CEDE

DOCUMENTO CEDE 2003-32
ISSN 1657-7191 (Edición electrónica)
NOVIEMBRE DE 2003

U.S. BUSINESS CYCLE VOLATILITY AND BANKING PRODUCTIVITY

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October, 2003

Abstract

In this paper I address two questions. First, is the fall in the cyclical volatility of U.S. commercial banking productivity a potential candidate to account for the mid-80's fall in U.S. business cycle volatility? Second, does the answer to the previous question change under the presence of financial frictions? The answer to the first question is that the fall in the cyclical volatility of banking productivity contributes significantly only to the volatility fall of the credit cycle. The answer to the second question is that allowing for financial acceleration does not change the results significantly.

Key Words: Cyclical volatility, credit channel, credit constraint, financial accelerator, commercial banking productivity.

JEL codes: E32, E44, G21.

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1 INTRODUCTION

The objective of this paper is to answer two questions. *First, is the fall in the cyclical volatility of U.S. commercial banking productivity a potential candidate to account for the mid-80's fall in U.S. business cycle volatility? Second, does the answer to the previous question change under the presence of financial frictions?* To answer these questions I construct and calibrate to U.S. post-Korean war data a general equilibrium business cycle model with costly financial intermediation and (optional) credit multipliers a-la Kiyotaki and Moore (1997) and Kocherlakota (2000). The model is developed in Arias (2002).

The main finding is that the fall in the cyclical volatility of banking productivity contributes significantly only to the credit cycle volatility fall. For the other macroeconomic aggregates, the contribution lies between 2 and 5 percentage points of volatility reduction (out of 50). I also find that allowing for financial acceleration does not change the previous results significantly if parameter values still replicate basic, empirical, macroeconomic regularities observed in the US during the post-Korean war period. According to the results, financial acceleration only augments the contribution of the fall in the cyclical volatility of banking productivity to the credit cycle volatility fall. In short, this paper adds even more skepticism to the quantitative importance of financial frictions as propagation and amplification mechanisms for macroeconomic shocks.

How should productivity fluctuations in the banking system be interpreted? Most of the empirical evidence documenting productivity fluctuations in the financial sector of the U.S. and of other countries identifies two elements as the main driving forces of the observed movements in financial productivity. The first one has to do with changes in banking regulation. A deregulatory process increases competitive forces in the financial system so that "banks not allocating their resources efficiently would perish unless they could become more like their efficient competitors by producing more output with existing inputs" (Alam 2001, pp. 122). [1]

This link between banking regulation and productivity adds more relevance to this paper given the major deregulatory process experienced by the U.S. banking industry in the early 80's.[2] If any link can be established between the mid-80's U.S. business cycle volatility fall and the contemporaneous volatility fall of U.S. commercial banking productivity, many avenues for future research will open up focusing, especially, on the

[1] However, it is important to highlight that the empirical literature contains results that do not always fit the conventional channel connecting tighter regulatory constraints and lower banking productivity growth. See Arias (2001) for a survey of the results and the state of the discussion.

[2] The Depository Institutions Deregulatory and Monetary Control Act of 1980 and the Garn-St. Germain Act of 1982 were the main building blocks of this process. The phasing out of regulation Q also began in 1980 and was finally achieved in 1986.

impact of banking regulation over business cycle volatility. This is a field that has not been explored yet.

Furthermore, when choosing the optimal banking regulatory levels, policymakers face a trade-off. More regulation probably alleviates moral hazard and asymmetric information problems that cause overinvestment and lending boom syndromes of the type that end with financial crashes and credit crunches.[3] On the other hand, more banking regulation hinders the versatility of financial intermediaries' operations, slows down the natural competitive forces of the banking arena and, hence, reduces the productivity of the financial sector. By shedding some light on the macroeconomic impact of productivity fluctuations in the banking sector and on the corresponding transmission mechanism, with and without financial frictions, this paper also contributes to a better understanding of the trade-off associated to more banking regulation.

The second main cause of fluctuations in the productivity of financial intermediaries is technological change. Indeed, the increased availability of new financial instruments and advances in information-processing technologies enhance the productivity of banks and other financial intermediaries by reducing the volume of real resources used up in project selection, intermediation and monitoring processes. It is not surprising that today, with the new information technologies, bankers are able to evaluate projects faster than 30 years ago. Indeed, it has been estimated that investment in technology by U.S. commercial banks rose from 5.5 billion dollars in 1982 to 13 billion dollars in 1991.[4]

The paper is organized as follows. In the next section the theoretical model is presented. Section 3 discusses the calibration procedure. Sections 4 presents some stylized facts while section 5 reveals the results of the experiment that was carried out to answer the question that motivates this paper. The last section concludes.

2 MODEL

In each period the economy is inhabited by a large number ($\mathbb{N}$) of identical, infinitely-lived, risk-averse households that discount the future at rate $1/\beta - 1$. Population grows at rate η and the initial population level is normalized to 1 [$\mathbb{N}_t = (1+\eta)^t$]. Each household is endowed with one unit of time which can be allocated to leisure or to labor. Labor is indivisible like in Hansen (1985). The shift length is fixed at $h < 1$ units of time and the household sends a fraction n of its members to work while the remaining fraction $(1-n)$ does not work at all. Households have log utility in

[3]See Rojas-Suarez and Weisbrod (1996), Caprio and Klingebiel (1996), Demirguc-Kunt and Detragiache (1997), Kaminsky and Reinhart (1998, 1999), Kaminsky (1999) and Demirguc-Kunt, Detragiache and Gupta (2000)

[4]The Economist, Oct. 3, 1992, pp. 21-24. [Reference taken from Tirtiroglu, Daniels and Tirtiroglu (1998)]

consumption (c) and leisure:

$$U = \log(c) + n \log(1 - h) \tag{2.1}$$

Households supply their labor services to a competitive market at wage w. Each household also owns capital (k) and land (l), which it can rent out in competitive markets at rental rates r and s, respectively. The final good of this economy, which is the numeraire, can be consumed (c) or accumulated as additional capital (k) by each household. Land, on the other hand, is a different good and its total supply is equal to the population level. Hence, land supply is fixed at 1 at the per capita level. To purchase an additional unit of land a household must pay q. The stock of capital depreciates at rate δ and the stock of land does not depreciate.

Besides households, two other actors play a role in this economy: a firm and a bank. The firm produces final output using labor, capital, land and the bank's output as inputs to a constant returns to scale (crs) technology. Note then that the bank's output is simply an intermediate input to the final good producing firm. To produce this intermediate input the bank combines deposits and labor in another crs production function. Let the relative price of the bank's output be denoted as $(1 + \rho)$. Given that the bank's output has the interpretation of an intra-temporal loan, $(1 + \rho)$ has the interpretation of an intra-temporal, gross, loan rate. Deposits come from abroad at exogenous, intra-temporal, gross rate $(1 + R)$. Note that the bank plays no role in transferring purchasing power across periods. Households can do this internally by accumulating capital or by purchasing land.

Finally, it is assumed that the final good producing firm and the bank are subject to stochastic, AR(1), productivity shocks z and x, respectively, and that they also exhibit deterministic, labor augmenting, technological progress at rates u and v, respectively. This distinguishes continuous, permanent, technological improvement (e.g. discovery of a new technology) from random, temporary, productivity shocks (e.g. regulatory changes). This also allows the model to exhibit a constant loan-deposit interest rate spread while the bank enjoys continuous productivity improvement.

The economy exhibits a balanced growth path along which the per-capita capital stock, per-capita consumption, per-capita final good output, per-capita deposits, the wage and the rental rate of land grow at a constant rate while per-capita landholdings, the employment rate and the rental rate of capital remain constant. The balanced growth path of the economy will be studied here.

2.1 Household

Let $\widetilde{\beta} = \beta(1 + \eta)$. The following sequential problem for one household can be mapped into a social planning problem for the aggregate economy if the utility of each household is weighted equally by the planner:

$Max_{\{c_t,\, k_{t+1},\, l_{t+1},\, n_t\}} \qquad E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left[\log(c_t) + n_t \log(1-h)\right]$
$s.t.$
$c_t + (1+\eta)k_{t+1} + q_t l_{t+1} = w_t n_t h + [r_t + (1-\delta)]k_t + (s_t + q_t)l_t$
$q_t,\, w_t,\, r_t,\, s_t,\, given$
$k_0,\, l_0 = 1\ given$

where c, k, l, and n represent the household's stock of capital, consumption level, stock of land and employment rate, respectively.

2.2 Final Good Producing Firm

In this economy the final good producing firm uses a Cobb-Douglas technology in four inputs of production: labor, capital, land and credit. Let k^d, n_1, b^d and l^d represent the per-capita volume of capital services, employees, credit and land services demanded by the firm. Thus, the firm's per-capita output can be represented as:

$$y_t = z_t \left(k_t^d\right)^{\alpha} \left[n_{1t} h (1+u)^t\right]^{\gamma} \left(b_t^d\right)^{\phi} \left(l_t^d\right)^{1-\alpha-\gamma-\phi} \tag{2.2}$$

where:

$$\log(z_{t+1}) = \rho_0 + \rho_1 \log(z_t) + \varepsilon_{t+1}, \qquad \varepsilon_t \backsim N(0, \sigma_\varepsilon^2) \tag{2.3}$$

The loans-in-the production function assumption articulates the credit channel of the economy. The motivation for this loan-in-the-production function assumption is that firms usually need to pay for some intermediate inputs (or labor services) in advance of production and must rely on liquid funds provided by banks to do so. Without these liquid external funds, firms cannot operate their technologies. In this sense, loans can be understood as a different input of production. Moreover, a model with a loans-in-the production function assumption is isomorphic to a model with a cash-in-advance (CIA) constraint on the intermediate input bill or wage bill of the final good producing firm (see Arias 2002). At the end of the day both treatments highlight the role of liquidity or working capital provided by financial intermediaries as essential to production processes. Due to its simplicity, the loans-in-the production function assumption is used hereafter to articulate a credit channel in the economy.

2.3 Bank

In order to study the macroeconomic impact of productivity fluctuations in financial intermediation, the model must employ an appropriate representation of the banking technology through which resources are intermediated. The model suggested here employs a technological specification for banks that follows the "intermediation approach" of Sealey and Lindley (1977). Under this approach all deposits and funds borrowed from financial markets are considered inputs of production (Freixas and Rochet 1998).[5]

Consider a setup where banks behave competitively and are price takers. Banks combine deposits and labor in a Cobb Douglas technology to produce the intra-period safe loans that the final good producing firm requires each period.[6] Let d_t and n_2 represent the per-capita volume of deposits and employees demanded by the bank. Thus, the banks's output, in per-capita terms, can be represented as:

$$b_t = x_t d_t^{\theta} [n_{2t} h (1 + v)^t]^{1-\theta} \tag{2.4}$$

where:

$$\log(x_{t+1}) = \varphi_0 + \varphi_1 \log(x_t) + \upsilon_{t+1}, \qquad \upsilon_t \backsim N(0, \sigma_{\upsilon}^2) \tag{2.5}$$

The financial intermediation technology is costly and similar to the one used by Cole and Ohanian (2000). In fact, $wn_2h \geqslant 0$ captures all the resources used in the intermediation process. This formalizes the idea that in order to intermediate deposits into loans, banks must carry out a variety of costly activities like evaluating creditors, managing deposits, renting buildings, maintaining ATMs, etc. (Edwards and Vegh 1997). Note also that with crs in the intermediation technology it is possible to assume an atomistic structure in the banking industry. This assumption is also consistent with the fact that firms of many sizes coexist in the financial sector.

2.4 Credit Constraint

To articulate a financial acceleration mechanism a credit constraint will be introduced.

[5]The idea behind this approach is that all liabilities in the bank's balance sheet (core deposits and purchased funds) plus financial equity capital provide funds and are considered to be inputs since they generate costs [Berger and Mester (2001)]. On the other hand, all assets (loans and investments outstanding) use bank funds to generate revenues and are considered outputs [Freixas and Rochet (1998)]. Note that following this approach implies interpreting depositor services as payments to financial inputs that do not receive interest remuneration (like demand deposits) [see Berger and Mester (2001) pp. 16]. Alternative approaches are the "production approach" and the "user cost approach" which treat depositor services as part of a financial intermediary's final output [e.g.: Tirtiroglu, Daniels and Tirtiroglu (1998)]

[6]Actually, any crs technology in the banking sector can be used. In fact, alternative functional forms for the bank's production function like Leontief or Leontief with adjustment costs in employment were also studied (adjustment costs capture the idea that banks pay certain cost when they change their employees due to specific information or knowledge that the employees have about the bank's clients). Here the Cobb-Douglas case is presented due to its analytical tractability.

To introduce a credit constraint into the model an environment like the one in Kocherlakota (2000) will be assumed. Suppose the bank is owned by the international depositors. Funding the firm's working capital is risky for the bank. The reason is that at the end of every period the owner of the firm -the household- can run away with the proceeds from the firm plus a fraction $\xi \in [0, 1]$ of his/her total assets (i.e. land plus the undepreciated stock of capital), without paying back the loan to the bank. Assume also that default is not penalized with market exclusion. The bank is aware of the risk involved in lending to the firm. As a result, the bank takes care not to let the firm borrow beyond the amount that would make it worth while for the owner to run away without repaying the loan:

$$b^d \leqslant \frac{(1-\xi)[ql^d + (1-\delta)k^d]}{(1+\rho)} \tag{2.6}$$

Under the previous constraint it is optimal for the firm never to default in equilibrium. In other words, in order to eliminate the risk of default, the bank imposes a natural credit constraint on the firm: *the outstanding value of the firm's debt at the end of the period* $[(1+\rho)b^d]$ *can never exceed the value of the owner's seizable/collateralizable resources at the end of the period* $\left((1-\xi)[ql^d + (1-\delta)k^d]\right)$. As in other credit limit models, borrowing is so tightly constrained by the volume of collateral that default never occurs in equilibrium. Note also that the credit constraint is a decreasing function of the gross loan rate. This captures the idea that any rise in the interest rate melts down collateral by reducing the volume of principal associated to any given volume of outstanding debt at the end of the period.

2.5 Balanced Growth Path

Along the balanced growth path of the economy the per-capita stock of capital, per-capita consumption, per-capita final good output, per-capita deposits, the wage and the rental rate of land grow at the same rate. Let g be this rate. On the other hand, employment allocated to each sector (i.e. bank and firm), the per-capita stock of land and the rental rate of capital remain constant. It can be shown that:

$$g = \left[(1+u)^{\gamma}(1+v)^{\phi(1-\theta)}\right]^{\frac{1}{1-\alpha-\phi\theta}} \tag{2.7}$$

To simplify notation, from now on all variables (which are already in per-capita terms) are also in growth-detrended terms.

2.6 Recursive Competitive Equilibrium

The aggregate state of the economy is given by the two stochastic shocks and the aggregate stock of capital: (z, x, K). At an individual level, the state is given by the individual capital stock and individual landholdings (k, l). The following definitions formalize the recursive competitive equilibrium of the per-capita economy along its balanced growth path, in terms of growth-detrended variables.

Definition 2.1. $P1$ is the following dynamic programming problem for the household:

$$\begin{aligned} V(z,x,K,k,l) = Max_{k',l',n}\{ & \log[w(z,x,K)nh + [r(z,x,K) + (1-\delta)]k + \\ & [s(z,x,K) + q(z,x,K)]l - (1+\eta)(1+g)k' \\ & -q(z,x,K)l'] + n\log(1-h) + \widetilde{\beta} EV(z',x',K',k',l')\} \end{aligned}$$

$s.t.$

$K' = H(z,x,K)$

$\log(z') = \rho_0 + \rho_1 \log(z) + \varepsilon', \qquad \varepsilon' \backsim N(0,\sigma_\varepsilon^2)$

$\log(x') = \varphi_0 + \varphi_1 \log(x) + \upsilon', \qquad \upsilon' \backsim N(0,\sigma_\upsilon^2)$

$cov(\varepsilon, \upsilon) = 0$

Definition 2.2. If there are no credit constraints, $P2$ is the following static problem for the final good producing firm:

$$\begin{aligned} Max_{\{n_1,k^d,l^d,b^d\}} \quad & y - w(z,x,K)n_1h - r(z,x,K)k^d - s(z,x,K)l^d \\ & -[1+\rho(z,x,K)]b^d \end{aligned}$$

$s.t.$

$y = z\left(k^d\right)^\alpha (n_1h)^\gamma \left(b^d\right)^\phi \left(l^d\right)^{1-\alpha-\gamma-\phi}$

If there is a credit constraint, $P2$ is the following static problem for the final good producing firm:

$$\begin{aligned} Max_{\{n_1,k^d,l^d,b^d\}} \quad & y - w(z,x,K)n_1h - r(z,x,K)k^d - s(z,x,K)l^d \\ & -[1+\rho(z,x,K)]b^d \end{aligned}$$

$s.t.$

$y = z\left(k^d\right)^\alpha (n_1h)^\gamma \left(b^d\right)^\phi \left(l^d\right)^{1-\alpha-\gamma-\phi}$

$b^d \leqslant \frac{(1-\xi)[q(z,x,K)l^d + (1-\delta)k^d]}{[1+\rho(z,x,K)]}$

Definition 2.3. $P3$ is the following static problem for the bank:

$$Max_{\{n_2,d\}} \quad [1+\rho(z,x,K)]b - (1+R)d - w(z,x,K)n_2h$$

$s.t.$

$b = xd^\theta (n_2h)^{1-\theta}$

Definition 2.4. A recursive competitive equilibrium (RCE) is

1. A value function: $V(z, x, K, k, l)$.
2. A set of individual decision rules: $k'(z, x, K, k, l)$, $l'(z, x, K, k, l)$ and $n(z,\ x,\ K,\ k,\ l)$.
3. A set of demands by the final good producing firm: $k^d(z, x, K)$, $n_1(z, x, K)$, $b^d(z, x, K)$ and $l^d(z, x, K)$.

4. A set of demands by the bank: $d(z,x,K)$ and $n_2(z,x,K)$

5. A set of pricing functions: $w(z,x,K), r(z,x,K), s(z,x,K), q(z,x,K)$ and $\rho(z,x,K)$.

6. An aggregate decision rule: $H(z,x,K)$.
   such that:

- Given (5) and (6), (1) and (2) solve ($P1$).
- Given (5), (3) solves ($P2$).
- Given (5), (4) solves ($P3$).
- Markets clear:

    1. $n_1(z,x,K) + n_2(z,x,K) = n(z,x,K,K,1)$
    2. $k^d(z,x,K) = K$
    3. $l^d(z,x,K) = 1$
    4. $l'(z,x,K,K,1) = 1$
    5. $b^d(z,x,K) = b(z,x,K) = xd(z,x,K)^\theta \left[n_2(z,x,K)h\right]^{1-\theta}$

- Aggregate Consistency: $k'(z,x,K,K,1) = H(z,x,K)$.

2.7 Financial Accelerator

The credit constrained economy displays a financial accelerator that can be decomposed into a static and a dynamic credit multiplier (see Kiyotaki and Moore 1997). Under this specification the economy takes longer to converge back to the steady state than in a financially frictionless setup.

3 CALIBRATION

Parameters were calibrated to a quarterly frequency using U.S. data for the period 1959-1999 (see calibration appendix). Specifically, parameter values were chosen so that the model (with and without a binding credit constraint), in stationary state, replicates the following 1959-1999 averages observed in the U.S.:

The following tables illustrate the calibrated parameter values if the credit constraint is left out (see calibration appendix):

The following tables illustrate the calibrated parameter values when the credit constraint is introduced and binds (see calibration appendix). These are the parameter

Table 1:

c/y	i/y	d/y	k/y	n	n1	n2
0.5914	0.3422	0.0661	10.1740	0.9399	0.9299	0.01

Table 2:

labor share	land share	capital share	deposit share
0.5394	0.0130	0.3811	0.0664

values of the model if it were true that the productive apparatus of the U.S. economy has faced credit constraints during the 1959-1999 period:

Except for α and ϕ, all parameters keep the same value under both setups. The reason for the difference in the calibrated values of α and ϕ is that, when there is a binding credit constraint, it can be shown that:

$$\begin{aligned} (1+\rho)b^d &< \phi y \quad (3.1) \\ rk^d + sl^d &> \alpha y + (1-\alpha-\gamma-\phi)y \quad (3.2) \\ w(n_1 h) &= \gamma y \quad (3.3) \end{aligned}$$

which means that the share of credit in output falls short of its natural share ϕ while the shares of capital and land in output exceed their natural shares α and $(1-\alpha-\gamma-\phi)$. These are natural results. With a binding credit constraint the firm cannot equate the marginal productivity of credit to the loan rate (or marginal cost of credit). Instead, the firm has to produce where the former exceeds the latter. This implies that the share of credit in output has to lie below its natural share ϕ. On the other hand, under a credit constrained environment land and capital contribute to output not only directly as inputs of production, but also indirectly due to their collateral properties (more land and capital imply more collateral, more loans and, consequently, more output). This implies that the shares of capital and land in output must exceed their natural shares α and $(1-\alpha-\gamma-\phi)$. Note, however, that labor share in the final good producing firm is still γ and that the zero profit condition still holds.

In consequence, with a binding credit constraint the calibrated values for $\alpha = 0.375$ and $(1-\alpha-\gamma-\phi) = 0.0110$ must fall short of the capital and land shares measured in the data and replicated by the model (0.3811 and 0.0130). Additionally, the calibrated values for $\phi\theta = 0.0736$ and $\gamma + \phi(1-\theta) = 0.5401$ must lie above the

Table 3:

β	δ	α	γ	ϕ	θ	h
0.994	0.025	0.381	0.534	0.072	0.920	0.621

Table 4:

g	η	R
0.00546	0.00268	0.00459

Table 5:

β	δ	α	γ	ϕ	θ	h	ξ
0.994	0.025	0.375	0.534	0.08	0.920	0.621	0.9946

Table 6:

g	η	R
0.00546	0.00268	0.00459

deposit and labor shares measured in the data and replicated by the model (0.0664 and 0.5394). Given that the calibrated values for θ and γ do not change with respect to the financially frictionless economy, the previous condition implies that, in the credit constrained economy, the calibrated value for ϕ must exceed the value calibrated for the unconstrained economy.

Overall, the calibration seems reasonable except for two features. First, the model's share of commercial banks in output is high (7.2%) considering that the gross product attributed to commercial banking activities as a percentage of total GDP has fluctuated between 1.1% and 2.7% between 1947 and 1987.[7] However, the model replicates with exactitude the share of deposits in income (6.64%). The second uncomfortable result of the calibration is that the fraction of time that agents spend in market activities ($nh = 0.58$) is high considering that this number has been estimated to be around 0.31. An alternative would be to calibrate the model so that it replicates this number. The problem with this calibration procedure is that it would not replicate exactly labor's share or land's share of output.

The steady state of the model implies that $ql/y = 3.4430$ and $b/y = 0.0519$. These ratios were not targeted with the calibration strategy. According to land market value data from the discontinued C.9 release of the Federal Reserve Board of Governors, the average land to output ratio was 0.3531 during the period $1959 - 1994$. According to data on commercial and industrial loans from commercial banks the average loans to output ratio is 0.0801 for the period $1959 - 1999$. Note then that the model does not replicate the land to output ratio and the loans to output ratio observed in the data. The mismatch is especially severe in the land to output ratio. However, land market value data is not very reliable; in fact, it is discontinued. Moreover, this data is not needed for the calibration strategy. Now, the data-model mismatch of the loans to output ratio is not too serious considering that the model still replicates accurately the observed deposit to output ratio. Recall that deposits are, ultimately, the relevant intermediate financial input into final good production.[8]

Now, recall the parameters of the stochastic processes governing $\log(z)$ and $\log(x)$:

$$\log(z_{t+1}) = \rho_0 + \rho_1 \log(z_t) + \varepsilon_{t+1}, \qquad \varepsilon_t \backsim N(0, \sigma_\varepsilon^2) \tag{3.4}$$

[7]Source: Dept. of Commerce, BEA. Data for the period 1987-2001 is only available for the aggregate of all depository institutions. Between 1987 and 2001 the gross product of all depository institutions as a percentage of total GDP has fluctuated between 2.8% and 3.7%.

[8]An alternative calibration strategy is to target the observed b/y instead of the observed d/y. Following such strategy requires the use of loan interest rate data while targeting the deposit to output ratio requires the use of deposit interest rate data. Given the heterogeneity implicit in the different loan interest rate series available, the choice of a representative or average loan interest rate is a difficult choice that can be avoided by choosing to target d/y instead of b/y.

Table 7:

$\widehat{\rho_0}$	$\widehat{\rho_1}$	$\widehat{\sigma_\varepsilon}$	$\widehat{\varphi_0}$	$\widehat{\varphi_1}$	$\widehat{\varphi_\nu}$
0.0153	0.9981	0.0069	-0.0262	0.9728	0.0160

$$\log(x_{t+1}) = \varphi_0 + \varphi_1 \log(x_t) + \upsilon_{t+1}, \qquad \upsilon_t \backsim N(0, \sigma_\upsilon^2) \tag{3.5}$$

The way in which z and x can be constructed from data is detailed in the shock identification appendix. U.S. quarterly data was used to construct series for z and x. The parameters of the AR(1) processes governing $\log(z)$ and $\log(x)$ were estimated with simple ordinary least squares techniques. The resulting estimates depend on whether data for deposits is used or not (see shock identification appendix). The following table reports the results of the estimation using the complete data set (i.e. including deposits) for the period $1959 - 1999$. Recall that this is the period to which the other parameters of the model were calibrated.[9]

Once the parameters of the model $(\beta, \delta, \alpha, \gamma,\ \phi, \theta, h, g, \eta, R, \xi)$ are calibrated and once the parameters of the stochastic processes governing $\log(z)$ and $\log(x)$ $(\rho_0, \rho_1, \sigma_\varepsilon, \varphi_0, \varphi_1, \sigma_\upsilon, \sigma_{\varepsilon\upsilon})$ are estimated, the recursive competitive equilibrium is solved with the linear-quadratic method (see Cooley and Hansen 1995 or Ljunqvist and Sargent 2000, chapter 4). See the solution appendix for a check on the accuracy and robustness of the solution method.

4 STYLIZED FACTS

Commercial banking productivity has been more volatile than productivity in the rest of the economy during the last decades. This fact is robust to different definitions and measures of productivity. The first four columns of the following table present the ratio between the standard deviation of the HP cyclical component of output per hour in commercial banks and the standard deviation of the HP cyclical component of four different output per hour measures for the rest of the economy, using BLS data.[10] The last two columns compare the volatility of the noise of the AR(1) process

[9]The estimates do not change significantly when deposits are removed from the data set to construct z and x (see shock identification appendix).

[10]Output per hour in U.S. commercial banks is series y_f/n in the productivity measurement appendix. Output per hour in the rest of the U.S.economy is series y_i/n $(i = 1, 2, 3, 4)$ of the productivity measurement appendix. The HP trend was calcu-

Table 8:

$\frac{\text{s.e}(y_f/n)_{cyc}}{\text{s.e}(y_1/n)_{cyc}}$	$\frac{\text{s.e}(y_f/n)_{cyc}}{\text{s.e}(y_2/n)_{cyc}}$	$\frac{\text{s.e}(y_f/n)_{cyc}}{\text{s.e}(y_3/n)_{cyc}}$	$\frac{\text{s.e}(y_f/n)_{cyc}}{\text{s.e}(y_4/n)_{cyc}}$	$(\frac{\widehat{\sigma_\nu}}{\widehat{\sigma_\varepsilon}})_1$	$(\frac{\widehat{\sigma_\nu}}{\widehat{\sigma_\varepsilon}})_2$
3.73	2.32	2.32	1.74	2.33	2.61

governing $\log(TFP)$ in commercial banks (i.e. σ_υ) to the volatility of the noise of the AR(1) process governing $\log(TFP)$ in non-financial sectors (i.e. σ_ε), using the TFP definitions in the theoretical model suggested above. Specifically, column 5 reports the ratio between the estimated σ_υ and the estimated σ_ε when deposit data is used to construct z and x while column 6 reports the same numbers when no deposit data is used to construct z and x[11]. The table shows that commercial banking productivity is between 1.75 and 3.75 times more volatile than productivity in the non-banking sectors of the economy.

In the theoretical model suggested here the volatility of the Solow residual depends critically on the volatility of both banking and non-banking TFP (x and z). Hence, studying the evolution of the volatility of banking TFP shocks (and of TFP shocks in the rest of the economy) is of crucial importance given the results of Arias, Hansen and Ohanian (2002). These authors document a 40%-60% fall in the volatility of the U.S. business cycle in 1984[12] and find that any explanation of this fall must also account for a 50% fall in the volatility of the Solow residual. They also find that the standard RBC model does a good job in reconciling these facts.

5 EXPERIMENT

After observing the stylized facts documented in the previous section, a natural question arises. Is banking productivity a potential contributor to the observed fall in the volatility of the U.S. business cycle? Or is it the other way around? The experiment conducted in this section aims at answering the previous question. The idea is to disentangle the contribution of banking and non-financial productivity shocks (i.e. x and z) to a fall in business cycle volatility. The first step of the experiment is to measure the volatility reduction of both shocks after 1984. To do so, the AR(1) processes governing $\log(x)$ and $\log(z)$ are estimated with data prior to 1984 and with data starting in 1984. The results depend on whether deposit data is used or not in the construction of x and

lated with a smoothing parameter value of 400. The same time interval (1967-1999) was used for all series in the application of the HP filter.

[11]See shock identification appendix.

[12]See also McConnell, Mosser and Perez Quiros (1999), Kahn, McConnell and Perez Quiros (2000), McConnell and Perez Quiros (2000)

Table 9:

	$\widehat{\rho_0}$	$\widehat{\rho_1}$	$\widehat{\sigma_\varepsilon}$	$\widehat{\varphi_0}$	$\widehat{\varphi_1}$	$\widehat{\varphi_\nu}$	$\widehat{\frac{\sigma_\varepsilon}{\sigma_\nu}}$
59.I-83.IV	0.0470	0.9919	0.0081	-0.0240	0.9742	0.0175	2.16
84.I-99.IV	-0.0154	1.0037	0.0042	-0.0175	0.9827	0.0134	3.19

z. The following table reports the resulting estimates using the complete data set (i.e. including deposits) which are the ones used in the experiment.[13] Note that, for both subsamples, the estimated volatility gap between the banking productivity shock and the non-financial productivity shock $\left(\widehat{\frac{\sigma_v}{\sigma_\varepsilon}}\right)$ is consistent with the volatility gap reported above for the whole sample (i.e. between 1.75 and 3.75).

The next step of the experiment is to compare the volatility of the economy's business cycle under two different sets of simulations, each representing either the $1959-1983$ or the $1984-1999$ subsample. Precisely, 200 periods (i.e. quarters) of the artificial economy are simulated 100 times using decision rules obtained under parameter values calibrated for the whole sample $(1959-1999)$ but estimates of $(\rho_0, \rho_1, \sigma_\varepsilon, \varphi_0, \varphi_1, \sigma_v)$ for the $1959.I-1983.IV$ subsample. In each simulation the initial state of the economy is set at its non-stochastic, stationary value and the first 100 periods of each simulation are discarded. At the end of the day each simulation represents the U.S. economy during the 25 years (or 100 periods) of the pre-1984 subsample (i.e. 1959-1983). Next, 164 periods of the economy are simulated 100 times using decision rules obtained under parameter values calibrated for the whole sample $(1959-1999)$ but estimates of $(\rho_0, \rho_1, \sigma_\varepsilon, \varphi_0, \varphi_1, \sigma_v)$ for the $1984.I-1999.IV$ subsample.[14]. Again, in each simulation the initial state of the economy is set at its non-stochastic, stationary value and the first 100 periods of each simulation are discarded. Thus, each of these simulations represents the U.S. economy during the 16 years (or 64 periods) corresponding to the post-1984 subsample (i.e. 1984-1999).

Traditional business cycle statistics are computed with each set of simulations. A comparison of these statistics across both sets of simulations should reveal the joint contribution of the fall in σ_v and σ_ε to the total fall in business cycle volatility. The following tables report, for both sets of simulations, the mean (across all 100 simulations) of the standard deviation of the cyclical component of output (y), consumption

[13] The estimates do not change significantly when deposits are removed from the data set to construct x and z.

[14] Note that the estimate of ρ_1 from subsample 1984.I-1999.IV is greater than one.This estimate cannot be used given that the model requires a stationary process for $\log(z)$. A value of 0.9919 is used (this is the estimate obtained under subsample 1959.I-1983.IV). This is not a problem given that the volatility of the business cycle does not depend critically on ρ_1.

Table 10: $\triangle$ s.e(a_{cyc}) for $a = (y, c, i, b, n)$: $\nabla\sigma_{\varepsilon}$, $\nabla\sigma_{\nu}$ and no credit constraint

	$\sigma(y_{cyc})$	$\sigma(c_{cyc})$	$\sigma(i_{cyc})$	$\sigma(b_{cyc})$	$\sigma(n_{cyc})$	$\sigma(\text{TFP}_{cyc})$
59-83	1.6726	0.7347	3.4336	3.0461	0.9712	1.1500
84-99	0.8359	0.3672	1.6901	2.0061	0.4861	0.5745
∇%	-50.02%	-50.02%	-50.78%	-34.14%	-49.95%	-50.03%

Table 11: $\triangle$ s.e(a_{cyc}) for $a = (y, c, i, b, n)$: $\nabla\sigma_{\varepsilon}$, $\nabla\sigma_{\nu}$ and and binding credit constraint

	$\sigma(y_{cyc})$	$\sigma(c_{cyc})$	$\sigma(i_{cyc})$	$\sigma(b_{cyc})$	$\sigma(n_{cyc})$	$\sigma(\text{TFP}_{cyc})$
59-83	1.5139	0.6978	3.3205	2.3288	0.8483	1.0551
84-99	0.7592	0.3497	1.6388	1.6824	0.4256	0.5290
∇%	-49.85%	-49.85%	-50.65%	-27.76%	-49.83%	-49.86%

(c), investment (i), credit (b), employment (n) and TFP of the whole economy.

The previous tables show that, in this artificial economy, business cycle volatility of the main macro aggregates (including total TFP) is approximately 50% lower under the second set simulations (i.e. during the $1984 - 1999$ period). This result is compatible with the facts documented by Arias, Hansen and Ohanian (2002) for the U.S. economy. Interestingly, with a binding credit constraint the volatility of the cyclical component of each macroeconomic variable is lower than in the absence of a credit constraint. This means that, in terms of cyclical *volatility levels*, the restriction to movement associated to the constraint itself dominates the amplification and propagation mechanisms of the underlying financial accelerator. Note also that, when there is a binding credit constraint, the observed *volatility reduction* in the cycle of the main macro aggregates is marginally or insignificantly lower than under the unconstrained case. The behavior of the cyclical volatility of credit is the only exception. Its volatility reduction under the binding credit constraint scenario is 7 percentage points lower than under the financially frictionless environment. In any case, the important point is that introducing a credit constraint into the model does not impede it from replicating the 50% volatility fall in the business cycle.

To isolate that part of the total fall in business cycle volatility attributable only to the fall in the volatility of the banking productivity shock (i.e. to the fall in σ_{υ}), the same process is repeated with some differences. As above, in a first set of simulations (i.e. the one that represents $1959 - 1983$) estimates of $(\rho_0, \rho_1, \sigma_{\varepsilon}, \varphi_0, \varphi_1, \sigma_{\upsilon})$ for the $1959.I - 1983.IV$ subsample are employed. In a second set of simulations (i.e. the one that represents $1984 - 1999$) estimates of $(\rho_0, \rho_1, \sigma_{\varepsilon})$ for the $1959.I - 1983.IV$

Table 12: $\triangle$ s.e(a_{cyc}) for $a = (y, c, i, b, n)$: $\nabla\sigma_\nu$ only and no credit constraint

	$\sigma(y_{cyc})$	$\sigma(c_{cyc})$	$\sigma(i_{cyc})$	$\sigma(b_{cyc})$	$\sigma(n_{cyc})$	$\sigma(\mathrm{TFP}_{cyc})$
59-83	1.6726	0.7347	3.4336	3.0461	0.9712	1.1500
84-99	1.5878	0.6872	3.2888	2.4264	0.9192	1.0936
∇%	-5.07%	-6.47%	-4.22%	-20.34%	-5.35%	-4.90%

Table 13: $\triangle$ s.e(a_{cyc}) for $a = (y, c, i, b, n)$: $\nabla\sigma_\varepsilon$ only and no credit constraint

	$\sigma(y_{cyc})$	$\sigma(c_{cyc})$	$\sigma(i_{cyc})$	$\sigma(b_{cyc})$	$\sigma(n_{cyc})$	$\sigma(\mathrm{TFP}_{cyc})$
59-83	1.6726	0.7347	3.4336	3.0461	0.9712	1.1500
84-99	0.8569	0.3716	1.7442	2.5437	0.5056	0.5855
∇%	-48.76%	-49.42%	-49.20%	-16.49%	-47.94%	-49.09%

subsample are maintained while estimates of $(\varphi_0, \varphi_1, \sigma_v)$ for the $1984.I - 1999.IV$ subsample are used. Then, in a third set of simulations estimates of $(\varphi_0, \varphi_1, \sigma_v)$ for the $1959.I - 1983.IV$ subsample are maintained while estimates of $(\rho_0, \rho_1, \sigma_\varepsilon)$ for the $1984.I - 1999.IV$ subsample are used. These three sets of simulations should isolate the impact of the fall in σ_v over the total fall in business cycle volatility. The following tables report the resulting business cycle statistics for the three sets of simulations under the unconstrained and the binding credit constraint environments.

Consider first the results from the unconstrained model (the first two tables). The results show that the fall in the volatility of the banking productivity shock alone contributes, at most, with 5 to 6 percentage points (out of 50) to the observed total fall in the volatility of the business cycle. The only exception is the fall in the volatility of the credit cycle (20 percentage point fall). Note that the results also show that the fall in the volatility of the non-financial productivity shock alone generates a 48 to 49 percentage point fall in the volatility of the overall business cycle (out of 50).

Table 14: $\triangle$ s.e(a_{cyc}) for $a = (y, c, i, b, n)$: $\nabla\sigma_\nu$ only and binding credit constraint

	$\sigma(y_{cyc})$	$\sigma(c_{cyc})$	$\sigma(i_{cyc})$	$\sigma(b_{cyc})$	$\sigma(n_{cyc})$	$\sigma(\mathrm{TFP}_{cyc})$
59-83	1.5139	0.6978	3.3205	2.3288	0.8483	1.0551
84-99	1.4338	0.6523	3.1711	1.7153	0.7999	1.0013
∇%	-5.29%	-6.52%	-4.50%	-26.34%	-5.71%	-5.10%

Table 15: $\triangle$ s.e(a_{cyc}) for $a = (y, c, i, b, n)$: $\nabla\sigma_{\varepsilon}$ only and binding credit constraint

	$\sigma(y_{cyc})$	$\sigma(c_{cyc})$	$\sigma(i_{cyc})$	$\sigma(b_{cyc})$	$\sigma(n_{cyc})$	$\sigma(\text{TFP}_{cyc})$
59-83	1.5139	0.6978	3.3205	2.3288	0.8483	1.0551
84-99	0.7815	0.3548	1.7000	2.1897	0.4460	0.5408
∇%	-48.38%	-49.15%	-48.80%	-5.97%	-47.42%	-48.74%

The only exception, again, is the volatility of the credit cycle (only a 16.5% volatility reduction).

Do these results change when there is a credit constraint that binds (the last two tables)? Only in the sense that the contribution of the fall in σ_v to the fall in the volatility of the credit cycle goes up (from 20 to 26 percentage points) while the contribution of the fall in σ_{ε} goes down (from 16.5 to 6 percentage points).

After taking all this into consideration it can be said that, *with or without a binding credit constraint (and, hence, financial acceleration), the contribution of the fall in the volatility of the banking productivity shock to the overall fall in the volatility of the U.S. business cycle seems to be minimal: between 2 and 5 percentage points out of 50.* All the action seems to come from the reduction in the volatility of the non-financial productivity shock. Only the volatility of the credit cycle is impacted significantly by the volatility fall of the banking productivity shock. This impact is enhanced when the financial accelerator mechanism is activated.

6 CONCLUSIONS

The objective of this paper was to answer the following two questions. First, is the mid-80's fall in the cyclical volatility of U.S. commercial banking productivity a potential candidate to account for the mid-80's fall in U.S. business cycle volatility? Second, does the answer to the previous question change under the presence of financial frictions? The answer to the first question is that the fall in the cyclical volatility of banking productivity contributes significantly only to the volatility fall of the credit cycle. For the other macroeconomic aggregates, the contribution lies between 2 and 5 percentage points of volatility reduction (out of 50). The answer to the second question is that allowing for financial acceleration does not change the previous results significantly if parameter values still replicate basic, empirical, macroeconomic regularities observed in the US during the $1959-1999$ period. According to the results, financial acceleration only augments the contribution of the fall in the cyclical volatility of banking productivity to the credit cycle volatility fall.

This paper gives some perspective to the role played by the financial sector (and monetary policy?) during the mid-80's U.S. business cycle volatility fall. According to this paper, if it played a role it was not a leading role. As Arias, Hansen and Ohanian (2002) suggested, it seems that the leading role was played by the behavior of the economy's overall productivity. This paper also adds to the findings of Kocherlakota (2000), Cole and Ohanian (2001), Chakraborty and Lahiri (2001) and Arias (2002) which question the quantitative significance of the effects of financial frictions over the *level* of economic activity. Indeed, this paper raises doubt on the quantitative significance of the effect of frictions in financial markets over the *volatility* of economic activity.

In the early 80's the U.S. banking industry went through a major deregulatory process. The Depository Institutions Deregulatory and Monetary Control Act of 1980 and the Garn-St. Germain Act of 1982 were the main components of this process. The phasing out of regulation Q, which began in 1980, was finally achieved in 1986. Is the mid 80's fall in the cyclical volatility of U.S. commercial banking productivity a result of this deregulatory process? If so, the results of this paper suggest that these deregulatory acts might have contributed significantly to the fall in the volatility of the credit cycle (but not to the fall in the volatility of the main macroeconomic aggregates). On the other hand, the results of this paper also suggest that the discovery of a significant link between banking deregulation, banking productivity and macroeconomic volatility requires the use of more stylized models than the ones we have at hand today. Nevertheless, the link between banking regulation and macroeconomic behavior is certainly an interesting avenue for future research.

7 CALIBRATION APPENDIX

Parameter values were chosen so that the model, in stationary state, mimics some long-run empirical regularities observed in the U.S. Specifically, the parameters were calibrated to a quarterly frequency using U.S. data for the period 1959-1999.

7.1 No Credit Constraint

The following system of equations characterizes the steady state variables of the no-constraint economy relative to output (recall $l = 1$):

7.2 Binding Credit Constraint

Let

$$\Gamma = \frac{b(1+\rho)}{y}$$

Table 16:

$(1+g)\frac{k}{y} = \beta\left(\frac{rk}{y} + (1-\delta)\frac{k}{y}\right)$ [1ss]	$\frac{q}{y} = (\frac{\widetilde{\beta}}{1-\beta})\frac{s}{y}$ [2ss]
$\frac{wh}{y} = -\log(1-h)\frac{c}{y}$ [3ss]	$\frac{wn_1h}{y} = \gamma$ [4ss]
$\frac{rk}{y} = \alpha$ [5ss]	$\frac{s}{y} = 1-\alpha-\gamma-\phi$ [6ss]
$\frac{b(1+\rho)}{y} = \phi$ [7ss]	$(1+R)\frac{d}{y} = \theta\frac{b(1+\rho)}{y}$ [8ss]
$\frac{wn_2h}{y} = (1-\theta)\frac{b(1+\rho)}{y}$ [9ss]	$\frac{c}{y} = 1-(\eta+g+\eta g+\delta)\frac{k}{y} - (1+R)\frac{d}{y}$ [10ss]
$n = n_1 + n_2$ [11ss]	

Table 17:

$\delta = \frac{1-(\eta+g+\eta g)\frac{k}{y} - \frac{c}{y} - \text{deposit share}}{\frac{k}{y}}$	$\beta = \frac{(1+g)\frac{k}{y}}{\text{capital share}+(1-\delta)\frac{k}{y}}$
$h = 1-\exp\left(\frac{-\text{labor share}}{\frac{c}{y}n}\right)$	$\gamma = \text{labor share}(\frac{n_1}{n})$
$\theta\phi = \text{deposit share}$	$\phi = \text{labor share} + \text{deposit share} - \gamma$
$\theta = \frac{\text{deposit share}}{\text{labor share + deposit share}-\gamma}$	$\alpha = \text{capital share}$

Table 18:

$(1+g)\frac{k}{y}=\beta\left(\frac{rk}{y}+(1-\delta)\frac{k}{y}\right) \quad [1^{cc}_{ss}]$	$\frac{q}{y}=(\frac{\widetilde{\beta}}{1-\widetilde{\beta}})\frac{s}{y} \quad [2^{cc}_{ss}]$
$\frac{wh}{y}=-\log(1-h)\frac{c}{y} \quad [3^{cc}_{ss}]$	$\frac{wn_1h}{y}=\gamma \quad [4^{cc}_{ss}]$
$\frac{rk}{y}=\alpha+(\frac{\phi}{\Gamma}-1)(1-\xi)(1-\delta)\frac{k}{y} \quad [5^{cc}_{ss}]$	$\frac{s}{y}=(1-\alpha-\gamma-\phi)+(\frac{\phi}{\Gamma}-1)(1-\xi)\frac{q}{y} \quad [6^{cc}_{ss}]$
$\Gamma=(1-\xi)\left[\frac{q}{y}+(1-\delta)\frac{k}{y}\right] \quad [7^{cc}_{ss}]$	$\frac{d(1+R)}{y}=\theta\Gamma \quad [8^{cc}_{ss}]$
$\frac{wn_2h}{y}=(1-\theta)\Gamma \quad [9^{cc}_{ss}]$	$\frac{c}{y}=1-(\delta+\eta+g+\eta g)\frac{k}{y}-(1+R)\frac{d}{y} \quad [10^{cc}_{ss}]$
$n=n_1+n_2 \quad [11^{cc}_{ss}]$	

Table 19:

$\delta=\frac{1-(\eta+g+\eta g)\frac{k}{y}-\frac{c}{y}-\text{deposit share}}{\frac{k}{y}}$	$\beta=\frac{(1+g)\frac{k}{y}}{\text{capital share}+(1-\delta)\frac{k}{y}}$
$h=1-\exp\left(\frac{-\text{labor share}}{\frac{c}{y}n}\right)$	$\gamma=\text{labor share}(\frac{n_1}{n})$
$\theta=\frac{\text{deposit share}}{\text{labor share + deposit share}-\gamma}$	$\xi=\frac{1-\text{deposit share}}{\theta\left[\left(\frac{\overline{\beta}}{1-\overline{\beta}}\right)\text{land share}+(1-\delta)\frac{k}{y}\right]}$
$\alpha=\text{capital share}-\left(\frac{\phi\theta}{\text{deposit share}}-1\right)(1-\xi)(1-\delta)\frac{k}{y}$	$\text{capital share}+\text{land share}+\gamma+\Gamma=1$

Suppose that the credit constraint binds. The following system of equations characterizes the steady state variables of the credit constrained economy relative to output (recall $l=1$).

7.3 Data to Measure Θ and Θ'

To construct the empirical counterparts of Θ and Θ' the following U.S. data was used:

For y, specifically:

$$y=GNP+y_G+y_D+\left(1+\text{Avg}_{1964-1999}\left[\mathbf{r_T(2)}*\left(\frac{\mathbf{d_T}}{\mathbf{d_{TOT}}}\right)\right]\right)\left[\mathbf{d_{TOT}}\left(\frac{\mathbf{b_{CI}}}{\mathbf{b_{TOT}}}\right)\right] \quad (****)$$

Table 20:

Variable Name	Description	Source	Original Frequency	Units
POP	Total population, all ages (including armed forces overseas)	2	M	Thousands
N	Civilian Labor force (16 yrs and older)	7	M	Percent
n_2	Commercial Bank employees (all employees)	7	M	Percent
$r_T(1)$	Three month certificate of deposit (cod) interest rate	5	M*	Percent
$r_T(2)$	National monthly cost of funds ratio to SAIF-insured institutions	6	M	Percent
b_{cr}	Commercial and industrial loans at all commercial banks	4	M	BD
b_{TOT}	Total loans and investment at all commercial banks	4	M	BD
d_{TOT}	Total checkable deposits plus total time deposits at commercial banks	3	M	BD
d_T	Total time deposits at commercial banks	3	M	BD
k_P	Current cost, net stock of private total fixed assets located at US that are owned by private business or nonprofit institutions	1	A	BD
K_G	Current cost, net stock of government's total fixed assets	1	A	BD
K_D	Current Cost, net stock of consumer durable goods	1	A	BD
c_{ND}	Personal consumption expenditures in non-durable goods	1	Q	BD
c_S	Personal consumption expenditures in services	1	Q	BD
C_G	Government consumption expenditures	1	Q	BD
i_P	Gross private domestic investment	1	Q	BD
i_G	Government gross domestic expenditures	1	Q	BD
i_D	Personal consumption expenditures in durable goods	1	Q	BD
NX	Net exports	1	Q	BD
GNP	Gross National Product	1	Q	BD
Corporate Profits	Corporate profits with capital consumption adjustment and inventory valuation adjustment	1	Q	BD
Net interest	Net interest	1	Q	BD
Proprietor/s income	Proprietor's income with capital consumption adjustment and inventory valuation adjustment	1	Q	BD
NNP	Net national Product	1	Q	BD
National income	National income	1	Q	BD
Depreciation	Consumption of fixed capital	1	Q	BD
Rental income	Rental income of persons with capital consumption adjustment	1	Q	BD
Price index	GNP chain-type price index	1	Q	1996=100

M: Monthly; Q:Quarterly; A: Annual; BD; Billion of Dollars; *: Average of Business Days.
Sources:
1. U.S. Dept of commerce, Bureau of Economic Analysis
2. U.S. Dept of commerce, Census Bureau
3. H.6 Release Federal Reserve Board of Governors
4. H.8 Release Federal Reserve Board of Governors
5. H.15 Release Federal Reserve Board of Governors
6. OTS 7. Bureau of Labor Statistics

Table 21:

$R = \frac{r_T d_T + r_{CH} d_{CH}}{d_{TOT}}$	$R = r_T(\frac{d_T}{d_{TOT}})$
$d = d_{TOT}(\frac{b_{CI}}{b_{TOT}})$	$k = k_p + k_G + d_D$
$c = c_{ND} + c_S + c_G$	$i = i_P + i_G + i_D + NX$
$y_P = \alpha_P GNP = (r + \delta_P)k[*]$	$y_P = \alpha_P GNP = rk_P + \text{Depreciation}$
$r = \frac{\alpha_P GNP - \text{Depreciation}}{k_P}$	$k_G^{'} = (1 - \delta_G)k_G + i_G$
$\delta_G = 1 + \frac{i_G}{k_G} - \frac{k_G^{'}}{k_G}$	$\delta_D = 1 + \frac{i_D}{k_D} + \frac{k_D^{'}}{k_D}$
$y_G = (r + \delta_G)k_G[**]$	$y_D = (r + \delta_D)k_D[***]$
$y = GNP + y_G + y_D + (1 + R)d$	

The average (as opposed to each observation) of $[\mathbf{r_T(2)} * (\mathbf{d_T}/\mathbf{d_{TOT}})]$ is used to construct y because data for such series is only available since 1964. If each observation of $[\mathbf{r_T(2)} * (\mathbf{d_T}/\mathbf{d_{TOT}})]$ is used to construct y then all the information of the other variables (i.e. GNP, y_G and y_D) prior to 1964 would be lost.

The measurement of the different elements of Θ and Θ' (which determine Ψ and Ψ') is then given by:

- $\frac{k}{y}$: $\left[Avg_{1959-1999}\left(\frac{\mathbf{k_P+k_G+k_D}}{y}\right)\right] * 4$
- $\frac{c}{y}$: $Avg_{1959-1999}\left(\frac{\mathbf{c_{ND}+c_S+c_G}}{y}\right)$
- n_1: $\text{Avg}_{1959-1999}(\mathbf{n})$-$\text{Avg}_{1972-1999}(\mathbf{n_2})$.
- n: $\text{Avg}_{1959-1999}(\mathbf{n})$.
- *capital share*: $\text{Avg}_{1959-1999}\left(\frac{y_p+y_G+y_D}{y}\right)$
- *land share*: $\text{Avg}_{1959-1999}\left(\frac{\textbf{Rental income}}{y}\right)$
- *deposit share*: $$\left(1+\text{Avg}_{1964-1999}\left[\mathbf{r_T(2)} * \left(\frac{\mathbf{d_T}}{\mathbf{d_{TOT}}}\right)\right]\right) \cdot$$ $$\text{Avg}_{1959-1999}\left[\mathbf{d_{TOT}}\left(\frac{\mathbf{b_{CI}}}{\mathbf{b_{TOT}}}\right)\frac{1}{y}\right]$$
- *labor share*: $1 - \textit{capital share} - \textit{deposit share} - \textit{land share}$
- η: $\left(\frac{\mathbf{pop}_{1999}}{\mathbf{pop}_{1959}}\right)^{\frac{1}{40*4}} - 1$
- g: $\left(\frac{(y/\mathbf{pop})_{1999}}{(y/\mathbf{pop})_{1959}}\right)^{\frac{1}{40*4}} - 1$

where y_p, y_G, y_D and y are defined and constructed according to (*), (**), (***) and (****).

8 SHOCK IDENTIFICATION APPENDIX

From (6)-(8) this equation implies with $n_2 = n - n_1$ this equation implies, rearranging::

$$\gamma n = [\gamma + (1-\theta)\phi]\, n_1$$

This, in turn, implies:

$$n_1 = \Omega n \tag{1sid}$$
$$n_2 = (1-\Omega)n$$

where:

$$\Omega = \frac{\gamma}{[\gamma + (1-\theta)\phi]}$$

Now recall the definition of per-capita final good output, using (1sid) in per-capita final good output, we obtain :

$$y = A\left(zx^{\phi}\right) k^{\alpha} d^{\theta\phi} (nh)^{\gamma+(1-\theta)\phi} \tag{2sid}$$

where:

$$A_1 = \Omega^{\gamma}(1-\Omega)^{(1-\theta)\phi}$$

From (2sid) final good total output is given by:

$$Y = y\mathbb{N} = A_1\left(zx^{\phi}\right) K^{\alpha} D^{\theta\phi} (H)^{\gamma+(1-\theta)\phi} L^{1-\alpha-\gamma-\phi} \tag{3sid}$$

where N stands for the total number of workers, H represents total work hours supplied by households and k and L the total stock of capital and land. Let e be (zx^{ϕ}) or the composite shock, representing TFP at the aggregate level. Given that A_1 is a constant and that K and L are pretty stable across time, equation (3sid) shows that e can be measured with:

$$e = \frac{Y}{H^{\gamma+(1-\theta)\phi} D^{\theta\phi}} \tag{4sid}$$

or, if D is also sufficiently stable across time, then there is no need for data on deposits and e can be measured with:

$$e = \frac{Y}{H^{\gamma+(1-\theta)\phi}} \tag{4sid'}$$

The latter way of measuring e is the standard way of measuring aggregate TFP. Now recall the definition of per-capita banking output, using (1sid) the per-capita banking output is :

$$b = A_2 x d^{\theta} (nh)^{1-\theta} \tag{5sid}$$

where:

$$A_2 = (1 - \Omega)^{1-\theta}$$

From (5sid) total banking output is given by:

$$B = b\mathbb{N} = A_2 x D^{\theta} H^{1-\theta} \tag{6sid}$$

where H represents total work hours supplied by households. Given that A_2 is a constant, equation (6sid) shows that x can be measured with:

$$x = \frac{B}{H^{1-\theta} D^{\theta}} \tag{7sid}$$

or, if D is sufficiently stable across time, then there is no need for data on deposits and x can be measured with:

$$x = \frac{B}{H^{1-\theta}} \tag{7sid'}$$

By definition, z can be measured with:

$$z = \frac{e}{x^{\phi}} = \frac{\frac{Y}{H^{\gamma+(1-\theta)\phi} D^{\theta\phi}}}{\left(\frac{B}{H^{1-\theta} D^{\theta}}\right)^{\phi}} = \frac{Y}{H^{\gamma} B^{\phi}} \tag{8sid}$$

U.S. quarterly data and equations (4sid), (7sid) and (8sid) [or, alternatively, equations (4sid'), (7sid') and (8sid) if no deposit data is to be employed] were used to construct e, x and z, respectively. Note that the construction of z is not sensitive to deposit data.

Table 22: **Shock identification appendix variables**

Variable Name	Description	Source	Original Frecuency	Units
Y	Seasonally adjusted annual rates	1	Q	Billions of chained 1996 USD
H	Total annual hours in the private non-farm sector (Seasonally adjusted)	2	Q	Billions of Hours
D	Total checkable deposits plus total time deposits at commercial banks, deflated by the GNP-chain-type price index (Seasonally adjusted stocks)	3	Q^*	Billions of chained 1996 USD
B	Commercial and industrial loans at all commercial banks deflated by the GNP-chain-type price index (Seasonally adjusted stocks)	4	Q^*	Billions of chained 1996 USD

Q^*:Quarterly average of monthly values.
Sources:
1. U.S. Dept of commerce, Bureau of Economic Analysis
2. Establishment survey, Bureau of Labor Statistics
3. H.6 Release Federal Reserve Board of Governors
4. H.8 Release Federal Reserve Board of Governors

The values of ϕ, θ and γ used for the construction of e, x and z were those resulting from the calibration of the model under no credit constraints (the calibrated values of θ and γ do not depend on whether there is a constraint or not but the value of ϕ does). Note also that the construction of e, x and z uses optimality conditions for the unconstrained environment. In fact, if there is a binding credit constraint $\gamma\frac{y}{n_1} = (1-\theta)\phi\frac{y}{n_2}$ does not hold. Instead: $\gamma\frac{y}{n_1} < (1-\theta)\phi\frac{y}{n_2}$. This does not allow equation (1sid) to hold. However, an expression similar to (1sid) can be found where Ω is not a constant but equal to $\gamma y/[(1-\theta)(1-\xi)(ql+(1-\delta)k)+\gamma y]$. If K, q and L are stable across time, the construction of e, x and z under no credit constraints should also apply for the binding credit constraint case.

The following list describes the data used to construct e, x and z:

Next, the stochastic processes governing $\log(e)$, $\log(x)$ and $\log(z)$ were estimated:

Table 23:

	$\widehat{\rho_0}$	$\widehat{\rho_1}$	$\widehat{\rho_\varepsilon}$
With deposit data (1959.I-1999.IV)	0.0153	0.9981	0.0069
Without deposit data (1959.I-1999.IV)	0.0158	0.9980	0.0073
	$\widehat{\varphi_0}$	$\widehat{\varphi_1}$	$\widehat{\varphi_\nu}$
With deposit data (1959.I-1999.IV)	-0.0262	0.9728	0.0160
Without deposit data (1959.I-1999.IV)	0.0475	0.9934	0.0191
	$\widehat{\pi_0}$	$\widehat{\pi_1}$	$\widehat{\sigma}$
With deposit data (1959.I-1999.IV)	0.0193	0.9973	0.0067
Without deposit data (1959.I-1999.IV)	0.0206	0.9974	0.0073
	$\sigma_{\widehat{\varepsilon\nu}}$	$\frac{\sigma_{\widehat{\nu}}}{\sigma_{\widehat{\varepsilon}}}$	$\widehat{\sigma_\varepsilon}$
With deposit data (1959.I-1999.IV)	$4.7x10^{-5}$	2.3262	2.3998
Without deposit data (1959.I-1999.IV)	$5.3x10^{-5}$	2.6120	2.6123

$$
\begin{aligned}
\log(z_{t+1}) &= \rho_0 + \rho_1 \log(z_t) + \varepsilon_{t+1}, && \varepsilon_t \backsim N(0, \sigma_\varepsilon^2) \\
\log(x_{t+1}) &= \varphi_0 + \varphi_1 \log(x_t) + \upsilon_{t+1}, && \upsilon_t \backsim N(0, \sigma_\upsilon^2) \\
\log(e_{t+1}) &= \pi_0 + \pi_1 \log(e_t) + \epsilon_{t+1}, && \epsilon_t \backsim N(0, \sigma^2)
\end{aligned}
$$

The estimates of the parameters in the AR(1) processes governing $\log(e)$, $\log(x)$ and $\log(z)$ depend on whether data for deposits is used or not [i.e. on whether equations (4sid), (7sid) and (8sid) or (4sid'), (7sid') and (8sid) are used to construct e, x and z]. The resulting estimates are:

9 SOLUTION APPENDIX

Once the parameters of the model (β, δ, α, γ, ϕ, θ, h, g, η, R) are calibrated and once the parameters of the stochastic processes governing $\log(z)$ and $\log(x)$ (ρ_0, ρ_1, σ_ε, φ_0, φ_1, σ_υ, $\sigma_{\varepsilon\upsilon}$) are estimated, the recursive competitive equilibrium is solved with the linear-quadratic method (see Cooley and Hansen 1995 or Ljunqvist and Sargent 2000, chapter 4).

The following tables provide a check on the accuracy and robustness of the solution method. The first line presents the values of the model's main macroeconomic aggregates under its non-stochastic, stationary version (SS) which, recall, replicates U.S. data averages for the period $1959-1999$ (independently of whether there is a binding credit constraint or no constraint at all). Lines two and three show, for the

Table 24:

	c/y	i/y	d/y	k/y	n	n_1	n_2
SS	0.5914	0.3422	0.0661	10.1740	0.9399	0.9299	0.0100
RULE SS	0.5914	0.3422	0.0661	10.1740	0.9399	0.9299	0.0100
RULE SS^{cc}	0.5918	0.3420	0.0659	10.1662	0.9402	0.9292	0.0110
SIM SS	0.5935	0.3404	0.0658	10.1174	0.9401	0.9301	0.0100
SIM SS^{cc}	0.5938	0.3404	0.0655	10.1038	0.9406	0.9296	0.0110

Table 25:

	labor share	land share	capital share	deposit share
SS	0.5394	0.0130	0.3811	0.0664
RULE SS	0.5394	0.0130	0.3811	0.0664
RULE SS^{cc}	0.5400	0.0131	0.3813	0.0662
SIM SS	0.5390	0.0130	0.3809	0.0661
SIM SS^{cc}	0.5396	0.0132	0.3814	0.0658

same aggregates, their non-stochastic, stationary values as inferred from the optimal, linear decision rules under the no-constraint and binding credit constraint scenarios (RuleSS and RuleSS^{cc}, respectively). The last two lines present, for the no-constraint and binding credit constraint scenarios (Sim and Sim^{cc}, respectively), the aggregates' means across 100 simulations of the economy of 264 periods (i.e. quarters) each. In each simulation the initial state is set at its non-stochastic, stationary value. The first 100 periods of each simulation are discarded so that each simulation represents 41 years (i.e. 1959-1999).

Prices yielded by the model depend on whether there is a binding credit constraint or no constraint at all [see equations (7)-(10) and (7^{cc})-(10^{cc}) and propositions 6 and 7]. The following table reports, for the model with no credit constraint, prices under its non-stochastic, stationary version, prices in stationary state as inferred from the optimal decision rules, and average prices across the simulations:

The following table reports, for the model with a binding credit constraint, prices under its non-stochastic, stationary version, prices in stationary state as inferred from the optimal decision rules, and average prices across the simulations:

It can be seen from the previous tables that the solution method is robust to the analytical version of the model. Note that under both versions of the model the loan rate (ρ) is unrealistically high (40%).

Table 26:

	w	r	s	q	ρ
SS	1.8432	0.0375	0.0260	6.8680	0.3916
RULE SS	1.8432	0.0375	0.0260	6.8980	0.3916
SIM	1.8663	0.0377	0.0264	6.9212	0.4025

Table 27:

	w	r	s	q	ρ
SS	1.7289	0.0375	0.0244	6.4421	0.3845
RULE SS^{cc}	1.7292	0.0375	0.0245	6.3784	0.3740
SIM^{cc}	1.7501	0.0378	0.0250	6.4243	0.3770

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