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Credit shocks in the financial deregulatory era: Not the usual suspects

Szilárd Benk [a,b], Max Gillman [b,c,d,*], Michal Kejak [e]

[a] *Magyar Nemzeti Bank, Hungary*
[b] *Central European University, Hungary*
[c] *Cardiff Business School*
[d] *Economics Institute of the Hungarian Academy of the Sciences*
[e] *CERGE-EI, Czech Republic*

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Abstract

The paper constructs credit shocks using data and the solution to a monetary business cycle model. The model extends the standard stochastic cash-in-advance economy by including the production of credit that serves as an alternative to money in exchange. Shocks to goods productivity, money, and credit productivity are constructed robustly using the solution to the model and quarterly US data on key variables. The contribution of the credit shock to US GDP movements is found, and this is 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 [What moves real GNP, Manuscript, Humbolt University, Berlin, 2003].

JEL classification: E13; E32; E44

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* Corresponding author at: Central European University, Department of Economics, Nador u. 9, H1051 Budapest, Hungary.

E-mail addresses: gillman@ceu.hu, gillman@cf.ac.uk (M. Gillman).

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1. Introduction

Identifying the sources of shocks that influence the real business cycle has become the focus of recent research. Chari et al. (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' 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) and Ingram et al. (1994, 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 sig-

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

nificant 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. Other representations of the shocks are possible, such as through the methods of Chari et al. (2003), but are left for future work.

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 et al. (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.

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.

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:

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

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:

$$M_{t-1} + T_t \geqslant a_t P_t c_t, \tag{2}$$

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:

$$T_t = \Theta_t M_{t-1} = \left(\Theta^* + \mathrm{e}^{u_t} - 1\right) M_{t-1}, \tag{3}$$

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:

$$u_t = \varphi_u u_{t-1} + \epsilon_{ut}, \qquad \epsilon_{ut} \sim N\left(0, \sigma_{\epsilon u}^2\right), \ 0 < \varphi_u < 1. \tag{4}$$

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

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

This can be written as

$$1 - a_t = A_F e^{v_t} \left(\frac{l_{Ft}}{c_t} \right)^{\gamma}, \tag{5}$$

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 exist productivity shocks that follow an autocorrelated process:

$$v_t = \varphi_v v_{t-1} + \epsilon_{vt}, \qquad \epsilon_{vt} \sim N\left(0, \sigma_{\epsilon v}^2\right),\ 0 < \varphi_v < 1. \tag{6}$$

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

$$n_t + x_t + l_{Ft} = 1. \tag{7}$$

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:

$$y_t = e^{z_t} k_{t-1}^{\alpha} n_t^{1-\alpha}, \tag{8}$$

$$z_t = \varphi_z z_{t-1} + \epsilon_{zt}, \qquad \epsilon_{zt} \sim N\left(0, \sigma_{\epsilon v}^2\right),\ 0 < \varphi_z < 1. \tag{9}$$

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:

$$k_t = (1 - \delta) k_{t-1} + i_t. \tag{10}$$

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:

$$w_t = (1 - \alpha) e^{z_t} k_{t-1}^{\alpha} n_t^{-\alpha}, \tag{11}$$

$$r_t = \alpha e^{z_t} k_{t-1}^{\alpha-1} n_t^{1-\alpha} + 1 - \delta. \tag{12}$$

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:

$$w_t P_t (1 - x_t - l_{Ft}) + P_t r_t k_{t-1} + T_t + M_{t-1} \geqslant P_t c_t + P_t k_t + M_t. \tag{13}$$

The consumer chooses consumption, leisure, time spent in credit service production, capital stock, the share of purchases made with cash, and the money stock $\{c_t, x_t, l_{Ft}, k_t, a_t, M_t\}_{t=0}^{\infty}$ to maximize lifetime utility (1) subject to the cash-in-advance constraint (2), budget constraint (13) and credit service technology (5).

2.1. Equilibrium

Dividing Eqs. (2) and (13) by the price level and substituting l_{Ft} expressed from (5), the Lagrangian of the maximization problem of the household is

$$L = E\sum_{t=0}^{\infty}\beta^t\left\{(\log c_t + \Psi \log x_t) + \lambda_t\left[\frac{M_{t-1}+T_t}{P_t} - a_t c_t\right]\right.$$
$$+ \mu_t\left[w_t\left(1 - x_t - \left(\frac{1-a_t}{A_F e^{v_t}}\right)^{1/\gamma} c_t\right)\right.$$
$$\left.\left. + r_t k_{t-1} + \frac{M_{t-1}+T_t}{P_t} - c_t - k_t - \frac{M_t}{P_t}\right]\right\}. \tag{14}$$

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

$$\frac{1}{c_t} - \lambda_t a_t - \mu_t w_t\left(\frac{1-a_t}{A_F e^{v_t}}\right)^{1/\gamma} - \mu_t = 0, \tag{15}$$

$$\frac{\Psi}{x_t} - \mu_t w_t = 0, \tag{16}$$

$$-\mu_t + \beta E_t\{\mu_{t+1} r_{t+1}\} = 0, \tag{17}$$

$$-\lambda_t c_t + \mu_t w_t c_t \frac{1}{\gamma A_F e^{v_t}}\left(\frac{1-a_t}{A_F e^{v_t}}\right)^{1/\gamma-1} = 0, \tag{18}$$

$$\frac{-\mu_t}{P_t} + \beta E_t\left\{\frac{\lambda_{t+1}+\mu_{t+1}}{P_{t+1}}\right\} = 0. \tag{19}$$

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 $p_t = P_t/M_t$ (and also denote real money balances by $m_t = M_t/P_t$). 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 (15)–(19) can be simplified to:

$$R^* - 1 = \frac{w^*}{\gamma^* A_F^*}\left(\frac{1-a^*}{A_F^*}\right)^{1/\gamma-1}, \tag{20}$$

$$\frac{x_t}{\Psi c_t} = \frac{1 + a^*(R^*-1) + w^*((1-a^*)/A_F^*)^{1/\gamma}}{w^*}, \tag{21}$$

$$r^* = \frac{1}{\beta}. \tag{22}$$

Equations (20)–(22) together with the steady-state versions of Eqs. (2)–(9) and (11)–(13) define the steady state of the system.

2.2. Calibration and numerical dynamics solution

The model is solved by using the log-linearization technique of King et al. (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 (4), (6) and (9).[2] 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 control and other endogenous variables, $\hat{c}_t$, $\hat{x}_t$, $\hat{n}_t$, $\hat{l}_{Ft}$, $\hat{a}_t$, $\widehat{w}_t$, $\hat{r}_t$, $\hat{y}_t$, $\hat{p}_t$ 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 $\mathbf{Y}_t^{'} = [\hat{c}_t \quad \hat{x}_t \quad \hat{n}_t \quad \hat{l}_{Ft} \quad \hat{a}_t \quad \widehat{w}_t \quad \hat{r}_t \quad \hat{y}_t \quad \hat{p}_t]$ 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:

$$\mathbf{X}_t = PP\,\mathbf{X}_{t-1} + QQ\mathbf{Z}_t, \tag{23}$$

$$\mathbf{Y}_t = RR\,\mathbf{X}_{t-1} + SS\,\mathbf{Z}_t, \tag{24}$$

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, 1989, 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 Eq. (22) a quarterly net real return 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 et al. (1993). Then, the steady-state first order conditions imply the fraction of hours spent in credit services production, which is $l_F = 0.00049$, as compared to 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, 1989). Persistence is set equal to $\varphi_z = 0.95$, as is common.

The money supply process is calibrated so that the M1 money aggregate varies in a way that is consistent with the US experience between 1959–2000. Following

[2] The details of the log-linearization can be found in Benk et al. (2004).

Cooley and Hansen (1989, 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):

$$\Delta \log M_t = \underset{(0.0011)}{0.005139} + \underset{(0.065)}{0.576748}\, \Delta \log M_{t-1} + \epsilon_t, \quad \sigma_\epsilon = 0.010022. \tag{25}$$

This implies $\varphi_u = 0.58$, $\sigma_{\epsilon u} = 0.01$, close to Cooley and Hansen's (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 Eqs. (23) and (24) takes the form

$$\hat{k}_t = 0.953\hat{k}_{t-1} + 0.117 z_t - 0.0003 v_t + 0.007 u_t, \tag{26}$$

$$\begin{bmatrix} \hat{c}_t \\ \hat{x}_t \\ \hat{n}_t \\ \hat{l}_{Ft} \\ \hat{a}_t \\ \widehat{w}_t \\ \hat{r}_t \\ \hat{p}_t \\ \hat{y}_t \end{bmatrix} = \begin{bmatrix} 0.564 \\ 0.110 \\ -0.265 \\ 0.100 \\ 0.042 \\ 0.456 \\ -0.028 \\ -0.606 \\ 0.190 \end{bmatrix} \begin{bmatrix} \hat{k}_{t-1} \end{bmatrix} + \begin{bmatrix} 0.399 & 0.014 & -0.120 \\ -0.321 & -0.005 & 0.002 \\ 0.772 & 0.011 & -0.023 \\ -0.551 & 0.056 & 10.430 \\ 0.085 & -0.432 & -0.949 \\ 0.722 & -0.004 & 0.008 \\ 0.052 & 0.0002 & -0.001 \\ -0.485 & 0.4184 & 1.068 \\ 1.494 & 0.007 & -0.015 \end{bmatrix} \begin{bmatrix} z_t \\ v_t \\ u_t \end{bmatrix}. \tag{27}$$

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 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

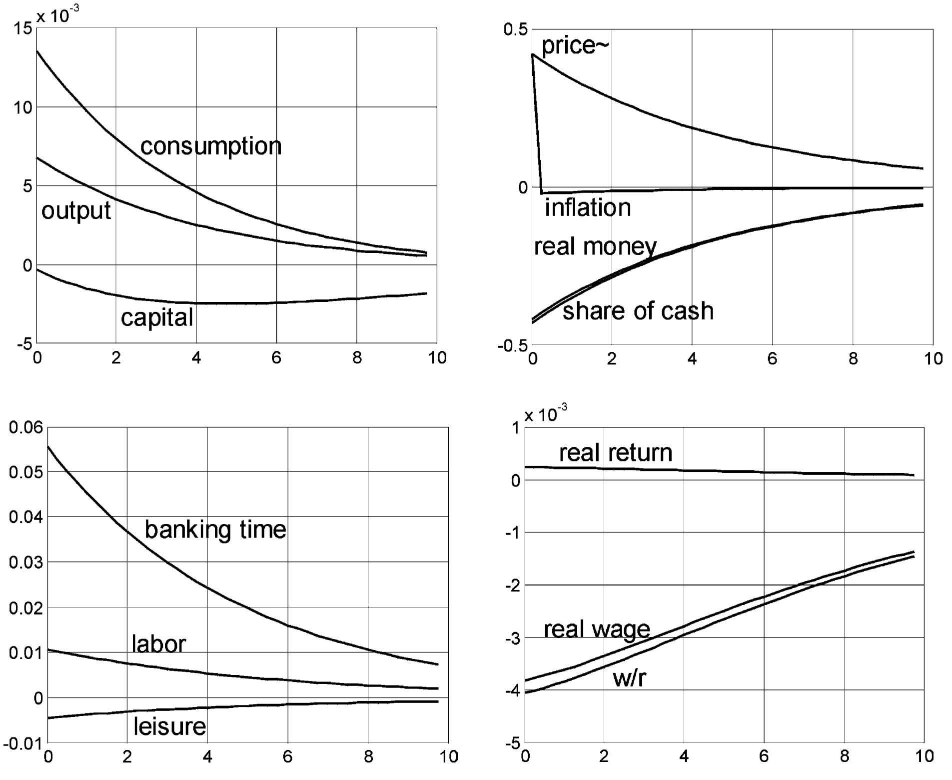

Fig. 1. Impulse responses to 1% credit productivity shock.

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 to 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. 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 to the recursive equilibrium system given in Eqs. (26) and (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.[3] 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 $\widehat{m}_t$ 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 et al. (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 (10) is used to generate $\hat{k}_t$.

The five equations with the now given values for $\hat{y}_t$, $\hat{c}_t$, $\hat{\imath}_t$, $\hat{l}_{Ft}$, $\widehat{m}_t$, and $\hat{k}_t$, allow for the ordinary least squares estimation of the three unknown shocks, z_t, v_t and u_t. To illustrate this, rewrite Eq. (27) in matrix form as

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

where A and B are the coefficient matrices from Eq. (27), and

$$X_t = \big[\hat{y}_t \quad \hat{c}_t \quad \hat{\imath}_t \quad \hat{l}_{Ft} \quad \widehat{m}_t\big]', \qquad E_t = \big[z_t \quad v_t \quad u_t\big]'.$$

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

$$\widetilde{E}_t = (B'B)^{-1}B'\big(X_t - A\big[\hat{k}_{t-1}\big]\big). \tag{28}$$

The magnitudes of the shocks are plotted in Fig. 2.

[3] 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.

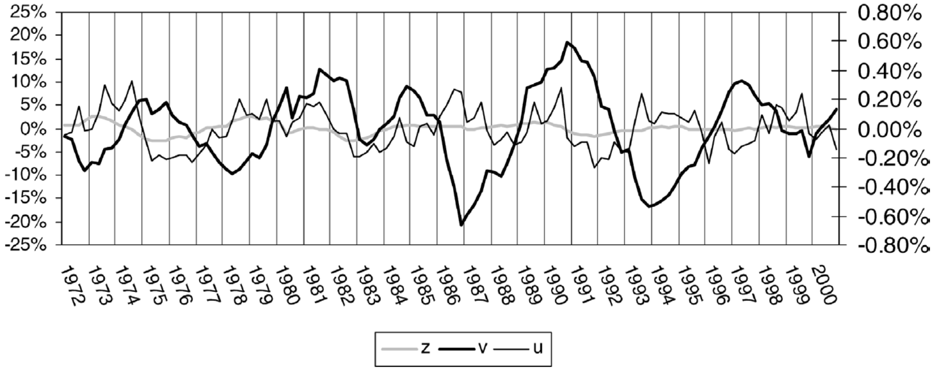

Fig. 2. Evolution of productivity (z), credit (v) and money (u) shocks (u on the right axis).

The estimated 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.

3.1. *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 Eq. (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 Fig. 3, 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 $GDP_{\text{actual}}/GDP|_{v=0} - 1$. 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 Eq. (28). This is graphed also in Fig. 3, 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.

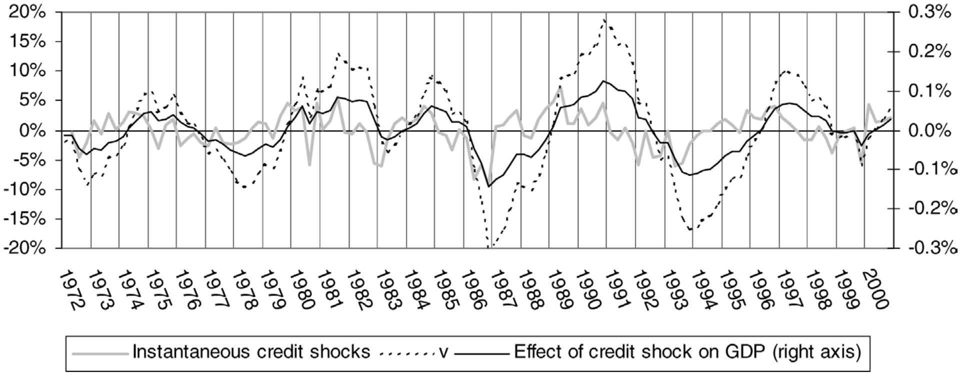

Fig. 3. Credit innovations ($\hat{\epsilon}_{vt}$), the credit shock (v_t), and the effect of credit shocks on GDP ($GDP_{\text{actual}}/GDP|_{v=0} - 1$).

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 Fig. 4 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 Fig. 4 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.

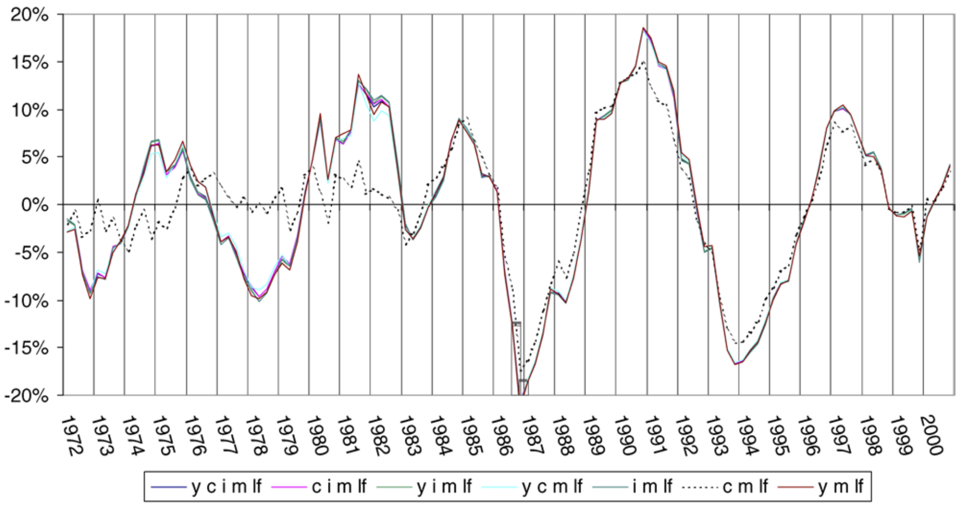

Fig. 4. The credit shock under alternative identifications.

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, 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 $\hat{y}_t, \hat{c}_t, \hat{\imath}_t, \hat{l}_{Ft}, \widehat{m}_t$; $\hat{y}_t, \hat{c}_t, \hat{l}_{Ft}, \widehat{m}_t$; $\hat{y}_t, \hat{\imath}_t, \hat{l}_{Ft}, \widehat{m}_t$; $\hat{c}_t, \hat{\imath}_t, \hat{l}_{Ft}, \widehat{m}_t$; $\hat{y}_t, \hat{l}_{Ft}, \widehat{m}_t$; and $\hat{\imath}_t, \hat{l}_{Ft}, \widehat{m}_t$. The latter two constructions are exact identifications that are made without estimation.

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 Eq. (6), when it uses the recursive equilibrium solution found in Eqs. (26) and (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 et al. (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 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 Fig. 5 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 ($\hat{y}_t$, $\hat{c}_t$, $\hat{\imath}_t$, $\hat{l}_{Ft}$, $\widehat{m}_t$) 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%.

Ingram et al. (1994) point out that only when shocks are completely uncorrelated with each other will the variance decomposition be unique. Table 1 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

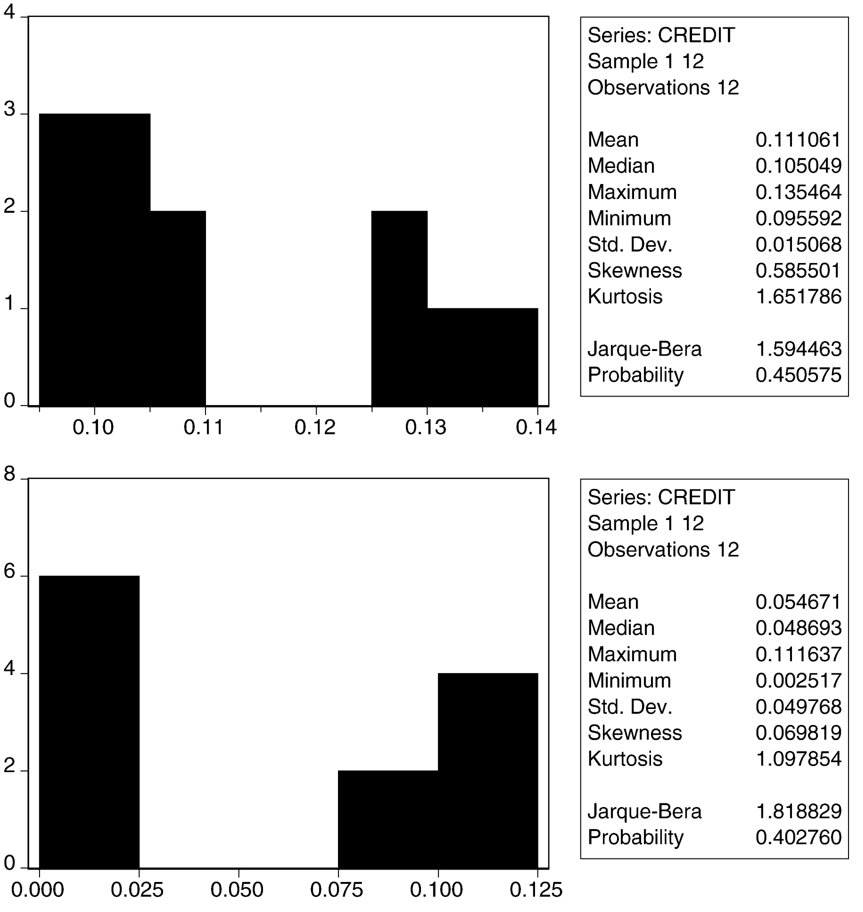

Fig. 5. Distribution of the variance decompositions of the credit shock, with 1st and 2nd orderings.

Table 1
Cross-correlations between the output sector and credit sector shocks

i	$\operatorname{corr}(z(t), v(t-i))$ lags	$\operatorname{corr}(z(t), v(t+i))$ leads
0	−0.2859	−0.2859
1	−0.3869	−0.1614
2	−0.4487	−0.0574
3	−0.4721	−0.0439
4	−0.4627	0.1308
5	−0.4327	0.2087
6	−0.3788	0.2682
7	−0.3075	0.3107
8	−0.2228	0.3388
9	−0.1385	0.3585
10	−0.0548	0.3929

by the credit shock, it is important to note that the credit shock construction remains unaffected by this variation.

4. Credit shocks and banking deregulation

The credit shock innovations and their effect on GDP, graphed in Fig. 3, 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.

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.[4]

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 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.[5]

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

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

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

repealed the McFadden Act and allowed interstate bank branching and consolidation. The Gramm–Leach–Bliley Act of 1999 repealed 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.[6]

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 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 columns 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

Table 2
Cycle characteristics: post-war averages, and individual cycle values

	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

[6] See Guzman (2003) for details on financial deregulations in the 1990s. Strahan (2003) documents other US changes. Cetorelli (2004) finds evidence of greater competition in banking in the EU following deregulation of the finance sector.

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 shows a positive 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’ 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.

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 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's (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.

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 et al., 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) and Ingram et al. (1994, 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 et al. (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.

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