Corporate Default, Investment, and the U.S. Great Depression

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Abstract: This paper investigates the role of corporate bond default risk during the U.S. Great Depression, and propose that the default risk is an effective amplifier of adverse technology and financial shocks. On the one hand, the massive wave of corporate bond defaults directly idled a considerable amount of capital, which was detrimental to production, investment, and employment. On the other hand, the indebted firms were inclined to cut more investment during the economic downturn, as they were also concerned about the increasing default risks besides the awful economic outlook. Based on the prominent work by Cooley and Quadrini (2001) and Miao and Wang (2010), I build a rational expectations DSGE model with firm default risk, which generates simulated investment dynamics that are much closer to the actual 1930s data series than in the standard RBC model. The model also predicts satisfactory declines in consumption, working hours and output. Moreover, I find that the default recovery rate decline caused by adverse financial shocks explains well the increasing corporate bond yield in the early 1930s.

Keywords: Corporate Default Risk, Investment, and the U.S. Great Depression

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1 Introduction

The U.S. Great Depression has attracted enormous economics research interest because of its mysterious, abrupt, dramatic and persistent downswings in almost all the important economic indicators. Economists traditionally look for the explanations from many perspectives such as rigid wages or prices, monetary restriction, financial turbulence, and comprehensive and intense fiscal or regulatory overhauls. Although none of them turn out to be fully responsible for the most severe recession in the U.S. history, the financial channel (*"not just the financial shocks"*) has been considered a favorite area to reveal the answers to all the puzzles, especially after the innovative works by Ben Bernanke[1]. It has been quite well accepted that "financial collapse is more than a symptom of economic decline." Much research has been devoted to establishing a connection between financial sector unease and real sector sloppiness in the U.S. Great Depression as well as investigating how financial concerns affected the decision of different agents. The study of the indebted business or household has won an extraordinary place among all these efforts.

The following are some prominent papers in this direction[2]: Fisher (1933) for the first time switches our focus to the debt market. He suggests that the liquidation debt selling in an over-indebted environment could trigger a nationwide deflation, as the dramatic decrease in outstanding loans reduces the velocity of money circulation. The fall of the general price level might lead to a significant loss in production, employment and net-worth, which would further reinforce the motivation for liquidation selling and therefore cause another round of liquidation debt selling. The worst scenario is "*the very effort of individuals to lessen their burden of debts increases it, because of the mass effect of stampede to liquidate in swelling each dollar owed*", namely a debt-deflation cycle. Frederic Mishikin shows that theories of consumer expenditures can postulate a link between household balance-sheet change and decrease of aggregate consumption in the 1930s. Mishkin (1978) exposits that the nondurable consumption could be reduced by the decline

[1]In 1980s, he wrote a series of papers exploring the impact of financial factors during the U.S. Great Depression. Most importantly, Bernanke (1983) argues that debt deflation and simultaneous sales of financial assets hurt the balance-sheet of banks or financial institutions and make them either fail or tighten their credit supply. In the presence of financial market imperfection, which makes professional financial intermediaries the only ones to allocate capital efficiently, the destruction of financial intermediaries could reduce investment and production.

[2]A more comprehensive survey by Calomiris (1993) provides the summaries and comments on almost every article about the financial factors and the US Great Depression.

of household net-worth according to the permanent income hypothesis, while durable consumption could be suppressed by the households' demand on liquidity[3]. Yet it is far from a well accomplished mission to understand the impact of debt during the U.S. Great Depression. There are still many aspects for successors to fill in. First, Fisher (1933) and Mishkin (1978) focus on the decline of output, working hours, net-worth, and consumption, and omit the business investment collapse; Second, most of the early papers about financial factors during the U.S. Great Depression rest their conclusions loosely on proposed theories and fail to offer structural models for quantitative analysis. Third, the existing theories lack a deeper and closer examination of the corporate bond market despite the fact that the corporate bond market actually experienced the same significant catastrophe and, more importantly, interacted with the real economy. Giesecke et al. (2011) shows that two corporate bond default peaks occurred during the 1930s and that the one between 1931 and 1935 was the second worst in the last 150 years. Hunter (1982) shows that the spending stream of large firms was drained away during the U.S. Great Depression because they had to raise liquidity in anticipation of a perceived default risk in the future; Hart and Mehrling (1995) proposes a hypothesis: "When a decline is under way, business men whose debts fall due in the visible future are obliged to do their best to remain liquid, which holds down business volume". In the meantime, the default risk is also found by Miao and Wang (2010) to be a powerful tool to understand the business cycles in a more general framework and wider time range. My paper is to improve on the above three fields, that is to build a well-parameterized quantitative structural model and shed some light on the relationship between business investment collapse and corporate bond default risk.

This paper builds a rational expectation DSGE model subject to the TFP and financial shock[4]. There are three agents: entrepreneurs, firms and workers. Entrepreneurs own the firms. Firms own the production capital and technology, rent labor and issue bonds. Workers buy bonds and supply labor. A credit shock identical and independent over firms and time hits the firms each period and randomly generates a financial expenditure proportional to their capital stock. Before making the investment and issuing new bonds, firms determine whether to default on their debt obligation after observing credit and financial shocks. Upon default

[3]This mechanism is named "Liquidity Hypothesis" and discussed in details by Mishkin (1976).

[4]There are various ways to model and measure the financial shocks. The one I implement here is proposed by Perri and Quadrini (2011) and Jermann and Quadrini (2012).

they redeem the ownership of their firms through costly negotiation and restructure process and continue their operation. After calibrating the model to the long-run economic facts of the U.S. economy and feeding the actual TFP and financial shock series into simulation, the quantitative results demonstrate that the adverse technology shocks could be tremendously aggravated by the default pressure on the corporate sector. On the one hand, the massive wave of corporate bond defaults directly idled a considerable amount of capital, which was detrimental to production, investment and employment. On the other hand, the indebted firms were inclined to cut more investment during the economic downturn, as they were also concerned about the increasing default risk besides the awful economic outlook. Besides, the default recovery rate decline caused by the financial turbulence fails to explain economic aggregates downswings well, but does contribute greatly to the awful risky corporate bond yield. More interestingly, the climbing of debt-capital ratio seems beyond the best interest of firms. It is a possible factor to deteriorate the recession. My model setups are basically built on Cooley and Quadrini (2001) and Miao and Wang (2010). Because the main focus of this paper is macroeconomic fluctuation, some specific features matching firm cross-sectional distribution and financial structure are eliminated while some additional properties are introduced. However, their key mechanism stays similar.

Finally, I want to remind readers that this paper does not intend to address the source or the nature of adverse technology and financial shocks during the U.S. Great Depression or to attribute the economic downturn completely to the firm default risk. Instead, I'm more interested in the following questions: how are these shocks propagated and amplified by the default risk and quantitatively how much of economic contraction, especially the investment decline, can be explained by this channel? My quantitative practice is restricted to the corporate sector. It does not mean that the mechanism proposed here is just within the corporate sector. It is because I have access only to the corporate data. The paper is organized as below: Section 2 presents the model; Section 3 characterizes the equilibrium properties; Section 4 introduces the data and parametrization; Section 5 illustrates the quantitative results and also provides some discussion. The final part concludes.

2 Model

I consider an infinite-horizon and discrete-time economy. Three types of agents live forever: entrepreneurs, workers and firms. Entrepreneurs exclusively own the firms. Firms have the production capital and technologies in this economy. They rent labor from workers and issue long-term bonds. Workers earn labor income from wages and receive bond payment. The detailed features of each agent are discussed in the following subsections.

2.1 Entrepreneurs

Entrepreneurs do not provide labor supply in this economy. Their problem is as follows:

$$\max_{\{c_t^e, s_{t+1}^j\}} \sum_{t=0}^{\infty} \beta^t \frac{c_t^{e\,1-\nu}}{1-\nu} \tag{1}$$

$$\text{subject to:} \quad c_t^e + \sum p_t^j s_{t+1}^j \leq \sum (p_t^j + d_t^j) s_t^j$$

c_t^e is the consumption of entrepreneurs at period t. s_t^j represents entrepreneurs' share holdings of firm j. p_t^j and d_t^j respectively stands for the share price and dividend of firm j. The first order conditions with respect to s_{t+1}^j is:

$$\beta \left(\frac{c_{t+1}^e}{c_t^e} \right)^{-\nu} = \frac{p_t^j}{p_{t+1}^j + d_{t+1}^j} \tag{2}$$

Entrepreneurs are homogeneous. Therefore the value of s_t^j equals to unity at equilibrium. Namely the representative entrepreneur possesses all the firms at the same time. Thus it is easy to get $c_t^e = \sum d_t^j$ at equilibrium. Define $D_t = \sum d_t^j$. Then $c_t^e = D_t$. Consequently, the first order condition can be transferred into:

$$\beta \left(\frac{D_{t+1}}{D_t} \right)^{-\nu} = \frac{V_t^j - d_t^j}{V_{t+1}^j} \tag{3}$$

and

$$V_t^j = d_t^j + \beta \left(\frac{D_{t+1}}{D_t} \right)^{-\nu} V_{t+1}^j \tag{4}$$

where V_t^j is the firm value including the dividend payout. Therefore the discount factor for firms is $\beta\left(\frac{D_{t+1}}{D_t}\right)^{-\nu}$.

2.2 Firms

The value of firm j at period t is given by $V(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t)$. k_t^j, b_t^j,and z_t^j are the individual state variables and respectively stand for the capital stock, outstanding debt and credit risk. A_t and ϵ_t are the aggregate TFP and financial shocks. Firms decide to default on their long-term bond if and only if $\tilde{V}(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t) < 0$. Equation (5) shows that the firm value equals to 0 if default and otherwise $\tilde{V}(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t)$. The bellman equation (6) defines $\tilde{V}(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t)$. It consists of three parts: operating profit $\pi(k_t^j, z_t^j; A_t)$, debt payment $-(1-\lambda)\vartheta b_t^j - \lambda b_t^j$ and continuing value $J(k_t^j, b_t^j; A_t, \epsilon_t)$. I assume a multiple-period long-term debt setup following Leland. (1994): $1/\lambda$ represents the terms to maturity; Firms pay back only λ of their outstanding debt and get charged a coupon payment at the rate ϑ over the remaining $1-\lambda$ each period.

$$V(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t) = \max\{0, \tilde{V}(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t)\} \tag{5}$$

$$\tilde{V}(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t) = \pi(k_t^j, z_t^j; A_t) - (1-\lambda)\vartheta b_t^j - \lambda b_t^j + J(k_t^j, b_t^j; A_t, \epsilon_t) \tag{6}$$

$$\pi(k_t^j, z_t^j; A_t) = \max_{h_t^j}\{F(A_t, k_t^j, h_t^j) - w_t h_t^j - z_t^j k_t^j\} = (R_t - z_t^j)k_t^j \tag{7}$$

$$J(k_t^j, b_t^j; A_t, \epsilon_t) = \max_{\{k_{t+1}^j, b_{t+1}^j\}} \{q_t[b_{t+1}^j - (1-\lambda)b_t^j] - x_t^j - \Gamma(k_{t+1}^j, b_{t+1}^j) + E_t \frac{\beta U'(d_{t+1})}{U'(d_t)} V(k_{t+1}^j, b_{t+1}^j, z_{t+1}^j; A_{t+1}, \epsilon_{t+1})\}$$

$$\text{subject to: } k_{t+1}^j = (1-\delta)k_t^j + \Psi_k\left(\frac{x_t^j}{k_t^j}\right)k_t^j \tag{8}$$

$$d_t^j = (R_t - z_t^j)k_t^j - \lambda b_t^j + q_t \Delta b_t^j - x_t^j - \Gamma(k_{t+1}^j, b_{t+1}^j) \tag{9}$$

$$F(k_t, n_t) = A_t^T k_t^\theta n_t^{1-\theta} \tag{10}$$

The operating profit $\pi(k_t^j, z_t^j)$ is a intra-period optimization problem given the aggregate price and state variables. It is affected by the exogenous stochastic credit risk z_t^j, which can be considered as the financial cost relevant to the short-term (intra-period) finance that is not captured by this model explicitly. It is possible to solve for the labor demand of firms n_t^j first and convert the maximization format of $\pi(k_t^j, z_t^j)$ into a regular function as in equation (7) if I employ the homogeneity property of the Cobb-Douglas production. R_t is the marginal return to the capital. It is also a function of k_t/n_t as the wage rate w_t and also identical for different firms as a result. If firms decide not to default, they immediately issue new long-term bond $q_t[b_{t+1}^j - (1-\lambda)b_t^j]$ and make investment x_t. $\Gamma(k_{t+1}^j, b_{t+1}^j)$ represents the financial cost, including the transaction commission and financial position adjustment cost[5]. The expected firm value next period is discounted with entrepreneurs' inter-temporal marginal rate of substitute in dividend payout $\beta\left(\frac{D_{t+1}}{D_t}\right)^{-\nu}$. The feature of equation (8) is taken from Jermann (1998). The adjustment cost $\Psi_k(i_t)$ is increasing and concave.

Because firms default if and only if $\tilde{V}(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t) < 0$, the solution for the following equation (11) is the default trigger. If and only if the realization of z_t is larger than $\tilde{z}_t$, the optimal choice for the entrepreneurs is to claim default. In consequence the default probability is $\Pr\{z_t > \tilde{z}_t\}$.

$$(R_t - \bar{z}_t)k_t^j - b_t^j[(1-\lambda)\vartheta + \lambda] + J(k_t^j, b_t^j) = 0 \tag{11}$$

Furthermore recall that the firm value $V(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t)$ is 0 upon default and $\tilde{V}(k_t^j, b_t^j, z_t^j; A_t, \epsilon_t)$ otherwise. The above information can help reduce the expected firm value next period.

$$\begin{aligned} E_t V(k_{t+1}^j, b_{t+1}^j, z_{t+1}^j) &= \int_{\tilde{z}_{t+1}^j}^{z_{\max}} 0 d\Phi(z) + \int_{z_{\min}}^{\tilde{z}_{t+1}^j} \tilde{V}(k_{t+1}^j, b_{t+1}^j, z_{t+1}^j) d\Phi(z) \\ &= k_{t+1}^j \int_{z_{\min}}^{\tilde{z}_{t+1}^j} (\tilde{z}_{t+1}^j - z) d\Phi(z) \end{aligned} \tag{12}$$

where $\Phi(z)$ is the CDF of random variable z.

[5]The detailed specification of financial cost and capital adjustment cost are discussed in the later subsection when the model is transferred into a solution-friendly format.

2.3 Workers

Workers have a instantaneous utility $U(c_t, n_t) = \log(c_t) + \eta \log(1 - n_t)$ as in King et al. (1988)[6]. Their discount factor over time γ is assumed to be larger than the one of entrepreneurs β, which implies that workers are more patient and therefore ask for a lower return on their savings. This is the reason why entrepreneurs borrow from workers at equilibrium. Wage earnings $w_t n_t$, bond payment and financial service fees are their income sources. Their asset pricing kernel and labor supply are listed below:

Pricing kernel:

$$\Lambda_t^w = \frac{1}{c_t^w} \tag{13}$$

Labor supply:

$$\frac{w_t}{c_t^w} = \frac{\eta}{1 - n_t} \tag{14}$$

c_t^w is the consumption of workers. The workers consider the default risk when they determine the bond price. There are two possible scenarios for each bond b_{t+1}^j: On the one hand, firms j can fulfill the obligation with a probability $\Phi(\tilde{z}_{t+1})$, that is λ of the outstanding debt retires and $1 - \lambda$ stays circulating in the market and only pays the coupon payment; On the other hand, it default with a probability $1 - \Phi(\tilde{z}_{t+1})$. Under the circumstances of default, workers claim all the operating profit and takeover the ownership of the firms temporarily. After they reduce the debt level to $\epsilon_t b_t$ through negotiation with creditors, firms are going to redeem their ownership and restore another round of operation. The negotiation and restructure process brings cost and cut the capital equal to $(1 - \epsilon)k_t$[7]. Therefore the initial state of the restructured firm j is $(\epsilon_t k_t^j, \epsilon b_t^j)$ and corresponding continuing value is $J(\epsilon_t k_{t+1}, \epsilon_t b_{t+1})$. The no arbitrage condition ensures the following bond price

[6]They find that $U(c_t, L_t) = \frac{c_t^\iota \upsilon(L_t)}{1-\iota}$ can capture the stylized facts of U.S. business cycles under particular assumptions, where L_t is leisure and equals to $1 - N_t$. Specifically, υ need to be increasing and concave if $0 \leq \iota < 1$; υ need to be decreasing and convex if $\iota > 1$; υ need to be increasing and concave if $\iota = 1$, that's the utility function in the same logarithm form as in this paper.

[7]This assumption is to obtain a unchanged leverage ratio for the convenience of computation. We will discuss this issue later in the transformation and optimization subsection.

determination equation:

$$q_t b_{t+1} = \gamma \frac{\Lambda^w_{t+1}}{\Lambda^w_t} \left[b_{t+1}[\lambda + (1-\lambda)(\vartheta + q_{t+1})]\Phi(\tilde{z}_{t+1}) + \int_{\tilde{z}_{t+1}}^{z_{\max}} \pi_{t+1} + J(\epsilon k_{t+1}, \epsilon b_{t+1}) d\Phi(z) \right] \tag{15}$$

where Λ^w_{t+1} is the pricing kernel of workers. Note the second term on the righthand side could not be directly multiplied by $1 - \Phi(\tilde{z}^j_{t+1})$ as $\pi(k^j_{t+1}, z^j_{t+1})$ is a function of $\tilde{z}^j_{t+1}$.

2.4 Transformation and Optimization

As Miao and Wang (2010) shows, the model with the above features satisfies the linear homogeneity. Namely all the equations still hold if they are divided by the same non-zero value, say k^j_t. Such mathematical manipulation decreases the dimension of state space in the original model. I follow the same procedures they suggest and reduce the individual state set from $\{k^j_t, b^j_t, z^j_t\}$ to $\{\varpi^j_t, z^j_t\}$, where $\varpi_t = b_t/k_t$. Besides, all the firms in this economy indeed face the same problem so I just eliminate the superscript j from now on for convenience. The trigger value $\tilde{z}_t$ determination equation is now:

$$R_t - \tilde{z}_t - \varpi_t[(1-\lambda)\vartheta + \lambda] + J(\varpi_t) = 0 \tag{16}$$

and the continuing operation value determination is into:

$$\begin{aligned} J(\varpi_t) = \max_{\{\varpi_{t+1}, i_t\}} &\{q_t[\varpi_{t+1} g(i_t) - (1-\lambda)\varpi_t] - i_t - \Gamma(\varpi_{t+1}) g(i_t) \\ &+ E_t \beta \left(\frac{D_t}{D_{t+1}} \right)^{\nu} g(i_t) \int_{z_{\min}}^{\tilde{z}_{t+1}} (\tilde{z}_{t+1} - z) d\Phi(z)\} \end{aligned} \tag{17}$$

where

$$g(i_t) = 1 - \delta + \Psi_k(i_t), \quad \text{and} \quad i_t = \frac{x_t}{k_t}$$

Again,the financial cost $\Gamma(\varpi_{t+1})$ includes the commission and financial position adjustment cost. The former one is proportional to the market value of the outstanding long-term debt while the latter one is just the cost to push debt-capital ratio to deviate from the steady state as in Miao and Wang (2010).

$$\Gamma(\varpi_{t+1}) = \psi q_t \varpi_{t+1} + \frac{(\varpi_{t+1} - \bar{\varpi})^2}{2} \tag{18}$$

I also assume a capital adjustment cost in the following format:

$$\Psi_k(i_t) = \frac{\bar{i}^{\alpha}}{1-\alpha} i_t^{1-\alpha} - \frac{\alpha \bar{i}}{1-\alpha} \tag{19}$$

where $\bar{i}$ is the steady state investment-capital ratio. After transforming the individual firm problem, it is straightforward that the key for the firm optimization is to search for the optimal debt-capital ratio ϖ_{t+1} and investment rate i_t to maximize the value of function $J(\varpi_t)$, because the first two terms in the equation (6) are either predetermined or exogenous. Then the necessary condition with respect to i_t is:

$$\frac{1}{g'(i_t)} = \overbrace{q_t \varpi_{t+1}}^{\frac{\text{Debt Capital}}{\text{Capital}}} + \underbrace{E_t \beta \left(\frac{D_t}{D_{t+1}}\right)^{\nu} \int_{z_{\min}}^{\tilde{z}_{t+1}} (\tilde{z}_{t+1} - z_{t+1}) d\Phi(z)}_{\frac{\text{Equity Value}}{\text{Capital}}} - \Gamma(\varpi_{t+1}) \tag{20}$$

The term on the on the left-hand side of equation (20) can be considered as the inverse of $\Delta k_{t+1}/\Delta x_t$, which represents the marginal transformation rate of investment into the capital and therefore the marginal cost to increase one extra unit of capital. It equals to 1 if there was no capital adjustment. In addition, the first term on the right-hand side is the debt value over capital, the second term is the equity value over capital, and the last term is the financial cost. The first two term together work as the ratio between the firm market value and the corresponding capital. Therefore the right-hand side is a modified *Tobin's Q*. Note, the transformation rate of investment to capital changes as the investment-capital ratio changes in the presence of the capital adjustment cost. Therefore the entrepreneurs would like to adjust i_t until the transform rate equal to the marginal Tobin's Q. It is interesting to do some qualitative conjecture here. If my model here is correctly set up, the debt price and equity value should both go down as the default risk increases. If there is no large movement of outstanding debt in the opposite direction, then the consequent decline of Tobin's Q on the right-hand side drives down the investment capital rate on the left-hand side as $g(i_t)$ is concave. This mechanism is at the core of this paper in explaining the investment dynamics.

$$q_t = E_t \beta \left(\frac{D_t}{D_{t+1}}\right)^{\nu} \Phi(\bar{z}_{t+1}) \frac{\partial \bar{z}_{t+1}}{\partial \varpi_{t+1}} + \Psi_b'(\varpi_{t+1}) - \frac{\partial q_t}{\partial \varpi_{t+1}} [\varpi_{t+1}(1-\psi) - (1-\lambda)\frac{\varpi_t}{g(i_t)}] \tag{21}$$

The equation (21) indicates the entrepreneurs' optimal choice in the debt-capital ratio and provides the fundamental for the financial structure decision. The left-hand side is all the benefit entrepreneurs could obtain from increasing a marginal unit of debt-capital ratio, that's the sale price of bonds, while the right-hand side offers the cost to increase a marginal unit of debt-capital ratio, including the present value of payment contingent on the non-default case, the marginal financial cost and the price fluctuation caused by the financial position change. It appears impossible to obtain any immediate qualitative results directly from the observation of equation (21) as a result of its complexity. So the dynamics of debt-capital movement under the current framework is a quantitative issue, which I will give a more detailed discussion in the quantitative result section.

2.4.1 Aggregate the Economy

The market clearing conditions in this model are nontrivial because of the heterogeneity among firms. The default firms and non-default firms make investment and financial decision according to identical decision rules but on different capital states. Specifically the default firms reorganize their assets and continue operation using only ϵ of their previous capital. Besides, I assume all the firms are heterogeneous only in their capital and debt size rather their debt-capital ratio. Thus the aggregate investment X_t, the aggregate capital next period K_{t+1}, capital accumulation equation, aggregate debt B_{t+1} and goods market clearing condition are:

$$X_t = (\Phi(\bar{z}_t) + [1 - \Phi(\bar{z}_t)]\epsilon_t)\, i_t K_t \tag{22}$$

$$K_{t+1} = g(i_t)(\Phi(\bar{z}) + [1 - \Phi(\bar{z})]\epsilon_t)K_t \tag{23}$$

$$B_{t+1} = \varpi_{t+1} K_{t+1} \tag{24}$$

$$Y_t = c_t^w + c_t^e + X_t \tag{25}$$

$$Y_t = A_t K_t^{\theta} n_t^{1-\theta} \tag{26}$$

Note I assume the production process happens before the default process. It does not receive any impact from the default. The capital used in production is K_t. The production function is the classic Cobb-Douglas function, where A_t^T is the technology shock that follows a vector autoregressive process in (27) together with ϵ_t.

$$\begin{bmatrix} A_t \\ \epsilon_t \end{bmatrix} = \Omega \begin{bmatrix} A_{t-1} \\ \epsilon_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{a,t} \\ \varepsilon_{\epsilon,t} \end{bmatrix} \tag{27}$$

3 Data and Calibration

The data in this paper are all annual. One period in the model hence corresponds to one year in reality. Although the standard calibration is usually in the quarterly frequency, mine is a compromise because of the shortage in consistent quarterly data series during the inter-war era. Most of parameters are obtained by calibrating to the long-term U.S. macroeconomic facts. The others are taken from relevant literatures. The data series to abstract the long-term targets range from 1929 to 1976[8]. The following session summarize the calibration strategy. The concrete data sources are offered in the Appendix.

[Table 1 about here.]

The parameters pinned down by the steady state targets are θ, η and δ. $1-\theta$ is set to equal to the share of labor relevant expenditure in the total nonfinancial corporate income; As the weight of leisure in the total utility, η guarantees the daily average working hours equal to 8 hours; δ is equal to the average of ratio between depreciation of non-residential capital and nonresidential capital stock of nonfinancial corporation. The relevant data are from National Income and Product Account of Bureau of Economics Analysis, NIPA henceforth. ν, λ, and ϵ are taken from literatures. I set the value of ν equal to 5 as in Jermann (1998); $1/\lambda$ represents the average years to maturity for the long-term debt. It is difficult to make any inference about the average years to maturity of U.S. long-term corporate bond. The recent study shows that the average maturity of long-term corporate debt in western economy is between 4 and 8.5 years and that the average maturity is pro-cyclical. Without loss of generalization the average years to maturity I take here is 5 years, namely $\lambda = 0.2$. ϵ is the recovery rate when a corporation files a default. Giesecke et al. (2011) says "*Hickman (1960) Table 152 implies that the average recovery rate of defaulted issues during the* $1900-1944$ *period is*

[8] Although the data availability and quality are very limited at that time, fortunately it is still possible to impute all the required data from different sources. Such methodology is certainly plagued by some inconsistences issues but it is definitely the best I could achieve for now.

about 62.5%". The remaining five parameters $\{\beta, \gamma, \psi, \alpha, \kappa\}$ are respectively the discount factor of entrepreneurs, the discount factor of workers, the commission rate, capital adjustment parameters and shape parameters for the distribution of z_t. They can not be identified individually. Therefore, I just let them work together to match five long-term business cycle moments: capital-output ratio, credit spread between Baa corporate bond and stock, debt-capital ratio, the relative volatility of investment to output, and the annual accumulative default probability. The cumulative density function of z is assumed to follow Miao and Wang (2010)

$$\Phi(z) = \left(z + \frac{\kappa}{1+\kappa}\right)^{\kappa} \quad z \in \left[-\frac{\kappa}{1+\kappa}, \frac{1}{1+\kappa}\right] \tag{28}$$

[Figure 1 about here.]

This distribution function is supported by the interval $[\frac{-\kappa}{\kappa+1}, \frac{\kappa}{\kappa+1}]$ and with the mean equal to 0.s My calibration successfully make the power format function generate a right-skewed and thin-tail density. See Figure 1. This feature is very important. Because it can further guarantees that only very few firms declare default and that a moderate movement of z_t around the right tail does not cause a large change of $\Phi(z)$. Solow residual series and the financial shocks series are the data to estimate the autoregressive system (27). I compute the Solow residual sequence in a standard approach. Take the log of the output, capital and working hours and derive $\hat{A}_t$ the following equation:

$$\hat{A}_t = \hat{y}_t - \theta \hat{k}_t - (1-\theta)\hat{h}_t$$

For the financial shocks series, I follow the procedures proposed by Jermann and Quadrini (2012), that's

$$\epsilon_t = \frac{\text{GDP}}{\text{end of period capital} - \text{end of period debt}}$$

End of period capital is the private fixed assets of nonfinancial firms in NIPA. End of period debt is the corporate long-term debt in the *Historical Statistics of United States*. GDP is the total value added of nonfinancial corporation in NIPA. The working hours sequence is a little complicated. The series before 1963 is the weekly working hours from Kendrick (1961) and Kendrick (1973). The series after 1963 is from the BLS private average weekly hours. All the value are in the real terms and the log values are all linearly detrended before estimation.

4 Quantitative Analysis

In this section I will present the computation strategy, simulation results and interpretation. Although the original equation system to characterize the equilibrium has been reduced much by the variable transformation in section 2, there still exists a large state-space and especially too many lagged state variables. It is an obstacle for nonlinear methods. Therefore, I solve the model linearly instead. It is worth pointing out that some endogenous variables take negative values at steady state. So it is not possible to apply the log-linear scheme. The full equation system and details to solve for the steady state are given in the Appendix. Once the laws of motion for state variables and decision rules for the jump variables are obtained, the simulation can be done by feeding into the model the actual realization of technology and financial shocks from year 1929 to 1939. Then I compare the simulated transition path of economic aggregates and financial variables with their data counterparts. In the meantime, a standard real business cycle model with an identical capital adjustment cost and inter-temporal elasticity of substitution is solved and simulated in the same way in order to identify the amplification by the default risk. The concrete setup and solution of this benchmark model is also in the Appendix.

4.1 Steady State and Impulse Response

My quantitative analysis starts with the exhibition of the steady state. Two first-order partial derivatives $\frac{\partial \tilde{z}_t}{\partial \varpi_t}$ and $\frac{\partial q_t}{\partial \varpi_{t+1}}$ are included in my endogenous variable set. $\frac{\partial \tilde{z}_t}{\partial \varpi_t} < 0$ implies that a higher debt-capital ratio decreases $\tilde{z}_t$ and further increases the default probability. It is quite intuitive because firms with heavier debt burden are more vulnerable to the default risk. In addition, the interpretation of $\frac{\partial q_t}{\partial \varpi_t} < 0$ is also very straightforward. The bond price has to go down when firms are exposed to heavier debt burden and higher default probability. These two features are both consistent with our observation in the financial market. The impulse response experiments are also taken around the steady state. The figure 2 and 3 respectively show the dynamics of all important economic indicators after the negative one-percent technology or financial shock hits the steady state economy. All the movements have been measured as the percentage deviation from steady state in the graphs. In Figure (2), the initial deviation of output and investment are both larger than the size of the original shock, which implies that the model with default risk is able to amplify the impact of the technology shock. especially the investment decline is as three times as the one in technology decline. Consumption shows about the 80% of the decline in the technology while the working hour is less than the half. The consumption decrease is delayed by the households' motive to smooth their utility stream. A large decrease in the working hours does not occur possibly because the strong wealth effect when the wage drops[9]. The debt-capital ratio and capital are both predetermined so their responses start from zero. The capital goes down for two reason: the default-reorganization cost and lower investment. The default process make firms lose 47.5% of their capital. Nonetheless, the fraction of the firms under such effect is small. On the contrary, most of firm would response to the impulse by cutting investment. Compared with the traditional case without default risk, the default risk emerges as another propeller to the investment collapse. As the equation (20) shows, both debt price and equity value will go down deeper because of the increase in probability to default, which finally leads to a more severe investment decline.

However, it is surprising to find out that the debt-capital ratio is increasing instead of decreasing. A reasonable explanation is that the total outstanding debt falls more slowly than the capital. It is definitely not a result of the default process. Because the model assumes that both capital and outstanding debt will be cut in the same proportion. Therefore the default process cannot bring down the value of debt-capital ratio. Thus the fall speed discrepancy only comes from the endogenous choice of entrepreneurs. At steady state the $\psi_k(\bar{\imath}) = 1$, which implies one unit investment decline can decrease one unit capital decline. However, the saved one unit investment expenditure isn't completely used to buy back outstanding bond. Because firms have to pay financial position adjustment cost and also want to use part of liquidity to smooth their dividend payout. Therefore the decline of outstanding debt is smaller than one unit.

[Figure 2 about here.]

[9]The labor income accounts for almost 70% of the total income. The wage rate drop might lead to a strong negative wealth effect and drive workers not to enjoy too much leisure. In the appendix I conduct a sensitivity analysis with a different utility function. When I introduce the utility function in Greenwood et al. (1988) and set the habit formation parameter equal to zero, the wealth effect of wage change is completely eliminated, The working hours decrease a lot as expected. So it is very reasonable to conjecture that the missing of working hours decline here is the result of wealth effect.

The figure 3 illustrates the impulse response to the negative financial shock. All the variables move in the same direction as they are hit by the negative technology shock except the consumption. The reason why consumption increases a little bit is that the negative financial shock drives the investment down but fail to make the same amount decline in the output. Consumption has to go up. A lower recovery rate makes the entrepreneurs more aware of the default and reduce the investment to avoid the default loss. The output based on the constant technology level and slightly changed capital capital won't lead to a deep downturn. In sum, the impact of financial shock is quantitatively small. Only the impacts on investment, capital and bond price are relatively significant but still minor compared with the technology impulse response.

[Figure 3 about here.]

4.2 Simulation

Three simulation experiments are done so that we can recognize the role of different shocks during the U.S. Great Depression. First, I consider both technology and financial shocks. Figure 4 shows that all the simulated aggregates but working hours generate a transition comparable to data. It is necessary to emphasize that the consumption I plot here is the consumption of workers rather than the sum of workers' consumption and entrepreneurs' dividend payout, because it is more aligned with the consumption definition in the traditional literature. The black dashed line is the simulation results from the benchmark RBC model. It shows that the amplification by the default risk is large, particularly in investment. The failure in matching working hours should be attributed to the strong wealth effect that was discussed in the impulse response subsection.

$$r_d = \frac{\lambda + (1-\lambda)\vartheta}{q} + 1 - \lambda \tag{29}$$

In addition, the financial indicators such as the default rate, bond yield and debt-capital ratio are also within our interest. According to Giesecke et al. (2011), there are two corporate bond default peaks during the U.S. Great Depression: one is between 1931 and 1934, and the other is between 1937 and 1938. Their standard in measuring the default peaks is that the annual cumulative default rate is higher than 2%. Thus, my model successfully predicts one of the most worst default peak between 1931 and 1934. The severity, the highest annual default rate 3%, and timing are all acceptable. I fail to reproduce the second one between 1937 and 1938 but the annual default rate is very close to the 2% line. The bond yield in this model is computed following the equation (29) and matches well with the middle-grade corporate bond yield from Susan B. Carter (2003). Unfortunately, the predicted debt-capital ratio is very different from the actual data series. The simulated transition path completely miss the huge climbing at the beginning of 1930s and instead produces a slightly decline. It is quite surprising because intuitively firms should deplete their debt obligation to ensure their solvency. The analysis on the $\frac{\partial \tilde{z}_t}{\partial \varpi_t}$ and $\frac{\partial q_t}{\partial \varpi_{t+1}}$ also says that higher debt-capital ratio is more likely to put firms in the danger of default. In Hart and Mehrling (1995) the author mentions that lots of large utility and railway firms stuck to their finance plan before the financial turbulence and issued massive volumes of long-term debt in 1930. This is an exceptional behavior during the hard time. Another candidate explanation to the discrepancy between the data and model is that my model doesn't capture the debt adjustment cost very accurately and underestimate the difficulty in adjusting financial position during a serious recession.

[Figure 4 about here.]

Another two experiments are respectively for the financial and technology shocks. From the simulation figure 6, it is not difficult to figure out that all the economics aggregates and financial indicators except the bond yield fail to match with the corresponding data if only the financial shock is considered. However, the results in figure 5 shows that conclusions from two-shock experiments are well preserved although the severity get slightly reduced. The bond yield is not well consistent with the actual one. This decompositions clearly demonstrate that the impact of TFP shocks is dominant and that the impact of financial shocks is minor in match the economic aggregates. However, the financial shock does help a lot in producing a jump in risky interest.

[Figure 5 about here.]

[Figure 6 about here.]

5 Conclusion

This paper attempts to investigate the roles of default risk during the U.S. Great Depression. My rational expectation RBC model shows that the adverse technology shocks can be amplified very much by the default risk. Intuitively, when the adverse technology shocks hit the economy, firms become more vulnerable to the credit risk and try to decrease the investment and debt heavily to maintain in solvency. Therefore the investment could get cut much more than in the case where the default risk is not considered. The simulation with TFP and financial shocks successfully explains the large decline in consumption, output and investment and nonetheless miss the working hours drop because of the strong wealth effect. In the meantime, the financial indicators such as default rate and bond yield are also very well predicted. The decomposition of simulation process tells that the effect of technology shocks dominates during the U.S. Great Depression whereas the financial shocks only play an important role in pushing up the long-term bond yield. More interestingly, the counterfactual debt-capital ratio could implies that there exists a serious obstacles for firms to unload their debt burden during the early 1930s, which therefore could be a important factor to deteriorate the economic recession.

However, the discussion is still far from ending. Jiang (2013) concludes that the adverse financial shocks could be an important aspect to understand working hours decline if the working capital or firm liquidity is correctly introduced. Besides, the monetary policy is not a negligible.factor when we discuss the corporate finance management and debt market. Thus, my future study will continue in the following directions: (1) to develop a comprehensive model that can incorporate both default risk and firm liquidity; (2) to introduce the money and cash management into the current framework.

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URL: *http://hsus.cambridge.org/HSUSWeb/toc/hsusHome.do*

A Data

- Nominal nonfinancial corporate capital stock: BEA FA6.1 Line 4
- Real nonfinancial corporate capital stock: BEA FA6.2 Line 3
- Real nonfinancial corporate investment: BEA FA6.8 Line 4
- Nominal nonfinancial corporate capital depreciation: BEA FA6.4 Line 4
- Real nonfinancial corporate capital depreciation: BEA FA6.5 Line4
- Nominal nonfinancial corporate production: BEA NIPA1.14 Line 17
- Real nonfinancial corporate production: BEA NIPA1.14 Line 41
- Nominal nonfinancial corporate long-term debt: Susan B. Carter (2003) data series cj870−889
- U.S. population between 18 and 65: Susan B. Carter (2003) data series Aa125 − 144
- U.S. private non-farm total man-hours 1929 − 1953: Kendrick (1961)
- U.S. private non-farm total man-hours 1948 − 1966: Kendrick (1973)
- U.S average weekly private working hours 1964 − 1976: BLS table ID EES00500005
- Nominal durable good consumption and services: BEA NIPA 1.1.5 Line 5 and Line 6
- GDP deflator: BEA NIPA1.1.5 Line 1
- Corporate Cash: Statistics of Income[10]
- Corporate inventories: Statistics of Income

[10] see the archive in the links http://www.irs.gov/uac/SOI-Tax-Stats-Archive—1934-to-1953-Statistics-of-Income-Report,-Part-2

B Mathematics

B.1 All the equations

$$R_t - \bar{z}_t - \varpi_t[(1-\lambda)\vartheta + \lambda] + J(\varpi_t) = 0 \tag{30}$$

$$-\frac{\partial \bar{z}_t}{\partial \varpi_t} - [(1-\lambda)\vartheta + \lambda] + \frac{\partial J(\varpi_t)}{\partial \varpi_t} = 0 \tag{31}$$

$$J(\varpi_t) = q_t[\varpi_{t+1} g(i_t) - (1-\lambda)\varpi_t] - i_t + g(i_t)\left[\beta \int_{z_{min}}^{\bar{z}_{t+1}} (\bar{z}_{t+1} - z) d\Phi(z) - \psi q_t \varpi_{t+1} - \Psi(\varpi_{t+1})\right] \tag{32}$$

$$\frac{\partial q_t}{\partial \varpi_{t+1}}[\varpi_{t+1} g(i_t) - (1-\lambda)\varpi_t - \psi \varpi_{t+1} g(i_t)] + q_t g(i_t)(1-\psi) + \beta g(i_t)\Phi(\bar{z}_{t+1})\frac{\partial \bar{z}_{t+1}}{\partial \varpi_{t+1}} - g(i_t)\Psi^{'}(\varpi_{t+1}) = 0 \tag{33}$$

$$\frac{\partial J(\varpi_t)}{\partial \varpi_t} = -q_t(1-\lambda) \tag{34}$$

$$q_t \varpi_{t+1}(1-\psi)g'(i_t) - 1 + g'(i_t)\beta \frac{c_t^e}{c_{t+1}^e} \int_{z_{min}}^{\bar{z}_{t+1}} (\bar{z}_{t+1} - z_{t+1}) d\Phi(z) - g'(i_t)\Psi(\varpi_{t+1}) = 0 \tag{35}$$

$$\begin{aligned} q_t \varpi_{t+1} = \Lambda_{t+1}^w \{ & \Phi(\bar{z}_{t+1}) q_{t+1} \varpi_{t+1}(1-\lambda) + [\lambda + (1-\lambda)\vartheta]\varpi_{t+1} \\ & - (1-\tau_p) \int_{\bar{z}_{t+1}}^{z_{max}} (z - \bar{z}_{t+1}) d\Phi(z) + (1-\epsilon) J(\varpi_{t+1})[1 - \Phi(\bar{z}_{t+1})] \} \end{aligned} \tag{36}$$

$$\begin{aligned} q_t + \frac{\partial q_t}{\partial \varpi_{t+1}} \varpi_{t+1} = \Lambda_{t+1}^w \{ & \Phi(\bar{z}_{t+1}) q_{t+1}(1-\lambda) + [\lambda + (1-\lambda)\vartheta] + (1-\lambda)\phi(\bar{z}_{t+1}) q_{t+1} \varpi_{t+1} \frac{\partial z_{t+1}}{\partial \varpi_{t+1}} \\ & + (1-\tau_p)(1 - \Phi(\bar{z}_{t+1})) \frac{\partial \bar{z}_{t+1}}{\partial \varpi_{t+1}} + (1-\epsilon) J(\varpi_{t+1}) \phi(\bar{z}_{t+1}) \frac{\partial z_{t+1}}{\partial \varpi_{t+1}} \\ & - (1-\epsilon)[1 - \Phi(\bar{z}_{t+1})] \frac{\partial J(\varpi_{t+1})}{\partial \varpi_{t+1}} \} \end{aligned} \tag{37}$$

$$\Lambda_{t+1}^w = \gamma \frac{c_t^w}{c_{t+1}^w} \tag{38}$$

$$\frac{w_t}{c_t^w} = \frac{\alpha}{1 - H_t} \tag{39}$$

$$X_t = (\Phi(\bar{z}_t) + [1 - \Phi(\bar{z}_t)]\epsilon)\, i_t K_t \tag{40}$$

$$K_{t+1} = (1 - \delta + i_t)\,(\Phi(\bar{z}) + [1 - \Phi(\bar{z})]\epsilon)\, K_t \tag{41}$$

$$B_{t+1} = \varpi_{t+1} K_{t+1} \tag{42}$$

$$Y_t = A_t K_t^{\theta} H_t^{1-\theta} \tag{43}$$

$$Y_t = C_t^w + C_t^e + X_t \tag{44}$$

$$w_t = (1-\theta) A_t K_t^{\theta} H_t^{-\theta} \tag{45}$$

$$R_t = \theta A_t K_t^{\theta-1} H_t^{1-\theta} \tag{46}$$

$$\begin{aligned} C_t^e =& [(1-\tau_p)R_t + \tau_p\delta]K_t + \tau_p[(1-q_{t-1})\lambda + (1-\lambda)\vartheta]\varpi_t\Phi(\bar{z}_t)K_t - [\lambda + (1-\lambda)\vartheta]\varpi_t\Phi(\bar{z}_t)K_t \\ &+ q_t[w_{t+1}g(i_t) - (1-\lambda)\varpi_t]\Phi(\bar{z}_t)K_t - i_t\Phi(\bar{z}_t)K_t - \phi q_t\varpi_{t+1}g(i_t)]\Phi(\bar{z}_t)K_t \\ &+ \{q_t[\varpi_{t+1}g(i_t) - (1-\lambda)\varpi_t] - i_t - \phi q_t\varpi_{t+1}g(i_t)\}(1-\Phi(\bar{z}_t))\epsilon K_t \end{aligned} \tag{47}$$

$$\begin{aligned} &\int_{z_{min}}^{\bar{z}_{t+1}} (\bar{z}_{t+1} - z)d\Phi(z) \\ =&\bar{z}_{t+1}\int_{z_{min}}^{\bar{z}_{t+1}} d\Phi(z) - \int_{z_{min}}^{\bar{z}_{t+1}} zd\Phi(z) \\ =&\bar{z}_{t+1}\Phi(\bar{z}_{t+1}) - z\Phi(z)|_{z_{min}}^{\bar{z}_{t+1}} + \int_{z_{min}}^{\bar{z}_{t+1}} \Phi(z)dz \\ =&\bar{z}_{t+1}\Phi(\bar{z}_{t+1}) - \bar{z}_{t+1}\Phi(\bar{z}_{t+1}) + \int_{z_{min}}^{\bar{z}_{t+1}} (z + \frac{\kappa}{\kappa+1})^{\kappa} dz \\ =&\frac{(\bar{z}_{t+1} + \frac{\kappa}{\kappa+1})^{\kappa+1}}{\kappa+1} \end{aligned}$$

$$\begin{aligned} &(1-\tau_p)\int_{\bar{z}_{t+1}}^{z_{max}} (z - \bar{z}_{t+1})d\Phi(z) \\ =&(1-\tau_p)[\int_{\bar{z}_{t+1}}^{z_{max}} zd\Phi(z) - \int_{\bar{z}_{t+1}}^{z_{max}} \bar{z}_{t+1}d\Phi(z)] \\ =&(1-\tau_p)\{z\Phi(z)|_{\bar{z}_{t+1}}^{z_{max}} - \int_{\bar{z}_{t+1}}^{z_{max}} \Phi(z)dz - \bar{z}_{t+1}[\Phi(z_{max}) - \Phi(z_{t+1})]\} \\ =&(1-\tau_p)[z_{max} - \bar{z}_{t+1}\Phi(\bar{z}_{t+1}) - \int_{\bar{z}_{t+1}}^{z_{max}} \Phi(z)dz - \bar{z}_{t+1} + \bar{z}_{t+1}\Phi(\bar{z}_{t+1})] \\ =&(1-\tau_p)[(z_{max} - \bar{z}_{t+1}) - \int_{\bar{z}_{t+1}}^{z_{max}} \Phi(z)dz] \\ =&(1-\tau_p)(z_{max} - \bar{z}_{t+1}) - (1-\tau_p)\frac{(z + \frac{\kappa}{\kappa+1})^{\kappa+1}}{\kappa+1}|_{\bar{z}_{t+1}}^{z_{max}} \\ =&(1-\tau_p)(z_{max} - \bar{z}_{t+1}) - (1-\tau_p)\frac{1}{\kappa+1}[1 - (\bar{z}_{t+1} + \frac{\kappa}{\kappa+1})^{\kappa+1}] \\ =&(1-\tau_p)(\frac{1}{\kappa+1} - \bar{z}_{t+1}) - (1-\tau_p)\frac{1}{\kappa+1}[1 - (\bar{z}_{t+1} + \frac{\kappa}{\kappa+1})^{\kappa+1}] \\ =&(1-\tau_p)[\frac{(\bar{z}_{t+1} + \frac{\kappa}{\kappa+1})^{\kappa+1}}{\kappa+1} - \bar{z}_{t+1}] \end{aligned}$$

The unknowns in the above system are $\{R, \bar{z}, q, \varpi, J, z\varpi, q\varpi, J\varpi, i, \Lambda^w, c^w, w, h, X, K, B, c^e, Y\}$.

B.2 Solution for the Steady State

$$-(1-\tau_p)\frac{\partial z_t}{\partial \varpi_t} + \tau_p[(1-q_{t-1})\lambda + (1-\lambda)\vartheta] - \tau_p\lambda\varpi_t\frac{\partial q_{t-1}}{\partial \varpi_t} - [(1-\lambda)\vartheta + \lambda] + \frac{\partial J(\varpi_t)}{\partial \varpi_t} = 0$$

$$-(1-\tau_p)\Omega^z + (\tau_p - 1)[\lambda + (1-\lambda)\vartheta] - \tau_p q\lambda - \tau_p\lambda\varpi_t\Omega^q - q(1-\lambda) = 0$$

$$\frac{\Omega^z}{q} = \frac{1}{1-\tau_p}\left[(\tau_p - 1)\frac{\lambda + (1-\lambda)\vartheta}{q} - \tau_p\lambda - \tau_p\lambda\varpi\frac{\Omega^q}{q} - (1-\lambda)\right]$$

$$\frac{\Omega^z}{q} = -\frac{\lambda + (1-\lambda)\vartheta}{q} - \frac{\tau_p\lambda + (1-\lambda)}{1-\tau_p} - \frac{\lambda\tau_p}{1-\tau_p}\frac{\varpi_t\Omega^q}{q} \tag{48}$$

$$\begin{aligned} q_t + \frac{\partial q_t}{\partial \varpi_{t+1}}\varpi_{t+1} = \Lambda^w_{t+1}\{&\Phi(\bar{z}_{t+1})q_{t+1}(1-\lambda) + [\lambda + (1-\lambda)\vartheta] + (1-\lambda)\phi(\bar{z}_{t+1})q_{t+1}\varpi_{t+1}\frac{\partial \bar{z}_{t+1}}{\partial \varpi_{t+1}} \\ &+ (1-\tau_p)(1-\Phi(\bar{z}_{t+1}))\frac{\partial \bar{z}_{t+1}}{\partial \varpi_{t+1}} + (1-\epsilon)J(\varpi_{t+1})\phi(\bar{z}_{t+1})\frac{\partial z_{t+1}}{\partial \varpi_{t+1}} \\ &- (1-\epsilon)[1-\Phi(\bar{z}_{t+1})]\frac{\partial J(\varpi_{t+1})}{\partial \varpi_{t+1}}\} \end{aligned}$$

$$\begin{aligned} \frac{1}{\gamma}\left[1 + \Omega^q\frac{\varpi}{q}\right] = &\frac{\lambda + (1-\lambda)\vartheta}{q} + \Phi(\bar{z})(1-\lambda) \\ &+ (1-\lambda)\phi(\bar{z})q\varpi\frac{\Omega^z}{q} \\ &+ \{(1-\tau_p)[1-\Phi(\bar{z})] + (1-\epsilon)J(\varpi)\phi(\bar{z})\}\frac{\Omega^z}{q} \\ &+ (1-\lambda)(1-\epsilon)[1-\Phi(\bar{z})] \end{aligned} \tag{49}$$

$$\frac{\partial q_t}{\partial \varpi_{t+1}}[\varpi_{t+1}(1-\delta+i_t) - (1-\lambda)\varpi_t] + q_t(1-\delta+i_t) + \beta(1-\tau_p)(1-\delta+i_t)\Phi(\bar{z})\frac{\partial \bar{z}_{t+1}}{\partial \varpi_{t+1}} = 0$$

$$\Omega^q_\varpi\frac{\varpi}{q}[(1-\delta+i) - (1-\lambda)] + (1-\delta+i) + \beta(1-\tau_p)(1-\delta+i)\Phi(\bar{z})\frac{\Omega^z}{q} = 0 \tag{50}$$

The linear system can help us solve for

$$\frac{\Omega^z}{q} = -\frac{\lambda + (1-\lambda)\vartheta}{q} - \frac{\tau_p \lambda + (1-\lambda)}{1-\tau_p} - \frac{\tau_p \lambda}{1-\tau_p}\frac{\varpi \Omega^q}{q} \tag{51}$$

$$\begin{aligned}\frac{1}{\gamma}\frac{\varpi \Omega^q}{q} = & \frac{\lambda + (1-\lambda)\vartheta}{q} + \Phi(\bar{z})(1-\lambda) - \frac{1}{\gamma} + (1-\lambda)(1-\epsilon)[1-\Phi(\bar{z})] \\ & + \{(1-\lambda)\phi(\bar{z})\varpi q + (1-\tau_p)[1-\Phi(\bar{z})] + (1-\epsilon)J(\bar{z})\phi(\bar{z})\}\frac{\Omega^z}{q}\end{aligned} \tag{52}$$

$$\frac{\varpi \Omega^q}{q}[(1-\delta+i) - (1-\lambda)] + (1-\delta+i) + \beta(1-\tau_p)(1-\delta+i)\Phi(\bar{z})\frac{\Omega^z}{q} = 0 \tag{53}$$

within this system three variables $\{1-\delta+i, q\varpi, J\}$need to be transformed into the function of $\bar{z}$ if possible. With the manipulation of the capital evolution, FOC with respect to i and the definition of function J, we can obtain their implication.

Transformed this linear system into a more friendly format. Define $a = \frac{\Omega^z}{q}$, $b = \frac{\lambda+(1-\lambda)\vartheta}{q}$ and $c = \frac{\varpi \Omega^q}{q}$. Also

$$CC_1 = -\frac{\tau_p \lambda + (1-\lambda)}{1-\tau_p} \tag{54}$$

$$LL_1 = -\frac{\tau_p \lambda}{1-\tau_p} \tag{55}$$

$$LL_2 = \frac{1}{\gamma} \tag{56}$$

$$CC_2 = \Phi(\bar{z})(1-\lambda) - \frac{1}{\gamma} + (1-\lambda)(1-\epsilon)[1-\Phi(\bar{z})] \tag{57}$$

$$MM_2 = (1-\lambda)\phi(\bar{z})\varpi q + (1-\tau_p)[1-\Phi(\bar{z})] + (1-\epsilon)J(\bar{z})\phi(\bar{z}) \tag{58}$$

$$LL_3 = (1-\delta+i) - (1-\lambda) \tag{59}$$

$$CC_3 = (1-\delta+i) \tag{60}$$

$$MM_3 = \beta(1-\tau_p)(1-\delta+i)\Phi(\bar{z}) \tag{61}$$

$$LL_3 = (1 - \delta + i) - (1 - \lambda) \tag{62}$$

The original linear system can be put into:

$$a = -b + CC_1 + LL_1 c$$

$$LL_2 c = b + CC_2 + MM_2 a$$

$$LL_3 c + CC_3 + MM_3 a = 0$$

The solution to this simplified system can be obtained easily and listed as below:

$$c = \frac{CC_3 + \frac{MM_3(CC_1 + CC_2)}{1 - MM_2}}{LL_3 + \frac{MM_3(LL_1 - LL_2)}{1 - MM_2}}$$

$$a = \frac{CC_1 + CC_2 + (LL_1 - LL_2)c}{1 - MM_2}$$

$$b = LL_2 c - CC_2 - MM_2 a$$

The conditions or equations we might use during solving the linear system:

$$1 - \delta + i = \frac{1}{\Phi(\bar{z}) + [1 - \Phi(\bar{z})]\epsilon} \tag{63}$$

$$i = \frac{1}{\Phi(\bar{z}) + [1 - \Phi(\bar{z})]\epsilon} - 1 + \delta \tag{64}$$

$$q\varpi = 1 - \beta(1 - \tau_p) \int_{zmin}^{\bar{z}} (\bar{z} - z) d\Phi(z) \tag{65}$$

$$J = q\varpi[(i + 1 - \delta) - (1 - \lambda)] - i + \beta(1 - \tau_p)(i + 1 - \delta) \int_{z_{min}}^{\bar{z}} (\bar{z} - z) d\Phi(z) \tag{66}$$

$$\Phi(z) = (z + \frac{\kappa}{\kappa + 1})^{\kappa} \left(-\frac{\kappa}{\kappa + 1}, \frac{1}{\kappa + 1} \right) \tag{67}$$

$$\phi(z) = \kappa(z + \frac{\kappa}{\kappa + 1})^{\kappa - 1} \tag{68}$$

Finally, we need a nonlinear equation to solve for the $\bar{z}$

$$\frac{1}{\gamma} = (1-\lambda)\Phi(\bar{z}) + \frac{\lambda + (1-\lambda)\vartheta}{q} - \frac{1}{q\varpi}\int_{\bar{z}}^{zmax}[(1-\tau_p)(z-\bar{z}) + (1-\epsilon)J(\bar{z})]d\Phi(z) \tag{69}$$

$$\int_{z_{min}}^{\bar{z}}(\bar{z}-z)d\Phi(z) = \int_{z_{min}}^{\bar{z}}\Phi(z)dz = \frac{(\bar{z}+\frac{\kappa}{\kappa+1})^{\kappa+1}}{\kappa+1} \tag{70}$$

Continuing on solving for the steady state variables:

$$(R_t - \bar{z}_t)(1-\tau_p) + \tau_p[(1-q_{t-1})\lambda\varpi_t + (1-\lambda)\vartheta\varpi_t + \delta] - \varpi_t[(1-\lambda)\vartheta + \lambda] + J(\varpi_t) = 0 \tag{71}$$

$$(R-\bar{z})(1-\tau_p) = -\tau_p[(1-q)\lambda\varpi + (1-\lambda)\vartheta\varpi + \delta] + \varpi[(1-\lambda)\vartheta + \lambda] - J(\bar{z}) \tag{72}$$

$$R = \frac{-\tau_p[(1-q)\lambda\varpi + (1-\lambda)\vartheta\varpi + \delta] + \varpi[(1-\lambda)\vartheta + \lambda] - J(\bar{z})}{1-\tau_p} + \bar{z} \tag{73}$$

Table 1: Parameters and Targets

Parameters		Targets	
θ	0.370	the ratio between labor expenditure and nonfinancial corporate output	0.37
δ	0.063	the ratio between the depreciation and nonfinancial corporation capital	0.24
η	2.170	working hours account for 1/3 of 24 hours	
α	0.230	the ratio between st.d of investment and GDP	2.04
β	0.885	the average capital-output ratio	2.00
γ	0.947	the gap between stock return and Baa corporate bond yield	5%
ϕ	0.050	the ratio between corporate long-term debt and capital	0.48
κ	0.042	accumulative annual default rate	1%
ϵ	0.625	historical default recovery ratio	62.5%
λ	0.200	literature	0.20
σ_a	0.019		
σ_ϵ	0.036		
$\Omega = \begin{bmatrix} 0.9509 & -0.0842 \\ 0.0743 & 0.7757 \end{bmatrix}$			

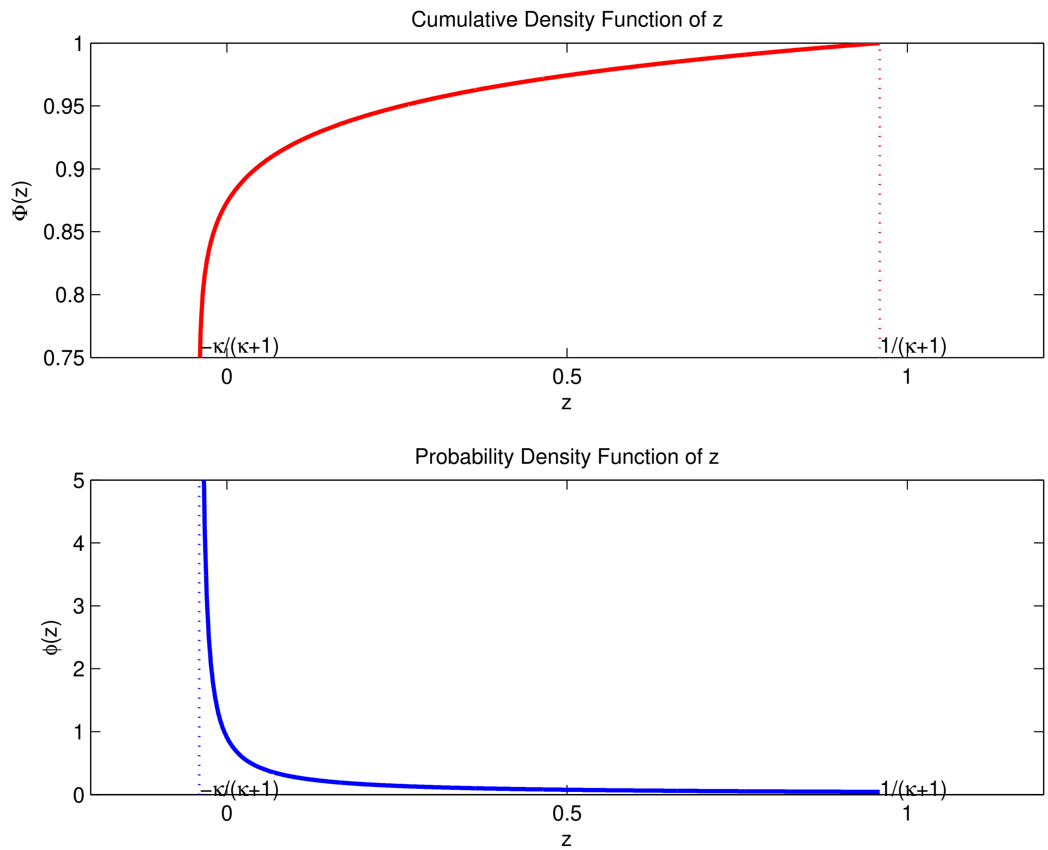

Figure 1: CDF and PDF of credit risk z

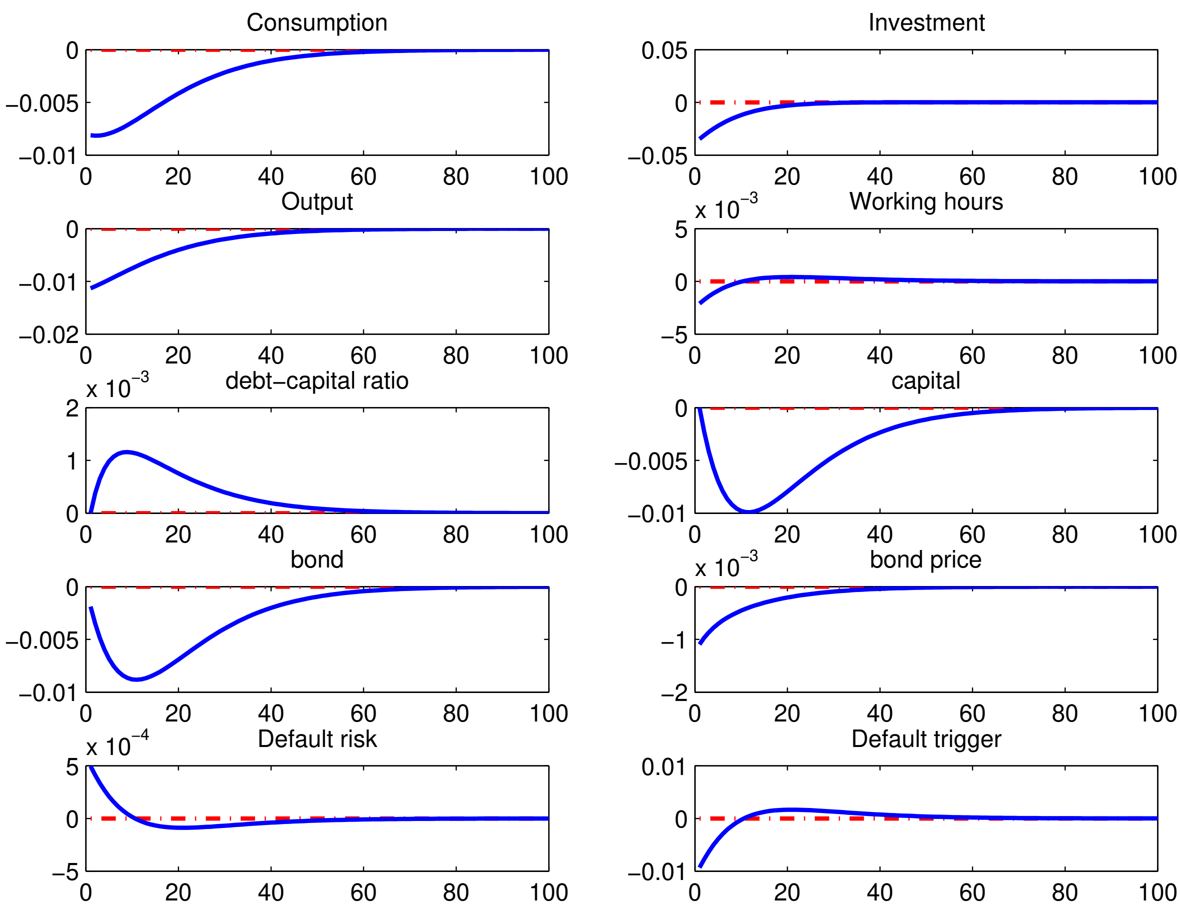

Figure 2: Impulse response to TFP shocks

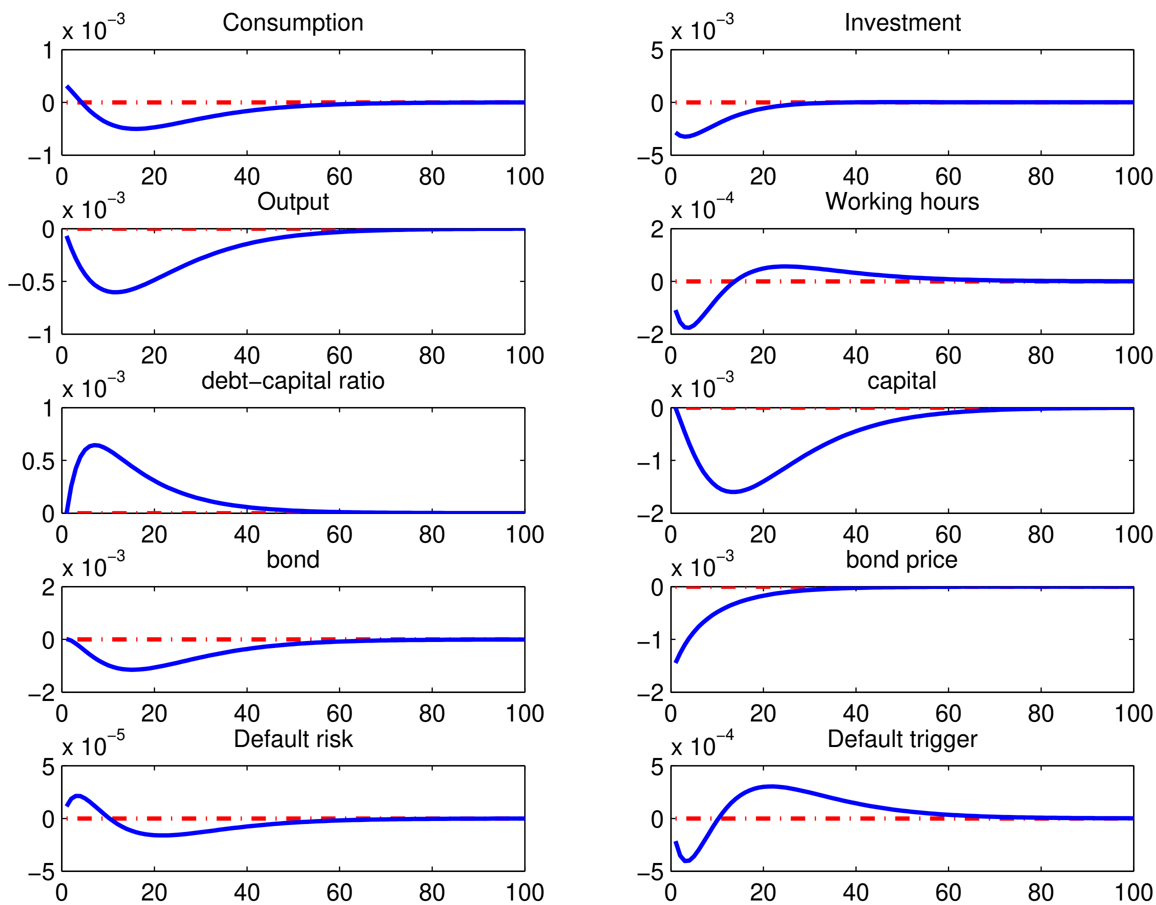

Figure 3: Impulse response to financial shocks

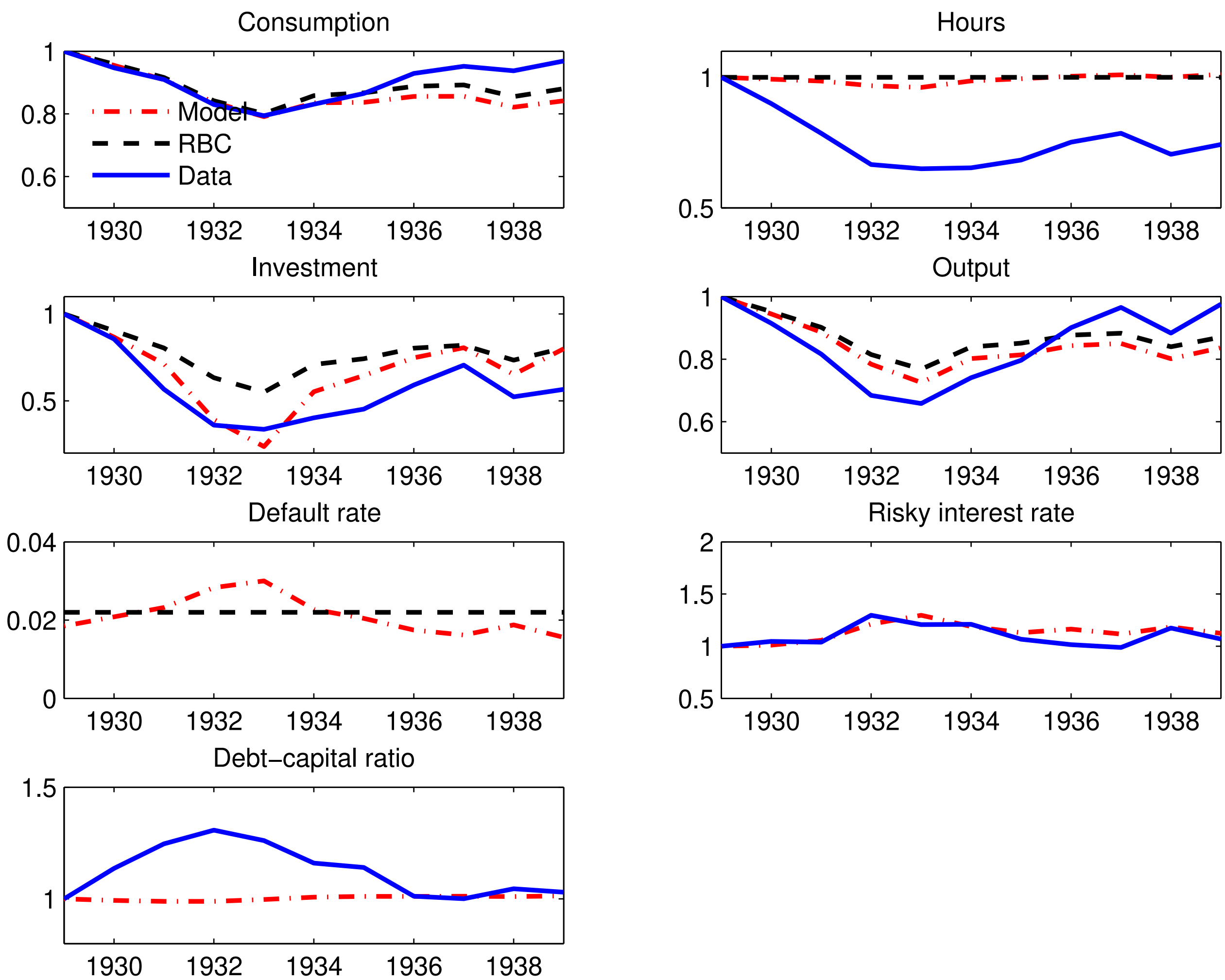

Figure 4: Counterfactual simulation with two shocks

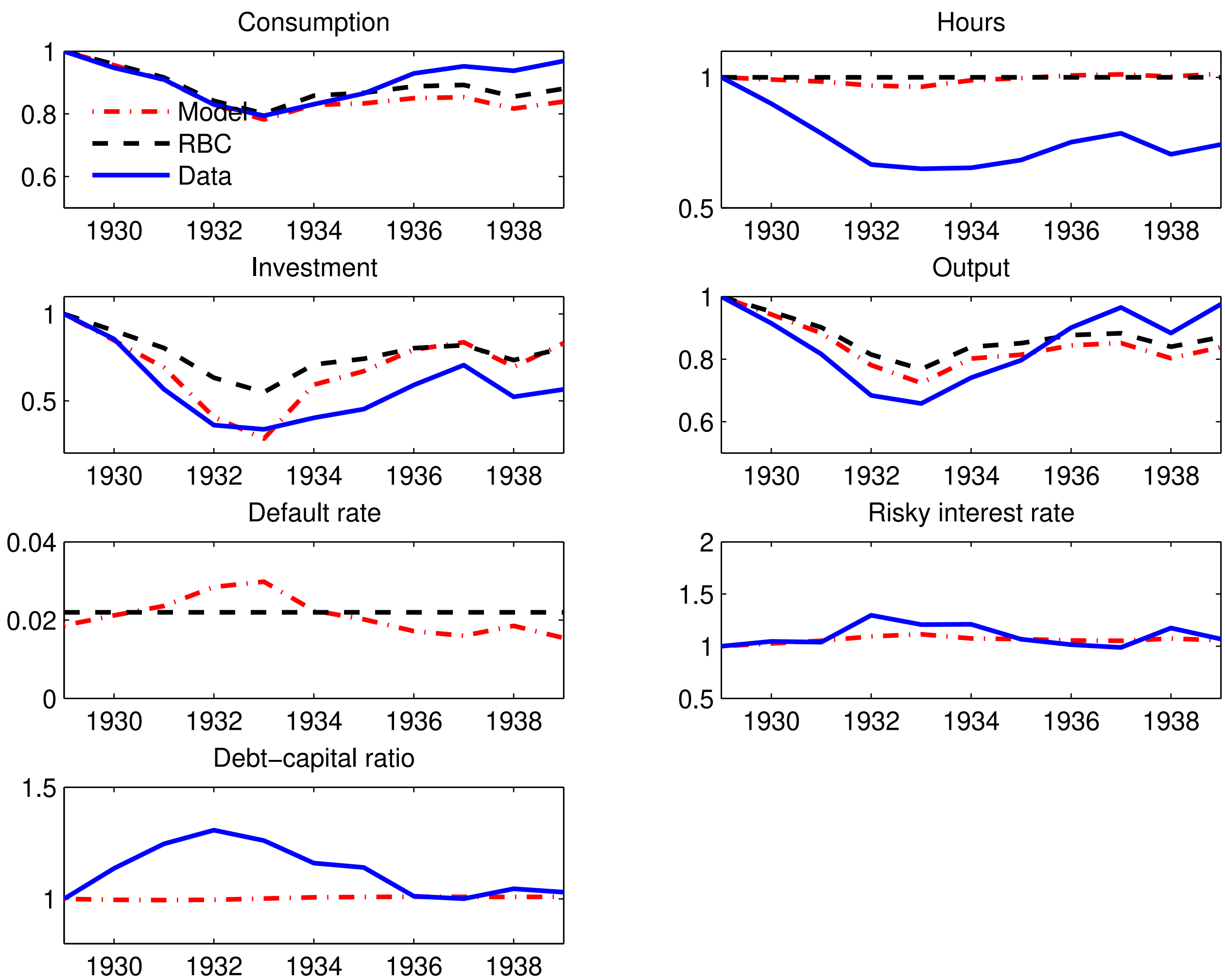

Figure 5: Counterfactual simulation with technology shock only

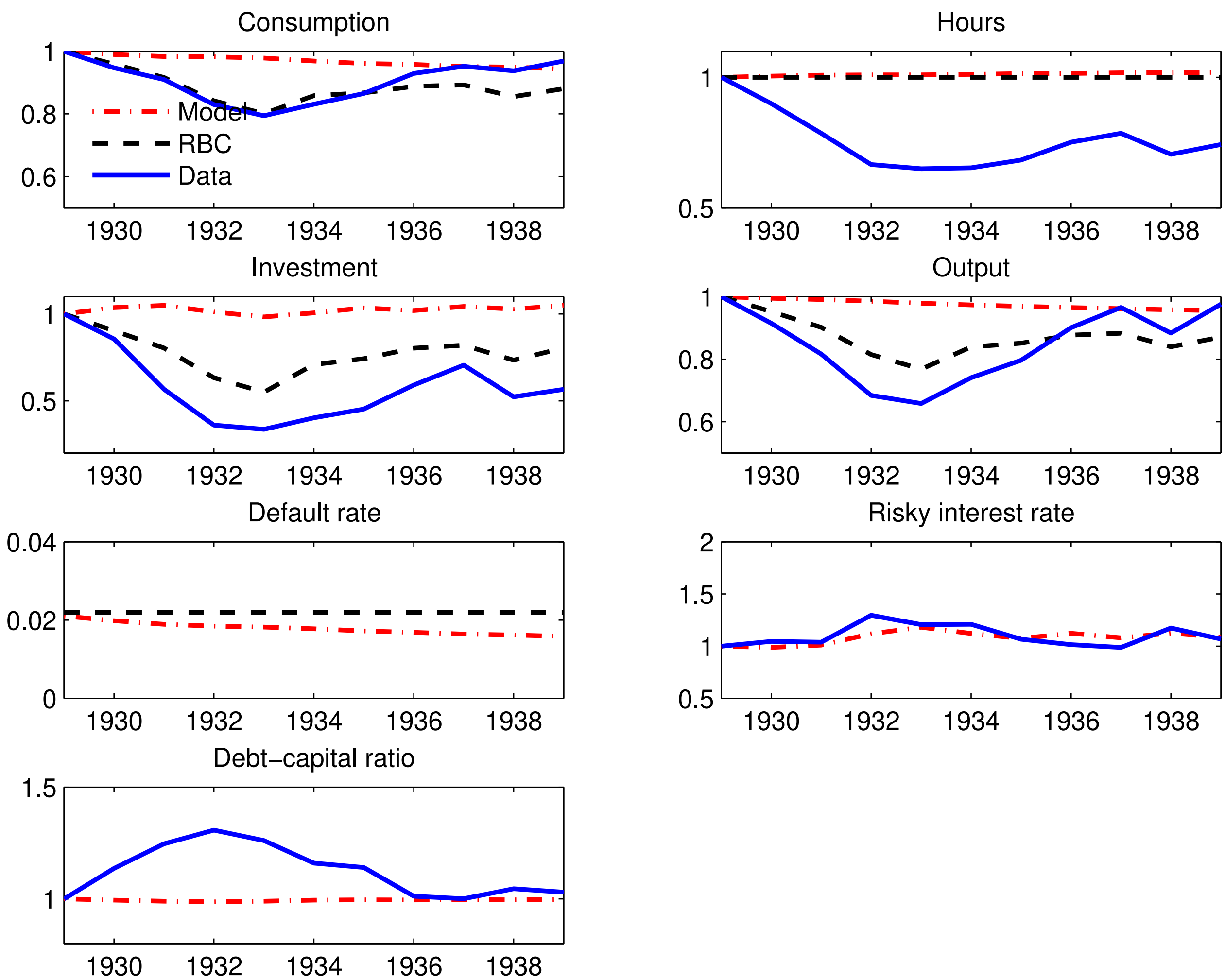

Figure 6: Counterfactual simulation with financial shock only