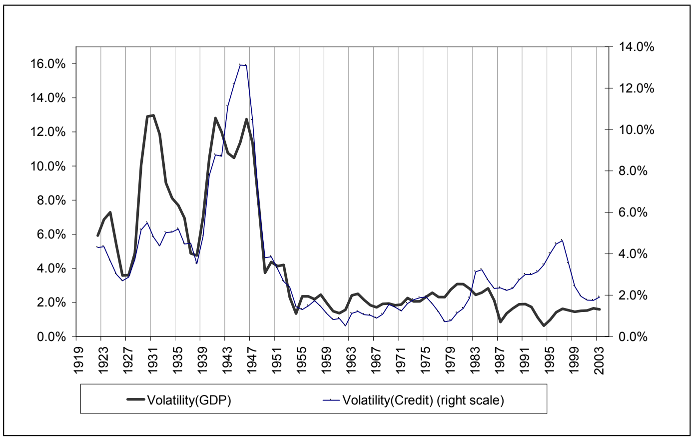

Figure 5.8: Volatilities of GDP and the Credit Shock, 1919-2004

These money and credit shocks are almost like the structural shocks that Chari, Kehoe, and McGrattan (2008) define as being invariant to policy changes, being interpretable in a plausible fashion and even in terms of good shocks versus bad shock with the possibility of trying to offset the bad shocks. They write that a consensus on the need for such structural shocks within the dynamic macro models is emerging, with the focus on a goods productivity, or "efficiency" shock, and a labor wedge shock. Our shocks include this same goods productivity shock, and the monetary and credit shocks both affect primarily the goods to leisure, or "labor", margin (through the shadow exchange cost of goods $\tilde{R}$ in equation 5.23).

Our shocks do reflect policy however, as the money shock is based on government action, either directly through the money supply, or perhaps it can be viewed as indirectly through inflation tax finance of deficits (especially during wartime). And credit shocks are linked potentially to changes in banking laws. This interpretation, seen also in Benk, Gillman, and Kejak (2005b), is related to that of Jermann and Quadrini (2006) and is not inconsistent with Perri and Quadrini's (2008) finding that financial integration decreases business cycle volatility. In terms of good and bad shocks: the good shocks to credit are those enhancing credit productivity, as during financial deregulation, and the bad shocks are those restricting credit, such as the bank collapses of the Great Depression. These bad shocks can be offset or minimized, such as through efficient forms of banking insurance, and the good ones can be enhanced such as through liberalization of markets combined with good regulation aimed towards full information revelation including proper accounting. The money shocks, on the other hand, contribute directly to inflation volatility which is linked closely to GDP volatility, thereby suggesting one possible conclusion that their volatility should be minimized.

5.7 Conclusion

The endogenous growth model explains 49% of the volatility of GDP, and 50% of the volatility of inflation, during the Great Moderation period, through a combination of money supply, credit productivity and goods productivity shocks. And with these shocks, the paper explains a particular puzzle through the role of the credit shock: the divergence of higher velocity and money aggregate volatilities post 1983 from lower GDP and inflation volatilities post 1983. The model's constructed credit shock also rises in volatility during the Great Moderation subperiod, while being relatively low during the Great Depression subperiod. We interpret the post 1983 increased credit volatility as reflecting the unleashing of credit through long run financial innovation during deregulation that created an inflation escape valve. This allowed monetary aggregate volatility to be manifested through higher credit volatility rather than turning into higher inflation and GDP volatility as in previous time, in particular during the Great Depression period. Credit liberalization appears to have diminished some of the inflation tax fluctuations that high money supply volatility can otherwise entail. With GDP volatility coinciding with the inflation volatility rather than the credit volatility, this helped lead to the lower GDP and inflation volatilities during the Great Moderation. Then, looking forward, this model predicts both greater inflation and output volatility at times when credit is constrained and the money supply is shocked upwards, such as during the recent credit crisis, with a subsequently greater inflation and output volatility.

One extension of the model that we are studying is to include investment in the exchange constraint, as in Stockman (1981), as this makes the inflation tax fall on a fraction of investment as well as consumption, which may be more realistic. This creates a negative effect of inflation on investment even while leaving the Tobin effect operative as manifested through an inflation-induced rise in the capital to effective labor across sectors. Another extension is to include the intermediation of intertemporal savings and investment through the banking system. Credit productivity shocks could then affect the share of loans going through to the goods producer. This might lead to a greater use of government bonds and a lessor supply of savings during the crisis, as may be consistent with evidence. And it could be a micro-founded banking component that is useful in extending the RBC model to explain banking crises, although perhaps a credit constraint as in Kocherlakota (2000) in addition may be necessary.

5.A Appendix.

5.A.1 Data Sources

Data used in the paper has been constructed on annual frequency, for the 1919 - 2004 time period. The main data sources were the Bureau of Economic Analysis (BEA) and the IMF International Financial Statistics (IFS). Series have been extended backwards until 1919 based on the series published in Kuznets (1941), Friedman and Schwartz (1963a) (F&S) and the online *NBER Macrohistory Database* (http://www.nber.org/databases/macrohistory/contents/) (NBER). [5]

The data series are as follows:
Gross Domestic Product (BEA, Kuznets).
Consumer Price Index (BEA, F&S).
Price Index for Gross Domestic Product (BEA, Kuznets).
Personal Consumption expenditures (BEA, Kuznets).
Gross private domestic investment (BEA, Kuznets).
Wage and salary accruals (BEA, Kuznets).
Wage and salary accruals, Finance, insurance, and real estate (BEA, Kuznets).
Full-time equivalent employees (BEA, Kuznets).
Full-time equivalent employees, Finance, insurance, and real estate (BEA, Kuznets).
M0 (IFS, NBER).
M1 (IFS, NBER).
M2 (IFS, NBER).
Treasury Bill rate (IFS, NBER).

5.A.2 Variance Decomposition

The decomposition of the variance of the GDP growth and velocity by shocks is based on the principle described in Ingram, Kocherlakota, and Savin (1994), and has been done as follows: Let z, v and u be the three, possibly correlated shocks. Let's assume the ordering z-v-u, that is, the movements in z are responsible for any comovements between z and v or z and u, and that movements in v are responsible for any comovements between v and u. We can formalize this notion by defining v_t^e to be the residuals in a regression of v_t on the vector $(z_t, ..., z_{t-s})$ and u_t^e to be the residuals in a regression of u_t on the vector $(z_t, ..., z_{t-s}, v_t, ..., v_{t-s})$. Thus we interpret v_t^e as capturing the movements of v that are not associated with current, future, or past movements in z.

Given this particular ordering, consider the decomposition of the variance of GDP growth ($\dot{\triangle} y_t$) into the components due to the various shocks that is obtained by running the regression:

$$\dot{\triangle} y_t = \underbrace{\sum_{s=0}^{S} \beta_{z,s} z_{t-s}}_{\dot{\triangle} y_t^z} + \underbrace{\sum_{s=0}^{S} \beta_{v,s} v_{t-s}^e}_{\dot{\triangle} y_t^v} + \underbrace{\sum_{s=0}^{S} \beta_{u,s} u_{t-s}^e}_{\dot{\triangle} y_t^u} + \varepsilon_t \tag{5.28}$$

Then the fraction of the variance of $\dot{\triangle} y_t$ explained by each shock is given by: $P^z = \frac{Var(\dot{\triangle} y_t^z)}{Var(\dot{\triangle} y_t)}$, $P^v = \frac{Var(\dot{\triangle} y_t^v)}{Var(\dot{\triangle} y_t)}$, $P^u = \frac{Var(\dot{\triangle} y_t^u)}{Var(\dot{\triangle} y_t)}$. A similar regression to that of (5.28) is run on velocity and the same shocks to determine its variance decomposition.

[5] Note that Romer's revised historical data for GDP was alternatively used. Miron and Romer (1990) reports Industrial Production rather than GDP, for the period up to 1939. This was chained to the GDP data for 1940 and after. Use of this alternative GDP series results in more volatility in the level and in the growth rate.of output. But the spectral decomposition results on volatility were not qualitatively affected. Therefore these alternative results are not reported.

Unless the shocks z, v and u are orthogonal to each other, the results are sensitive to the ordering adopted. We considered all six possible orderings of the shocks. Results presented are the average for the two cases when the goods productivity shock is ordered first.

The proportion of variance of a series due to SR, BC and LR components can be obtained as in Levy and Dezhbakhsh (2003): it amounts to estimating the spectral density of the series, normalizing it by the series variance, and then computing its integral over the corresponding frequency band. If we denote by $f(\omega)$ the spectral density of the series and by σ^2 its variance, then the fraction of variance due to each frequency component is given by $H^{SR} = \int_{2\pi/3}^{2\pi/2} f(\omega)/\sigma^2 d\omega$, $H^{BC} = \int_{2\pi/8}^{2\pi/3} f(\omega)/\sigma^2 d\omega$, $H^{LR} = \int_{2\pi/\infty}^{2\pi/8} f(\omega)/\sigma^2 d\omega$. The frequency bands are determined by the mapping $\omega = 2\pi/p$, where p measures the cycle length (2, 3 or 8 years).

We are using an alternative, equivalent measure for the fractions of variance (suggested also by Levy and Dezhbakhsh (2003)): this consists of passing the series through a band-pass filter, estimating the variance of the filtered series and relating it to the variance of the original series. We employ the Christiano and Fitzgerald (2003) asymmetric band-pass filter with the afore-mentioned $2-3$, $3-8$ and >8 year bands. This procedure is applied to the simulated series of output growth and velocity, where simulations have been run by feeding back the estimated variance-covariance structure of the shocks into the model. The variance-covariance matrices have been estimated separately for each of the subperiods, this way we obtained simulated series and decompositions that differ by subperiods.

To assess the fraction of variance explained by each shock in turn at each frequency, we decompose each of the frequency component further, by shocks. The variance decomposition procedure is similar to that described in equation (5.28). The difference consists in pre-filtering the target series and the shock series to extract the adequate frequency component. According to this, the Christiano and Fitzgerald (2003) asymmetric band-pass filter with the 2-3, 3-8 and >8 year bands is applied to the output growth and velocity series, as well as to the productivity, money and credit shock series.

5.A.3 Construction of Shocks

Assume that $\bar{\xi}$ denotes the steady state value of variable ξ, and $\hat{\xi}$ denotes its percentage deviation from the steady state ($\hat{\xi} = \log(\xi) - \log(\bar{\xi})$). With $\tilde{k} \equiv k/h$, and any variable with a tilde above indicated the ratio of that variable to h, and using the solution of the model from section 5.2, the log-deviations of the model variables can be written as linear functions of the state $s = (\widehat{\tilde{k}}, z, u, v)$. By stacking the equations, the solution can be written in matrix form as follows:

$$X_t = A \left[\begin{array}{c} \widehat{\tilde{k}}_t \end{array} \right] + B \left[\begin{array}{ccc} z_t & u_t & v_t \end{array} \right]', \tag{5.29}$$

where $X = \left[\begin{array}{cccccccc} \widehat{\tilde{c}} & \hat{x} & \hat{l} & \hat{n} & \hat{f} & \hat{s}_G & \hat{a} & \hat{\pi} \end{array} \right]'$, and $\tilde{c} \equiv c/h$. From (5.29), one can construct the solution of any variable of the model, by forming the appropriate linear combination of the appropriate rows of (5.29), the linear combinations being given by the linearized versions of equations (5.3)-(5.8).

Given the model solution (5.29) (that is, knowing the value of matrices A and B), the series of shocks $\begin{bmatrix} z_t & u_t & v_t \end{bmatrix}$ can be constructed by using data on X_t and $\widehat{\tilde{k}}_t$ and "solving" the system of linear equations (5.29). It can be easily seen, that in order to identify the three series of shocks, we need data on at least three variables from X_t. In a three-variable case the shocks represents the solution of a system of three linear equation. If more that three variables are used, then the shocks are "overidentified" as we have more equations than unknowns. In such a case we apply a least-square procedure as we illustrate below.

In the procedure of constructing the shocks, we employ the variables on which we were able to find reliable data. We construct stationary variables c/y, i/y, π and m/y, and on which we use data to construct the shocks. We also use data on labor hour in banking sector f. and on the wage rate in banking - the latter series being used as a proxy for the marginal product of labor in banking ($mplb$). The data series on $\widehat{\tilde{k}}$ is constructed by using for k the capital accumulation equation (5.5), data on investment to compute $\widehat{\tilde{\imath}}_t$ and the initial condition $\widehat{\tilde{k}}_{-1} = 0$. For human capital, because of a lack of a series going back to 1919, we use a smooth trend, as data in Jorgenson and Stiroh (2000) for 1959-1998 indicates.

Having the data series on $\widehat{\tilde{k}}$, $\widehat{c/y}$, $\widehat{\pi}$, $\widehat{i/y}$, $\widehat{m/y}$, $\hat{f}$ and $\widehat{mplb}$, we set up a system of linear equations:

$$XX_t = AA \begin{bmatrix} \widehat{\tilde{k}}_t \end{bmatrix} + BB \begin{bmatrix} z_t & u_t & v_t \end{bmatrix}', \tag{5.30}$$

where $XX = \begin{bmatrix} \widehat{c/y} & \widehat{i/y} & \widehat{\pi} & \widehat{m/y} & \widehat{f} & \widehat{mplb} \end{bmatrix}'$ and the rows of the matrices AA and BB result from the linear combinations of the corresponding rows of matrices A and B, the appropriate linear combinations being given by the linear equations that define the variables from XX as functions of the variables from X. The marginal product of labor in banking, is derived from equation (5.11), while the definition of the other terms of the matrix XX is straightforward.

The least square "estimates" for the shock series are computed as follows:

$$est \begin{bmatrix} z_t & u_t & v_t \end{bmatrix}_t' = (BB'BB)^{-1} BB' (XX_t - AA \begin{bmatrix} \widehat{\tilde{k}}_t \end{bmatrix}).$$

In this approach we used six variables to construct the economy's three shocks. To test for the robustness of the process of shock construction, we repeated the computation by using combinations of six variables taken five at a time, six taken five at a time and six taken four at a time, allowing for twenty-one more possible ways to construct the shocks. The results show that all combinations that include π, m/y, either c/y or i/y, and either f or $mplb$ generate nearly the same shock series, while other combinations show randomness and lack of conformity. Thus, we found that the results are robust as long as the variables are included that correspond to the model's three sectors in which the three shocks occur.

5.A.4 Shock Profiles

The next three figures show each of the computed shocks. Figure 5.9 shows the money shock, with a rise in the money supply during the 1920s, up until

1931 and then a large drop until 1939. After a WWII bounce, it then rises up with a long surge in the 1960s and 1970s, after which if falls again. There are some differences between the exogenous and endogenous growth models, such as during WWII, and in the late 1990s.

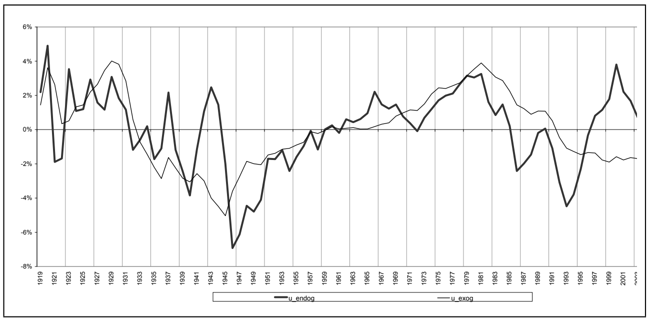

Figure 5.9: Money Shocks, Endogenous and Exogenous Growth Models, 1919-2004

Figure 5.10 shows a strong negative effect of the goods sector productivity shock during the Great Depression, consistent with total factor productivity stories of the Great Depression (Kehoe and Prescott 2002). The shock is little changed from the exogenous growth version of the model.

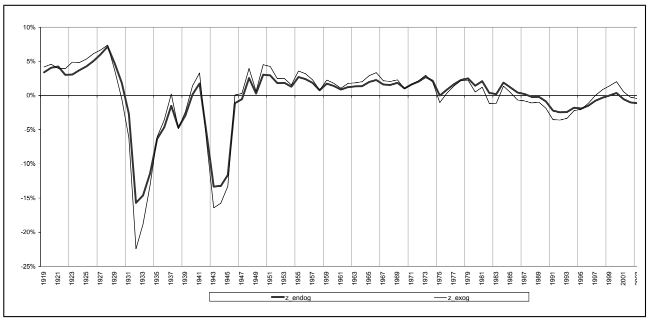

Figure 5.10: Productivity Shocks, Endogenous and Exogenous Growth Models, 1919-2004

Figure 5.11 shows the credit shock. During the Depression, the baseline endogenous growth shows a positive effect of the credit shock in the early part until 1932, when banking could partially provide a means of exchange instead of money; this was reversed then by the subsequent banking collapse. And some positive effects are apparent during the 1970s and 1980s, when interest ceilings were controverted by new non-bank banks and when deregulation began.

5.A.5 Impulse Responses

The impulse responses show how the shocks affect the economy in the short run, in that the shocks eventually die out. Here we report the simulated impulse responses of the baseline model's variables to the three shocks on goods sector

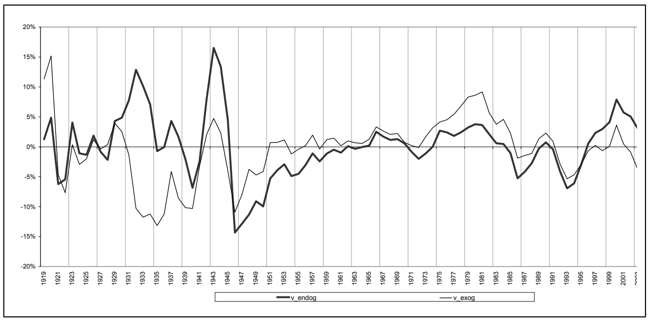

Figure 5.11: Credit Shocks, Endogenous and Exogenous Growth Models, 1919-2004

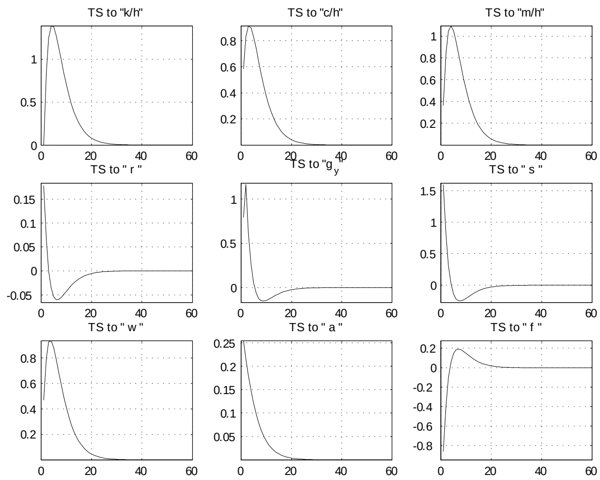

Figure 5.12: Impulse responses to the technological shock - Part 1

productivity (TS), the money supply growth rate (MS) and the credit sector productivity (CS), with two panels for each of the three shocks.

The first set of goods productivity impulses show that the output growth rate (g_y), the real interest rate (r), the real wage (w), normalized consumption (c/h) and money demand (m/h), the money to consumption ratio (a) and the capital to effective labor in the goods sector (s) all initially rise, while bank labor (f) falls, and the physical capital to human capital ratio (k/h) gradually rises after the first period.

The second set shows that normalized output and investment, labor in goods production, the income velocity of money (vel) and leisure all rise initially, while the growth of human capital (g_h) the labor in human capital production, inflation and the nominal interest rate all fall initially.

Money shocks cause an initial drop in the capital to human capital ratio, normalized consumption and money demand, the real interest rate, the output growth rate, the capital to effective labor ratio in goods production, and the money to consumption ratio, while causing an increase in the real wage and

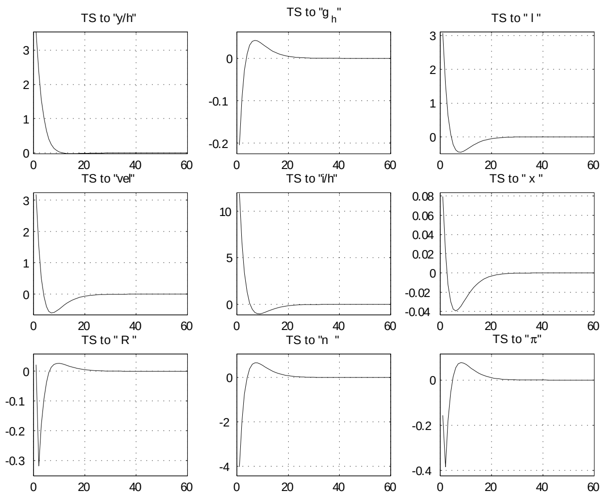

Figure 5.13: Impulse responses to the technological shock - Part 2

labor time spent in the bank sector.

The decrease in the real interest rate is like a liquidity effect, even while the nominal interest rate rises because of expected inflation. But rather than the real interest rate decrease being due to more capital entering the capital markets, as with a liquidity effect of a money supply increase, here the dynamics are that the physical capital investment decreases and output growth decreases, even as the growth rate of human capital increases.

It also causes a fall in normalized output, labor in goods production, and normalized investment (i/h), while raising the growth rate of human capital, the income velocity of money, leisure, the nominal interest rate and the inflation rate, and time in human capital investment.

A credit shock causes almost the exact opposite to a money shock.

In sum, the goods sector and bank sector productivity shocks increase output growth and decrease inflation, while the money shock has the opposite effect on these variables.

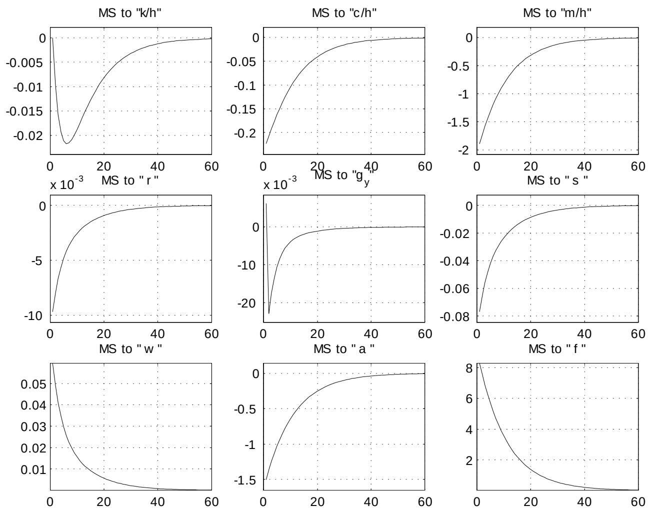

Figure 5.14: Impulse responses to the monetary growth shock - Part 1

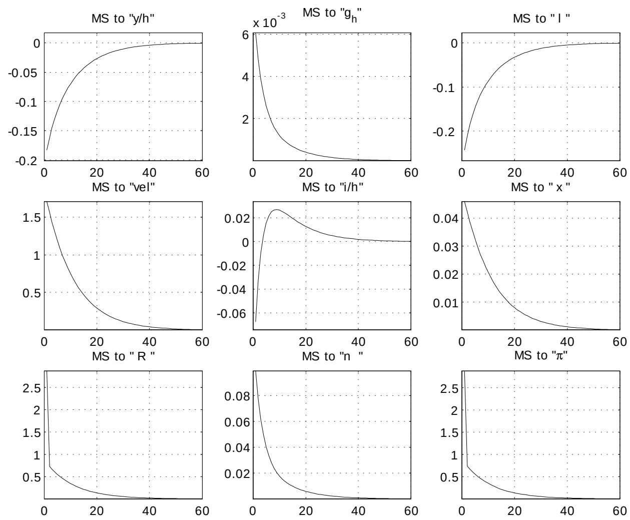

Figure 5.15: Impulse responses to the monetary growth shock - Part 2

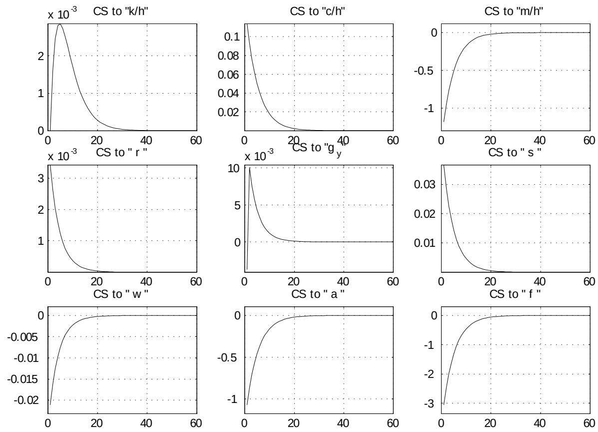

Figure 5.16: Impulse responses to the credit sector productivity shock - Part 1

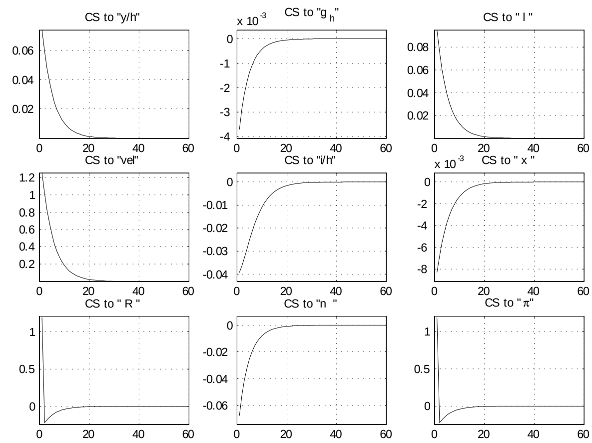

Figure 5.17: Impulse responses to the credit sector productivity shock - Part 2

Chapter 6

Money and credit effects on the business cycle in Eastern Europe: Three countries, one story

6.1 Introduction

The contribution of monetary and financial factors to the US business cycle developments have been studied in the previous chapters. The approach was a credit production one, where a microfoundation based financial intermediation implies an additional margin relative to more standard models, that in turn improves the performance of the business cycle model. Credit shocks for the US economy have been constructed using the solution to the monetary business cycle model and quarterly US data on key variables. Benk, Gillman, and Kejak (2005b) (Chapter 3) demonstrated the contribution of the credit shock to US GDP movements, and interpreted in terms of changes in banking legislation during the US financial deregulation era. Benk, Gillman, and Kejak (2009) (Chapter 5) documented some puzzling features of the US post-1983 moderation that coincided with an ahistorical divergence in the money aggregate growth and velocity volatilities away from the downward trending GDP and inflation volatilities. The volatility divergence is explained then by the upswing in the credit volatility that kept money supply variability from translating into inflation and GDP volatility.

While modeling the US financial sectors and explaining business fluctuations through financial innovations involves a rich literature (discussed in the previous chapters), little work has been done on modeling the financial sector side of transition countries. This chapter fills this gap by extending the credit model set forth in Chapter 1 to Central and Eastern European economies.

Macroeconomic and banking sector developments in Central and Eastern European Countries shared a number of special common characteristics during the transition period, such as the high inflationary period with a significant drop in aggregate output in the early and mid 1990s, banking crises and the inheritance of bad loan portfolios from earlier times, bank consolidations and privatizations, various banking regulatory legislative changes and a switch to the inflation targeting regime. These common developments allow a common modeling framework and the possibility of a comparative analysis of these economies. Further, the various events in the CEE banking history might be set in parallel with the specific events from the post-1980 US financial regulatory-deregulatory era. Moreover, the developments in the volatilities of various economic series share some common features with the developments of the volatilities of the US data series from the aforementioned period.

This chapter calibrates a monetary business cycle model with endogenous growth and credit shocks, identifies the main shocks in the recent monetary and financial history of Hungary, Czech Republic and Poland and explains the financial sector developments within this common model. Credit shocks are estimated by using the model solution equations and data. A chronological conformity of the credit shocks and the timing of various events from the banking sector history is shown, along with the impact of shocks on GDP and inflation movements. Further, it documents the evolution of the volatilities of output, inflation, money and money velocity, emphasizing a puzzling bifurcating pattern between the volatilities of money and money velocity on the one hand, and that of inflation and output on the other hand. This patters shows similarities to what has been observed in US data and documented in Benk, Gillman, and Kejak (2009) (Chapter 5), the explanation to such behavior being offered here within the credit model.

6.2 The Banking Sector Developments in Hungary, Poland and Czech Republic

Macroeconomic and banking sector developments in Central and Eastern European countries have had a number of special common characteristics during the transition period. The early and mid 1990s saw a high inflationary period with a significant drop in aggregate output. These developments have been paired by banking crises that emerged from a set of factors discussed in Szapary (2001): a sharp drop in aggregate demand and output, the inheritance of bad loan portfolios from earlier times when credit was centrally directed, segmentation of the credit market and lack of competition, shortcomings in the regulatory and supervisory frameworks, and weak management. These crises then ended with bank consolidations and then a privatization of the banking sector, leading to an ownership structure by the late 90s where foreign owners played the predominant role. The foreign ownership dominance have been preserved along with the relatively high concentration in the market structure.

As most CEE countries followed similar development paths during the transition period, the banking sectors of these countries share common structural characteristics.[1] Despite an upward trend the level of financial intermediation is still relatively low. Economic agents rely more heavily on bank finance than on direct market finance, while customer deposits are the most important funding sources for banks. In the past few years household lending - and in particu-

[1] For a detailed analysis see "Banking structures in the new EU Member States", 2005, ECB

lar mortgage lending - has been the fastest growing area. The high growth in lending has been paired in the last decade by a rapid growth in household's indebtedness (although still below the average indebtedness level of the EU), illustrating a tendency of households to catch up in consumption standards to the highly developed countries' level.

Hungary

Hungary experienced high inflation in during the early transition period, 1990-1994. This was paired by increasing external disequilibrium and considerable twin deficit, which by the end of 1994 have determined the government and policymakers to implement severe stabilization measures. These measures consisted in a fiscal tightening along with a switch to a crawling peg exchange rate regime, the tightening being implemented mainly through reducing the budgetary expenses in real term by generating inflation. This way inflation peaked above 30% in 1995 coupled by high inflation volatility. Since then, inflation was gradually reduced within the crawling peg regime although it continued to persist at values around 10% while the crawling peg regime offered only a limited room for maneuver. As a consequence a more effective anti-inflationary policy, the inflation targeting regime has been implemented that reduced further inflation down to around 4% by 2006.

Regarding developments in the banking sector, a consolidation started in late 1992[2]. The consolidation and restructuring took place in several stages. It implied first a cleaning of the portfolios where banks received government bonds in exchange for their bad loans made to state-owned enterprises. This, however, did not solve the problems of the banking sector, and a full recapitalization was necessary that led to an increased state ownership in the sector. The following important step was the privatization of the banking sector that started in 1995 with the selling of six state-owned banks to foreign banks. The largest Hungarian bank was privatized through the stock exchange. This way state ownership fell to 20 by the end of 1997. This process implied a big improvement in the share of non-performing loans by 2000 (about only 3%), and moreover, the presence of foreign banks triggered an increase in the quality and variety of banking products and services. These episodes can be interpreted within a stylized model as upward shifts in bank sector productivity.

A proper regulatory and supervisory framework was also essential for a well-functioning banking sector.[3] The framework was modelled along EU regulations and Basel principles. The liberalization of licensing enabled banks to perform more diverse activities and serve a wider clientele: commercial banks were licensed to offer retail-banking services while retail banks were granted full commercial bank license. In 1997 legal provisions have been created for foreign branch establishments. Also in 1997 the supervision responsible for banks and investment service providers was combined. In 2000 a single supervising organization was established which also integrated the supervision of insurance and pension funds.

An other important change in the Hungarian banking sector occurred with the adoption of the new Central Bank Act in 2001 that instituted the new inflation targeting regime instead of the previous practice of exchange rate targeting

[2] Szapary (2001) discusses in details these developments in the Hungarian banking sector.
[3] Várhegyi (2002) discusses this in more detail.

with crawling peg. This aimed to reduce inflation from the previous levels of around 10% to levels consistent with price stability, together with reducing its variance.

An important episode in the banking system is related to the housing boom that started around 2000 as a result of the increased government subsidies to mortgage loans. The fast expansion in housing loans have then been coupled later also by a strong expansion in consumer credit. Thus, during the 2000s the growth of credit to households represented the most important factor behind the expansion in the banking sector.

Czech Republic

In the Czech Republic the high inflation during the early transition stabilized around 8-10% with low volatility in the mid 90s. The 1997 - 1998 period then was characterized by high and volatile inflation along with economic recession. From the start of 1998 the Czech National Bank switched to inflation targeting. The economy recovered gradually during 1999 - 2001 and inflation has been stabilized. Since 2002 inflation volatility has been gradually declined while inflation level has been relatively low and stable.

The bank reforms in the Czech Republic were broadly similar to that in Hungary but were implemented at a somewhat later date. Over the 90s the Czech banking sector has undergone a massive transformation process marked by numerous bank failures, the accumulation of huge amounts of non-performing loans (especially in the early phase of economic transition) and credit rationing blames. Restructuring of the Czech banking sector took place in three stages. First, the large banks have been consolidated in the early 1990s followed by the consolidation of medium-sized and small banks in the mid-1990s and finally by the stabilization of small banks. In order to improve the management and operation of the banks, the government adopted a new privatization program in 1997 (after the initial coupon-based privatization) with the aim of selling the large banks to foreign banks.

The entire financial sector has undergone concentration, the number of banks decreased first due to their poor financial situation, then in the 2000s due primarily to mergers. Banking was oriented predominantly towards classic banking, accepting deposits and providing credits. Similarly to Hungary, retail banking expanded rapidly in the 2000s as demand for mortgage an consumer loans grew particularly fast after the recession of 1998-2001 and contraction in loans.

Poland

Inflation developments in Poland show some similarities with Hungary both in terms of its level and its volatility. Inflation gradually fell since 1993 until 1999 together with its volatility. The monetary policy followed a crawling peg regime with a narrow fluctuation band for the exchange rate, then in 1999 switched to the inflation targeting regime. After peaking in 2000 inflation has been stabilized at relatively low levels.

The Polish banking sector has been stabilized through privatization and recapitalization in a similar way as in Hungary. Gillman and Nakov (2004) document shifts in money velocity and associate them with changes in banking productivity as a result of changes in major banking laws, such as the bank privatization laws of 1996 and the new central bank acts of 1998 and 2001. The latter is interpreted as a change in the expected variance and mean of the inflation rate, that may act as a shift down in the banks productivity in producing credit or other instruments used to avoid the inflation tax.

Historical trends

A number of clear historical trends can be derived from figures 6.1 and 6.2 that are common across the three countries:

1. All three countries experienced a deflationary trend over the period 1993-2006, although with some differences. While inflation in Poland declined steadily, in Hungary and especially in Czech Republic it presented some swings.

2. While inflation in the three countries evolved differently, the level of inflation rate and its volatility moved together (with the exception of CZ in the early 90s period). This suggests that explaining inflation's level is related to the explanation of its volatility.

3. GDP growth volatility tracts well inflation volatility in all three countries.

Some differences arise however between the three countries:

1. M1 volatility traces the declining pattern of inflation volatility in Hungary up until 2002 when they diverge from each other and M1 volatility started to rise steadily. Some bifurcation can be observed also in Poland around 2002 and in the Czech Republic after 2000.

2. The volatility of money velocity in Hungary follows inflation and GDP volatility up until 2002 but then diverges together with M1 volatility. In Czech Republic and in Poland it traces better inflation volatility although some divergence can be seen from 2000 in the Czech Republic, and from 2003 in Poland.

3. While the magnitude of volatilities of inflation are comparable across the three countries, Poland experienced a much higher GDP volatility than the other two countries.

6.3 The Model Economy

The representative agent economy is an application of the model described in chapter 1. The agent allocates resources amongst three sectors: goods production, human capital investment, and exchange credit production as a means to avoid the inflation tax. There are three random shocks at the beginning of the period observed by the consumer before the decision process, which follow a vector first-order autoregressive process for goods sector productivity, z_t, the money supply growth rate, u_t, and credit sector productivity, v_t :

$$Z_t = \Phi_Z Z_{t-1} + \varepsilon_{Zt} \tag{6.1}$$

where the shocks are $Z_t = [z_t \; u_t \; v_t]'$, the autocorrelation matrix is $\Phi_Z = diag\{\varphi_z, \varphi_u, \varphi_v\}$ and $\varphi_z, \varphi_u, \varphi_v \in (0,1)$ are autocorrelation parameters, and the shock innovations are $\varepsilon_{Zt} = [\epsilon_{zt} \; \epsilon_{ut} \; \epsilon_{vt}]' \sim N(\mathbf{0}, \mathbf{\Sigma})$. The general structure of the second-order moments is assumed to be given by the variance-covariance matrix $\mathbf{\Sigma}$. These shocks affect the economy as described below.

The representative agent's period t utility over consumption c_t and leisure x_t is $\frac{(c_t x_t^{\Psi})^{1-\theta}}{1-\theta}$, with $\theta \geq 0$ and $\Psi > 0$. Output of goods (y_t) is produced with

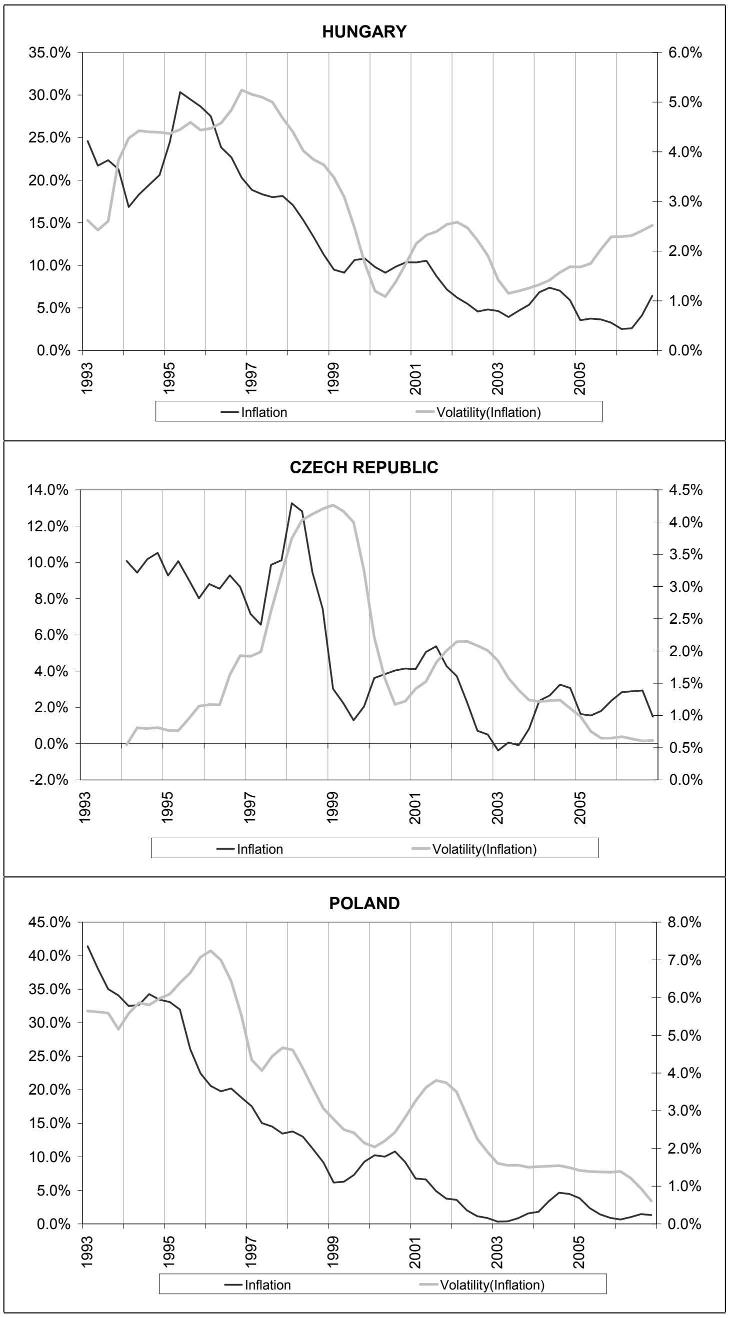

Figure 6.1: Inflation level and volatility

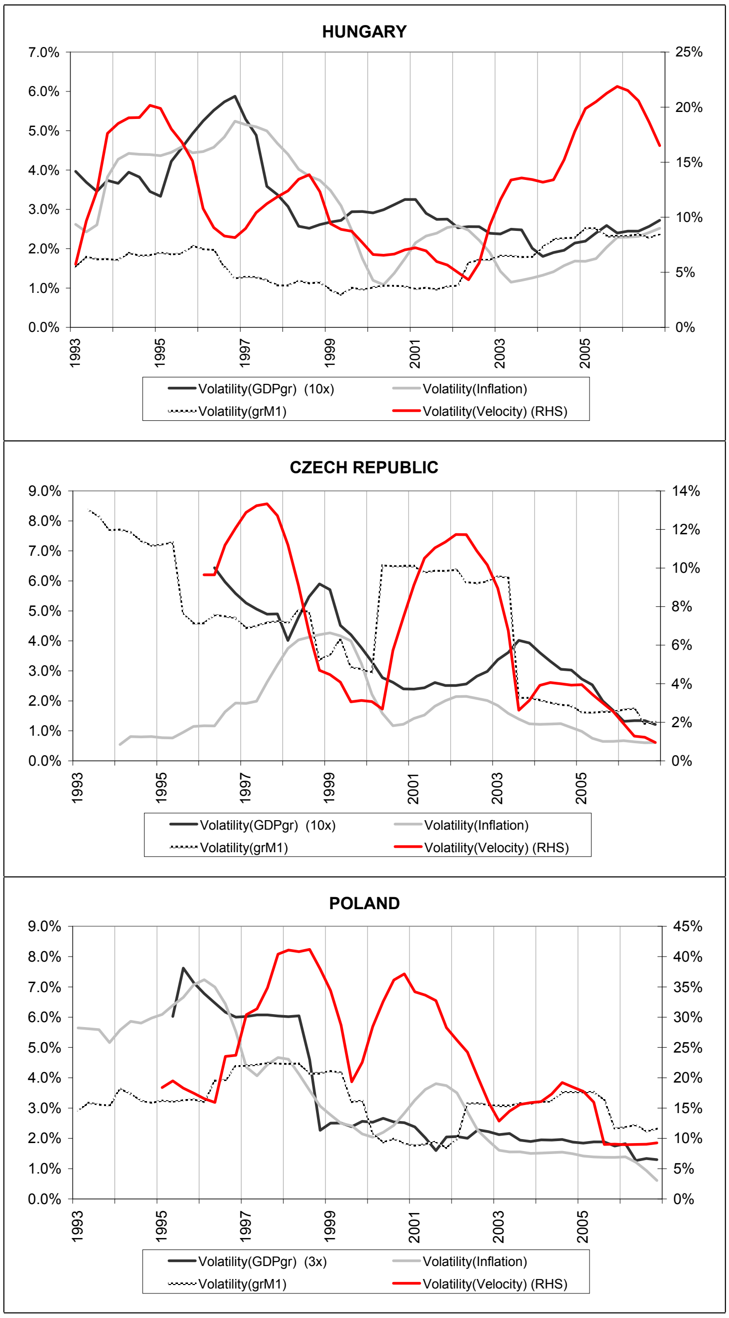

Figure 6.2: Volatilities of GDP growth, inflation, money growth and velocity

physical capital (k_t) that depreciates at the rate δ_k and with effective labor, through Cobb-Douglas production functions. Investment (i_t) is given by the accumulation equation $k_{t+1} = (1-\delta_k)k_t + i_t$. A unit of time is divided amongst leisure (x_t) and work in goods production (l_t), human capital investment (n_t), and exchange credit production (f_t):

$$1 = x_t + l_t + n_t + f_t. \tag{6.2}$$

With h_t denoting human capital, the effective labor employed across sectors is $l_t h_t$, $n_t h_t$, and $f_t h_t$ respectively. Given $A_H > 0$, $\delta_h \geq 0$, human capital accumulates with a labor-only technology (Lucas 1988):

$$h_{t+1} = (1-\delta_h)h_t + A_H n_t h_t. \tag{6.3}$$

Let $a_t \in (0,1]$ denote the fraction of consumption goods that are purchased with money (M_t); then the exchange constraint can be expressed as

$$M_t + T_t \geq a_t P_t c_t, \tag{6.4}$$

where M_t is the money stock carried from the previous period and T_t is the nominal lump-sum money transfer received from the government at the beginning of the current period. Exchange credit (q_t) is produced by the consumer acting in part as a bank to provide a means to pay for the rest of the purchases, without having to hold cash in advance of trading, and instead paying off the debt at the end of the period; this gives that

$$q_t = c_t \left(1 - a_t\right). \tag{6.5}$$

The consumer deposits all income that is not invested, of $y_t - i_t = c_t$, in its bank, makes purchases of goods c_t with the cash and credit taken out of deposits d_t, where $d_t = \left[\left(M_t + T_t\right)/P_t\right] + q_t = a_t c_t + \left(1-a_t\right)c_t = c_t$. As a bank, the consumer uses a case of the now-standard Clark (1984) financial services technology to produce the exchange credit q_t. Clark assumes a constant returns to scale function in labor, physical capital, and financial capital that equals deposited funds Here for simplicity no physical capital enters; with $A_F > 0$ and $\gamma \in (0,1)$, the CRS production technology is $q_t = A_F e^{v_t} \left(f_t h_t\right)^{\gamma} d_t^{1-\gamma}$, where v_t is the shock to factor productivity; since deposits equal consumption, this can be written as

$$q_t = A_F e^{v_t} \left(f_t h_t\right)^{\gamma} c_t^{1-\gamma}. \tag{6.6}$$

Solving for q_t/c_t from equation (6.6), substituting this into the relation $a_t = 1-(q_t/c_t)$ from equation (6.5), and substituting this relation for a_t back into the exchange constraint (6.4), yields an exchange constraint analogous to a shopping time constraint as extended to endogenous growth:

$$M_t + T_t \geq \left[1 - A_F e^{v_t} \left(f_t h_t/c_t\right)^{\gamma}\right] P_t c_t. \tag{6.7}$$

Let w_t and r_t denote competitive wage and rental rates. Nominal wages ($P_t w_t l_t h_t$) and rents ($P_t r_t k_t$) plus any unspent cash ($M_t + T_t - a_t P_t c_t$), make up the consumer's income, while set-aside cash (M_{t+1}) plus end-of-period credit debt payments $[c_t \left(1-a_t\right)]$, and investment (i_t) are expenditures:

$$P_t w_t l_t h_t + P_t r_t k_t + T_t + M_t - M_{t+1} - P_t c_t - P_t k_{t+1} + P_t(1-\delta_k)k_t \geq 0. \tag{6.8}$$

The government transfers a random amount T_t given by

$$\frac{T_t}{M_t} = \Theta_t = \Theta^* + e^{u_t} - 1 = \frac{M_{t+1}}{M_t} - 1, \tag{6.9}$$

so that Θ^* is the stationary gross growth rate of money.

The competitive firm maximizes profit given by $y_t - w_t l_t h_t - r_t k_t$, with production technology $y_t = A_G e^{z_t} {k_t}^{1-\alpha}(l_t h_t)^{\alpha}$. Then

$$w_t = \alpha A_G e^{z_t} \left(\frac{k_t}{l_t h_t}\right)^{1-\alpha}; \tag{6.10}$$

$$r_t = (1-\alpha) A_G e^{z_t} \left(\frac{k_t}{l_t h_t}\right)^{-\alpha}. \tag{6.11}$$

Denoting the state of the economy by $s = (k, h, M, z, u, v)$, and with $\beta \in (0, 1)$, the representative agent's optimization problem can be written in a recursive form as:

$$V(s) = \max_{c,x,l,n,f,k',h',M'} \left\{ \frac{(cx^{\Psi})^{1-\theta}}{1-\theta} + \beta E V(s') \right\} \tag{6.12}$$

subject to the conditions (6.2), (6.3), (6.7) and (6.8). Define the competitive equilibrium as a set of policy functions $c(s)$, $x(s)$, $l(s)$, $n(s)$, $f(s)$, $k'(s)$, $h'(s)$, $M'(s)$, pricing functions $P(s)$, $w(s)$, $r(s)$ and the value function $V(s)$, such that (i) households maximize utility $V(s)$, given the pricing functions and that the policy function $V(s)$ solves the functional equation (6.12); (ii) firms maximize profits, with the functions w and r given by (6.10) and (6.11); (iii) the goods and money markets clear, in equations (6.8) and (6.9).

Calibration

The calibration of the model implies choosing values for the model parameters such that certain features of the model match the corresponding values observed in the time series of the real economy over the time horizon 1993-2006. During the calibration we account for the differences among the three countries, in terms of differences in inflation, interest rate, output growth rate, investment rate and (inverse) money velocity. These target variables have the following values: Hungary: $i/y = 0.22$, $pi = 12.7$, $g = 3.5$, $R = 15.3$, $a = 0.29$. Czech Republic: $i/y = 0.3$, $pi = 4.2$, $g = 3$, $R = 5.6$, $a = 0.4$. Poland: $i/y = 0.22$, $pi = 7$, $g = 4.5$, $R = 12.4$, $a = 0.2$. The quarterly depreciation rates of physical capital is set as in the Hungarian Quarterly Projection Model of Benk, Jakab, Kovács, Párkányi, Reppa, and Vadas (2006). Human capital depreciation rate is $\delta_H = 0.016$. The capital share parameter in the goods sector, $1 - \alpha$, equal to 0.4 as in Benczúr, Simon, and Várpalotai (2002), and the annual discount factor $\beta = 0.99$. The parameters of the utility function are $\theta = 2$ and $\Psi = 4$. The the share of the labor in the banking sector is $\gamma = 0.13$.

The parameters of the shock structure (persistence and variance-covariance) are chosen in a different way from the literature: The business cycle literature usually sets the persistence and the volatility of productivity shocks such that the second moments of the model's simulated output match the values observed in data, while money supply parameters are directly estimated from data. Here shocks are derived from real data as described in Section 2.1, then the shock parameter structure is directly estimated from the shock series. The estimated parameters are then fed back to the model and the shocks are re-constructed. This iterative process continues until convergence is achieved in the parameter structures (see Section 1.1 for more details on the calibration methodology).

6.4 Results: Shocks and Banking History, Variance Decomposition

In that follow, we identify the main shocks in the recent monetary and financial history of Hungary, Czech Republic and Poland and explain the financial sector developments within this common model. together with the puzzling bifurcating pattern between the volatilities of money and money velocity on the one hand and that of inflation and output on the other hand.

6.4.1 Data

A quarterly data set is constructed for Hungary ,Czech Republic and Poland. Data is collected starting from the early transition period, where available. A general obstacle in collecting data is the availability of quarterly National Accounts data, series that in the early transition periods have been typically reported only at annual frequencies. A balance data set was available for Hungary for the period 1993-2007, for Czech Republic for the period 1996-2007 and for Poland for the period 1995-2007. Data series have been downloaded from the IMF-IFS database. In case of Hungary, since quarterly GDP components have been published only starting from 1995, we extrapolated backwards the quarterly data by using the seasonally adjusted quarterly growth rates derived from the quarterly GDP components estimated by Várpalotai (2003) for the period 1993-1995.

6.4.2 Shocks: level movements and impacts on GDP and inflation

The productivity, money and credit shocks are constructed as described in Chapter 1 by using the model's solution (variables as function of the state variable and shocks) and data on the variables on which we were able to find reliable data. The variables employed in this procedure are c/y, i/y, m/y, labor hour in banking sector f and on the wage rate in banking - the latter series being used as a proxy for the marginal product of labor in banking ($mplb$). Data series have been detrended by using the Christiano-Fitzgeral asymmetric band-pass filter with a window of 2-56 quarters.

The resulting series of credit shocks are depicted in figure 6.3, along with their volatilities. Although there are some remarkable differences among the patterns of the credit shocks in the three countries, their evolution confirm a consistent story that emerges from the history of the banking system in these three countries. In particular, the credit shocks appear to have some significant chronological conformity to the timing of bank privatization, reorganization and banking reform legislation, outlined at the beginning of this chapter, in a similar way to the conformity pointed out by Benk, Gillman, and Kejak (2005b) for the US.

In this respect, consider first Hungary: the sharp increase in the credit shock in the upper panel of Figure 6.3 after the stabilization package of 1995 corresponds to the beginning of the privatization of the Hungarian banking sector. Credit shock remained at elevated levels in the subsequent years as state ownership declined considerably by the end of 1997. In 1997 the legal provisions for foreign branch establishment have been created, visible again in another peak around 1997 in the credit shock series. After this date, however, there had been implemented several reorganization measures regarding bank supervision, ending by the establishment of a single supervising organization in 2000. This is again clearly visible in the continuously declining credit shocks until 2000. On overall these events and legislation changes and the corresponding movement in the estimated credit shocks are very similar to the changes in the US banking in legislation and the subsequent credit shocks documented by Benk, Gillman, and Kejak (2005b) and in Chapter 3. Going further, after the recovery of the credit shocks in 2000-2001 (that could be associated with the housing boom and the subsequent credit boom) the year 2001 saw the introduction of the inflation targeting monetary policy regime in Hungary. Such a regime change could be interpreted as change in the expected variance and mean of the inflation rate, that may act as a shift down in the banks productivity in producing credit or other instruments used to avoid the inflation tax. This is well visible in the declining credit shocks after 2001. However, credit shocks recovered again peaking around 2005, that could signal not only the strong expansion in housing loans (backed by government subsidies) and in consumer credit but also the increased competition and the need for innovation in the financial sector, generated by the EU accession in 2004.

Regarding the credit shocks in the Czech Republic and Poland, they evolved rather similarly to each other. Despite the fact that they differ considerably from credit in Hungary, they show chronological conformity to various historical events, just as it has been documented in the case of Hungary and the US. The new privatization program launched in 1997 in the Czech Republic improved the management of the banking sector, the subsequent improvement in productivity being visible in the rise in credit shocks seen in the middle panel of figure 6.3. The positive effect of privatization is visible also in the increase in the Polish credit shocks in the late 90s (lower panel). The introduction of the inflation targeting regime triggered a decline in credit shocks both in the Czech Republic and Poland starting from 1999 just as it has happened later in Hungary after switching to IT. Later, the impact of the Czech recession on bank productivity during 2000-2002 is clearly visible as well as the aftermath recovery from 2003 supported also by the expansion in retail banking, mortgage and consumer lending.

Having established the connection between a series of historical events and the estimated credit shocks, Figure 6.4 quantifies the effect of these shocks on GDP and inflation, across all three countries, in a similar way to what has been done in Benk, Gillman, and Kejak (2005b) and in Chapter 3 Figure 3.2 for the US. Productivity shocks influenced more severely the GDP development in Poland than in the other two countries, while the average impact of money and credit shocks are comparable across countries. As for inflation, productivity shocks had less impact in Hungary while the contribution of the other two shocks

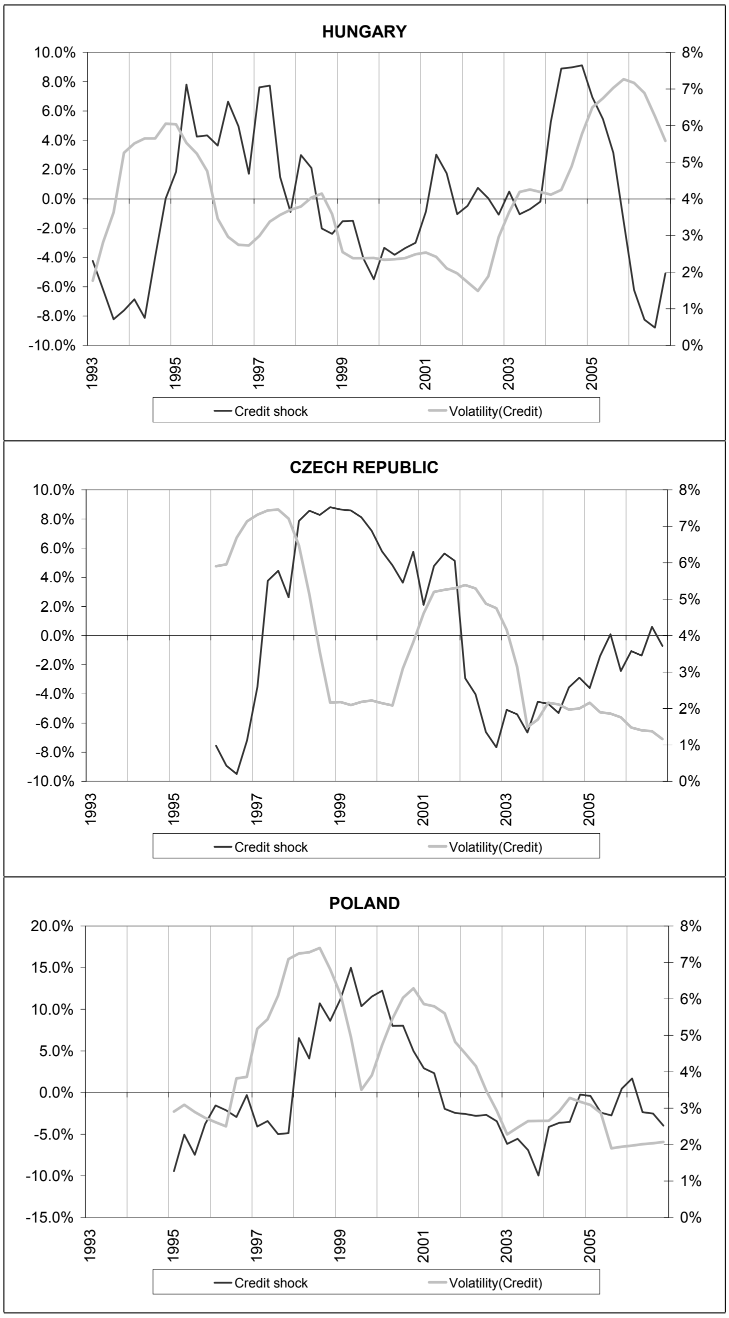

Figure 6.3: Credit shocks and their volatility

were in the same range across countries.

In Hungary money shocks contributed negatively to GDP in the years when inflation escalated in 1995-1996, then again around 2004, while it contributed positively in the stabilization periods. Credit shocks had opposite effects, they contributed positively in the inflationary periods indicating presumably that credit helped to counterbalance the detrimental effects of the inflation tax.

Another aspect of the possible comovements across countries is given by the various frequency components of the shocks. Figure 6.5 shows the Christiano-Fitzgerald band pass filter of the three shocks at the short-run (2-6quarters), business cycle (6-24 quarters) and long-run (above 24 quarters) frequencies across the whole sample period, and across the three countries. The first remarkable result is that while the shocks show only one long-run cycle for Czech Republic and Poland, in the case of Hungary we can observe two cycles that roughly corresponds to the pre- and post IT regimes, 1993-2000 and 2001-2006. The long-run credit shock cycles in the Czech Republic and Poland show much coincidence, they move together along the bank privatization episodes, changes is banking sector regulations and also later during the credit boom. These episodes can be identified also in the long-run component of the Hungarian credit shock although their timing differed somehow from what has been observed in the other two countries. The Hungarian business cycle and the short-run component in terms of volatility seem to have similar patterns at the first and the second part of the sample. Short-run fluctuations appear to be more intense in Poland during the 90s.

6.4.3 Volatility and Variance decomposition

Figures 6.2 and 6.3 contrast the evolution of the volatilities of output, inflation money and money velocity, with the evolution of the credit shock and its volatility. A puzzling bifurcating pattern between the volatilities of money and money velocity on the one hand, and that of inflation and output on the other hand – similar to what has been documented in Chapter 5 for the US – can be identified here in the data series of the transition countries as well. This puzzling evolution is most visible in the Hungarian data series, although some similar patterns can be identified also in the Czech and Polish data.

The similarities between the evolution of US and transition countries' data volatilities can be explained within the same common framework of the credit model. Hungary experienced a steady increase in credit shock volatility starting from 2002. At the same time, money volatility and money velocity volatility increased as well while GDP volatility declined and inflation volatility stood at relatively low levels. We interpret the increased credit volatility as reflecting the liberalization of credit that diminished some of the inflation tax fluctuations that high money supply volatility can otherwise entail. Thus, financial liberalization allowed monetary aggregate volatility to be manifested through higher credit volatility rather than turning into higher inflation and GDP volatility. In the Czech Republic such similar evolution can be observed after 2000. However, in this case the picture is less clear since the Czech Republic saw a recession in this period when credit shocks also declined, thus one can give multiple interpretation to such observations. In Poland, however, starting from 2003 a more clear picture emerges where the increase in the credit shock and its volatility along with the increase in money and money velocity volatility and

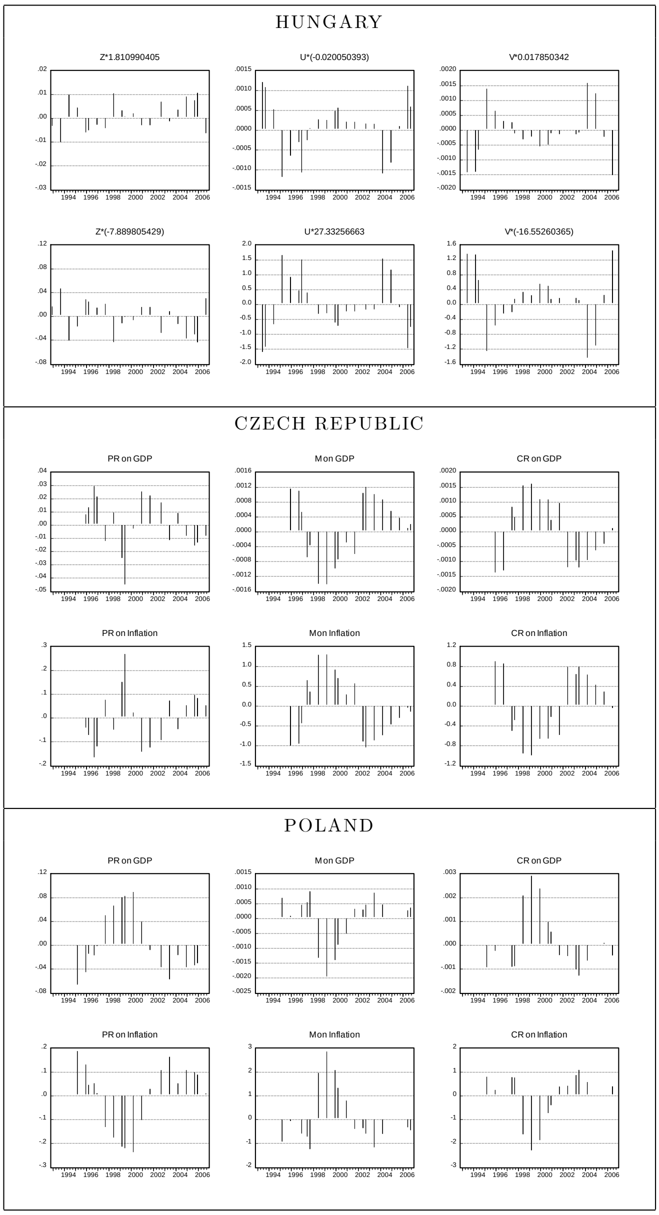

Figure 6.4: Effect of shocks on GDP and Inflation, for HU, CZ and PO

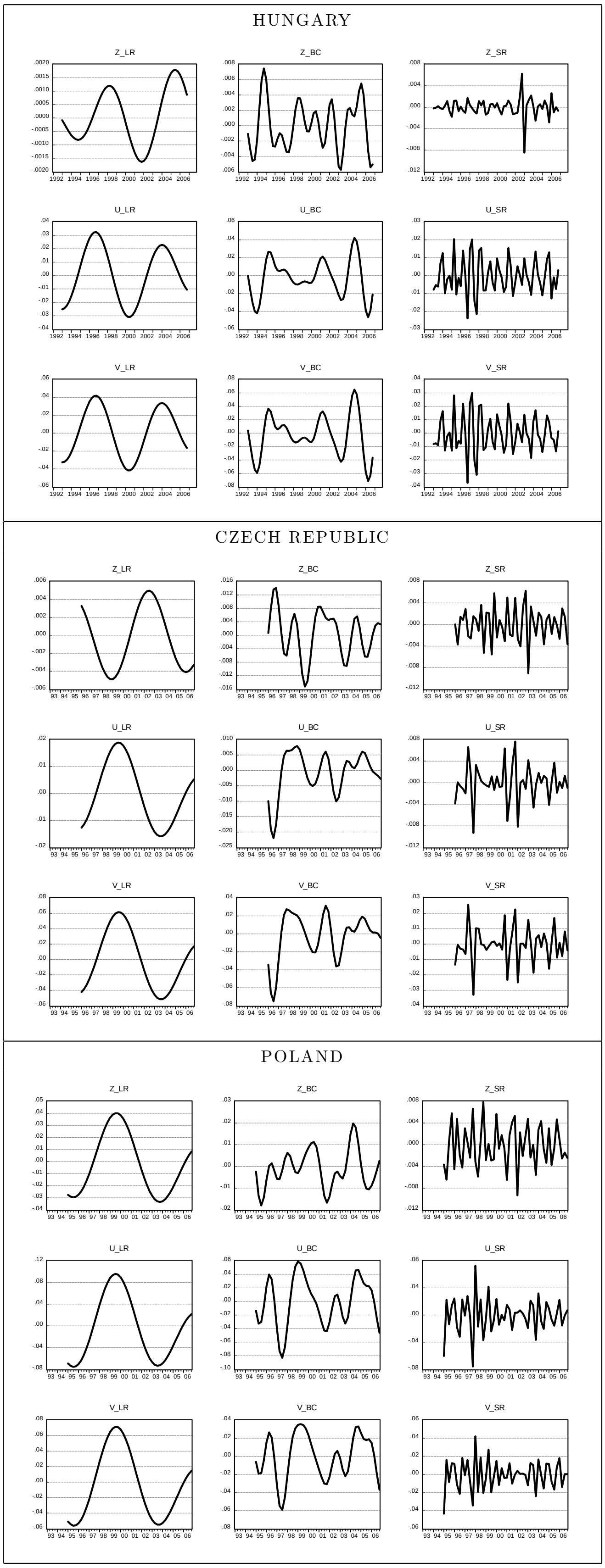

Figure 6.5: LR, BC and SR (horizontal) components of PR, M and CR shocks (vetical), for HU, CZ and PO

		StdDev	Correlation PR	M	CR
HUNGARY					
1993-2000					
	PR	**0.003**	1.00	0.00	0.02
	M	**0.037**	0.00	1.00	0.99
	CR	**0.048**	0.02	0.99	1.00
2001-2006					
	PR	**0.005**	1.00	0.35	0.38
	M	**0.032**	0.35	1.00	0.99
	CR	**0.050**	0.38	0.99	1.00
1993-2006					
	PR	**0.004**	1.00	0.18	0.22
	M	**0.035**	0.18	1.00	0.99
	CR	**0.049**	0.22	0.99	1.00
CZECH REPUBLIC					
1983-2004					
	PR	**0.009**	1.00	-0.41	-0.40
	M	**0.017**	-0.41	1.00	0.99
	CR	**0.056**	-0.40	0.99	1.00
POLAND					
1919-2004					
	PR	**0.032**	1.00	0.81	0.84
	M	**0.083**	0.81	1.00	0.99
	CR	**0.061**	0.84	0.99	1.00

Table 6.1: Variance and covariance structure of shocks

the moderating GDP and inflation volatility show much similarities to the post-2002 Hungarian era and the era of the late 80s and 90s in the US.

The volatilities and the covariance structure of the productivity, money and credit shocks are shown in Table 6.1. It is Poland that experienced the most volatile shocks, especially productivity and money, while the volatilities of the credit shocks are comparable across countries. The cross correlation structure also differs across countries. While money and credit shocks are positively correlated in all countries, the correlations between productivity-money, and productivity-credit are slightly positive in Hungary, highly positive in the Czech Republic and negative in Poland. One can also observe the evolution of these indicators over time in Hungary from levels around zero to more positive ones. The variance of all three shocks remained relatively stable in Hungary, with some increase for the variance of the productivity shock.

The decomposition of variance of output growth, inflation and money velocity is presented in Table 6.2, which shows how much of the total variance is explained by each of the shocks: the productivity (PR), money (M) and credit (CR) shocks. Tables 6.3, 6.4 and 6.5 decompose the variance further by frequencies, for all three countries. The short-run (SR) frequency band corresponds to cycles of 2-6 quarters, the business cycle (BC) frequency band to cycles of 6-24 quarters, and the long-run (LR) band to cycles of above 24 quarters. The last column ("all") shows the total variance found within each frequency.

There are some similarities in the factors that generate the volatility of the economies of the three countries. It is the productivity shock that explains more than half of the variance of GDP growth in all three countries, while money and credit shocks have less and fairly equal contribution. Inflation is

		PR	M	CR
GDP				
Hungary	1993-2000	69%	16%	15%
	2001-2006	72%	15%	13%
	1993-2006	48%	26%	26%
Czech Republic	1996-2006	65%	15%	20%
Poland	1995-2006	73%	11%	16%
INFLATION				
Hungary	1993-2000	12%	43%	45%
	2001-2006	27%	35%	38%
	1993-2006	4%	48%	49%
Czech Republic	1996-2006	14%	46%	40%
Poland	1995-2006	17%	47%	36%
VELOCITY				
Hungary	1993-2000	4%	48%	48%
	2001-2006	19%	41%	40%
	1993-2006	6%	47%	47%
Czech Republic	1996-2006	10%	45%	45%
Poland	1995-2006	78%	11%	11%

Table 6.2: Variance decomposition by shocks

		PR	M	CR	all
Hungary	**1993-2006**				
	SR	5%	13%	16%	35%
	BC	29%	18%	16%	63%
	LR	1%	0%	1%	2%
Czech Republic	**1996-2006**				
	SR	7%	5%	9%	21%
	BC	45%	14%	18%	76%
	LR	0%	1%	1%	2%
Poland	**1995-2006**				
	SR	22%	21%	30%	74%
	BC	13%	3%	1%	17%
	LR	8%	1%	1%	9%

Table 6.3: Variance decomposition of GDP growth by shocks and frequencies

explained mainly by money and credit shocks, with roughly equal contribution in Hungary and somewhat bigger contribution of money shocks in Czech Republic and Poland. The volatility of money velocity is explained mainly by money and credit shock in Hungary and Czech Republic, while in Poland it is explained in large part by productivity shocks. As regards the evolution in time of the individual contributors in Hungary, the importance of shocks shifted somewhat towards productivity, out from money and credit, although the changes are insignificant.

Table 6.3 shows the composition of GDP growth volatility by shocks and frequencies. In Hungary and the Czech Republic most of the fluctuations take place at business cycle frequency while in Poland the short-run fluctuations dominate. Money and credit shocks, however, exert a significant contribution in Hungary also at short-run frequency.

For inflation volatility Table 6.4 indicates that most of the fluctuations appear at short-run frequency, and these fluctuations can be attributed to money and credit shocks.

		PR	M	CR	all
Hungary	**1993-2006**				
	SR	2%	31%	33%	66%
	BC	3%	14%	13%	30%
	LR	0%	2%	2%	4%
Czech Republic	**1996-2006**				
	SR	5%	22%	28%	55%
	BC	8%	13%	15%	37%
	LR	5%	2%	2%	8%
Poland	**1995-2006**				
	SR	14%	33%	26%	73%
	BC	14%	4%	3%	20%
	LR	1%	3%	3%	7%

Table 6.4: Variance decomposition of inflation by shocks and frequencies

		PR	M	CR	all
Hungary	**1993-2006**				
	SR	0%	4%	4%	8%
	BC	7%	17%	16%	40%
	LR	35%	8%	9%	52%
Czech Republic	**1996-2006**				
	SR	0%	2%	2%	4%
	BC	1%	6%	6%	14%
	LR	72%	5%	5%	82%
Poland	**1995-2006**				
	SR	0%	3%	3%	7%
	BC	2%	7%	7%	15%
	LR	75%	2%	1%	78%

Table 6.5: Variance decomposition of money velocity by shocks and frequencies

As opposed to inflation, fluctuations in money velocity take place mainly at long-run frequencies as Table 6.5 shows. This is especially true for Czech Republic and Poland, where these long-run fluctuations are mainly driven by productivity shocks, while in Hungary the business cycle component is also important which is driven by money and credit shocks.

Further information can be distilled from the evolution of these frequency components over time in the case of Hungary (see tables in the Appendix). While the business cycle fluctuations in GDP growth were strong, they moderated over time and shifted towards short-run fluctuations. This was due to the weakening impact of productivity shocks at business cycle frequency and the strengthening of the money and credit shock contributions at short-run frequency. Money and credit shocks shifted also the inflation volatility towards shorter-run frequencies. As velocity concerns, the opposite effect can be observed where the business cycle component has been strengthened, although not only at the expense of the short-run component but also at the expense of the long-run component.

6.5 Conclusion

The financial sectors of Central and Eastern European countries share a number of common characteristics that alow studying and modeling them in a common framework. This chapter calibrates a monetary business cycle model with endogenous growth and credit shocks, and explains the financial sector developments of Hungary, Czech Republic and Poland within this common model. Credit shocks are estimated by using the model solution equations and data. A chronological conformity of the credit schocks and the timing of various events from the banking sector history is found, and the impact of shocks on GDP and inflation movements is emphasized.

This chapter also documents the evolution of the volatilities of output, inflation money and money velocity, emphasizing a puzzling bifurcating pattern between the volatilities of money and money velocity on the one hand, and that of inflation and output on the other hand. This patters shows similarities to what has been observed in US data and documented in Capter 5, the explanation to such behaviour being offered here within the credit model.

The results suggest that the model is able to capture and explain the monetay and financial developments not only in the US but also in the transition countries. These altogether confirm the validity of the credit model as well as the role of financial innovations in explaining movements in inflation and output and the volatility patterns seen in data.

6.A Appendix

		PR	M	CR	all
1993-2000					
	SR	9%	8%	8%	24%
	BC	41%	16%	16%	74%
	LR	1%	0%	0%	2%
2001-2006					
	SR	8%	25%	38%	71%
	BC	7%	9%	9%	25%
	LR	3%	1%	1%	4%
1993-2006					
	SR	5%	13%	16%	35%
	BC	29%	18%	16%	63%
	LR	1%	0%	1%	2%

Table 6.6: GDP growth, Hungary

		PR	M	CR	all
1993-2000					
	SR	9%	28%	28%	65%
	BC	9%	11%	11%	31%
	LR	1%	2%	2%	4%
2001-2006					
	SR	12%	32%	32%	76%
	BC	10%	6%	6%	23%
	LR	1%	0%	0%	1%
1993-2006					
	SR	2%	31%	33%	66%
	BC	3%	14%	13%	30%
	LR	0%	2%	2%	4%

Table 6.7: Inflation, Hungaryn

		PR	M	CR	all
1993-2000					
	SR	0%	5%	5%	10%
	BC	11%	4%	4%	19%
	LR	55%	8%	8%	70%
2001-2006					
	SR	0%	2%	3%	5%
	BC	34%	16%	17%	66%
	LR	27%	1%	1%	29%
1993-2006					
	SR	0%	4%	4%	8%
	BC	7%	17%	16%	40%
	LR	35%	8%	9%	52%

Table 6.8: Velocity, Hungary

Summary and Conclusions

This thesis consisted of a series of papers, each of them investigating the role of credit and money shocks and the banking sector in explaining some aspects of the economic history and in particular business cycle fluctuations. We set up a stochastic model that allowed for a banking sector and shocks to its productivity. It was found that the credit model improves the performance of the standard monetary business cycle models. We constructed credit shock series and showed the congruence with changes in US banking laws during the financial deregulatory era of the 1980s and 1990s. We also explained the behavior of money velocity, pointing out that shocks to the money supply growth rate have a significant impact on velocity, especially during the high inflation period, while credit shocks have an important impact on GDP during the deregulatory era. Credit shocks helped also in explaining the puzzle of the divergence of increased velocity and money aggregate volatilities post 1983 from decreased GDP and inflation volatilities post 1983. Post 1983 credit became unleashed through long run financial innovation during deregulation and so allowed monetary aggregate volatility to be manifested through higher credit volatility rather than turning into higher inflation and GDP volatility as in previous time, in particular during the Great Depression period. Finally, we pointed out the role of credit also during the transition period of a set of Central and Eastern European countries, especially in explaining the divergence in the money aggregate growth and velocity volatilities away from the downward trending GDP and inflation volatilities, observed otherwise also in the US data.

These results altogether are suggesting that modeling banking sector and credit productivity shocks are important in explaining certain features of the economic time series and in explaining financial history by allowing to account for changes in banking regulations.

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