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REVISED MARCH 2014

Stellenbosch Economic Working Papers: 16/13

KEYWORDS: EQUITY PRICE CHANNEL, ASSET PRICING, FINANCIAL FRICTIONS, BANK CAPITAL, NEW-KEYNESIAN, BAYESIAN
JEL: E32, E43, E44, E51, G12

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A WORKING PAPER OF THE DEPARTMENT OF ECONOMICS AND THE
BUREAU FOR ECONOMIC RESEARCH AT THE UNIVERSITY OF STELLENBOSCH

The equity price channel in a New-Keynesian DSGE model with financial frictions and banking

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July 2013

Abstract

This paper studies the role of the equity price channel in business cycle fluctuations, and highlights the equity price channel as a different aspect to general equilibrium models with financial frictions and, as a result, emphasizes the systemic influence of financial markets on the real economy. We develop a canonical New-Keynesian DSGE model with a tractable role for the equity market in banking, entrepreneur and household economic activities. The model is estimated with Bayesian techniques using U.S. data over the sample period $1982Q01 - 2012Q01$. We show that a New Keynesian DSGE model with an equity price channel well mimics the U.S. business cycle. The model reproduces the strong procyclicality of the equity market. The equity price channel significantly exacerbates business cycle fluctuations through both financial accelerator and bank capital channels. Our results support the increasing emphasis on common equity capital in Basel III regulations. This is beneficial in terms of financial stability, but amplifies and propagates shocks to the real economy.

JEL codes: E32, E43, E44, E51, G12

Keywords: Equity price channel, asset pricing, financial frictions, bank capital, New-Keynesian, Bayesian

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‡The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the NRF. Financial support from Economic Research Southern Africa is also greatly acknowledged.

1 Introduction

This paper studies the role of the equity price channel in business cycle fluctuations, and highlights the equity price channel as a different aspect to general equilibrium models with financial frictions and, as a result, emphasizes the systemic influence of financial markets on the real economy. To do so, we develop a canonical New-Keynesian dynamic stochastic general equilibrium (DSGE) model incorporating the financial accelerator channel (see Bernanke and Gertler, 1989; Bernanke et al., 1999) and the bank capital channel (see, Markovic, 2006; Meh and Moran, 2010). Moreover, we introduce a tractable role for the equity market in banking, entrepreneur and household economic interactions. By synthesizing the roles of the bank's capital structure, the entrepreneur's net worth and the demand side of the equity market, we highlight the systemic influence of the equity price channel on business cycle fluctuations through consumption, production and banking activities.

Asset prices have prevalent consequences for real economic activity.[1] On the one hand, asset price fluctuations affect the real economy through, for example, households' financial wealth and the market value of collateral (e.g., Iacoviello, 2005). On the other hand, asset prices absorb and react to market expectations and macroeconomic conditions which, in turn, reflect information about the expected path of the business cycle (e.g., Castelnuovo and Nisticò, 2010). This ubiquitous interconnection between financial markets and the real economy, however, has received much less attention in general equilibrium models (BCBS, 2011).

There are at least three reasons for including a direct role for equity in consumption, production and banking activities. Firstly, the strong correlation between financial markets and the U.S. business cycle is well established (e.g., Bernanke and Lown, 1992; Brunnermeier, 2009; Adrian and Shin, 2011; Gilchrist and Zakrajšek, 2012; Jermann and Quadrini, 2012). Fig. 1 highlights the common occurrence of equity price collapses and U.S. recessions. Moreover, Christiano et al. (2008) and Farmer (2012) show how self-fulfilling asset price expectations can induce equity market collapses and macroeconomic instability. Secondly, banking sector data supports the inclusion of the equity price channel in models with financial frictions. Fig. 2 illustrates the importance of capturing the market capitalization of bank equity capital.[2] Over the period $1992Q04 - 2003Q04$, the total bank capital structure of all commercial banks in the U.S. consistently comprised, on average, 46.7% equity surplus and 44.6% retained earnings. However, since $2003Q04$ the ratios diverged considerably, with equity surplus peaking at 77.2% and retained earnings declining to 18.8% by the end of 2009. Finally, regulatory authorities are increasingly emphasizing common equity as a safety-net to adverse bank shocks. Fig. 3 shows the minimum capital requirements for banks according to the proposed Basel III regulations (BIS, 2012). By 2015, tier 1 common equity must reach a minimum of 4.5% of risk-weighted assets (RWA). By 2019, two additional common equity requirements must be met: a 2.5% capital conservation buffer and a $0 - 2.5\%$ country-specific discretionary counter-cyclical buffer. This implies a potential $7 - 9.5\%$ common equity requirement out of a possible $10.5 - 13\%$ of RWA minimum bank capital requirement. The requirement for retained earnings falls from 2% to 1.5% of RWA. Both Fig. 2 and Fig. 3 show the significant structural shift towards greater common equity capital leveraging in U.S. commercial

[1] Cochrane (2008) provides an extensive overview of asset prices in financial markets and the real economy.
[2] Data source: Federal Deposit Insurance Corporation (FDIC, 2012).

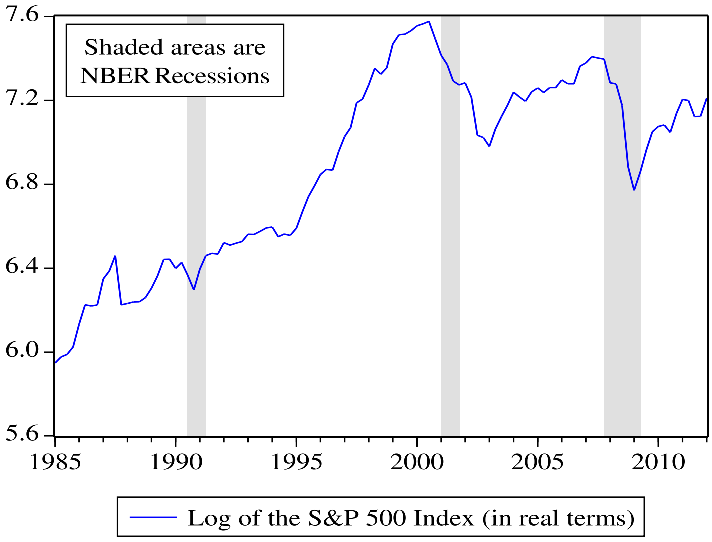

Figure 1: Equity market collapses and U.S. recessions

banks.

This paper is related to the literature on the demand-side interaction between equity prices and the real economy. The interaction between equity prices and the real economy, through the household wealth effect, specifies an active role for the demand-side effect of the equity market in a standard dynamic New-Keynesian business cycle analysis. Wei (2010) argues that the expanding literature on the interaction between equity pricing and the macroeconomy has not been widely studied within the New-Keynesian framework. Moreover, previous studies often fell short of including both an explicit demand-side equity market interaction and a coherent way for allowing equity prices to directly impact consumption, production and financial activities. For instance, Christiano et al. (2010) incorporate both the bank funding channel and equity prices (using the price of capital as a proxy) in their study. Their analysis validates the important contribution of the credit market and the equity market for replicating the U.S. business cycle. However, the ad hoc way of capturing the crucial information from equity prices – without a tractable, micro-founded framework for equity pricing – is a significant shortcoming of the model.[3] Castelnuovo and Nisticò (2010) use the stock market wealth effect on households as the sole propagating channel to study the relationship between equity markets and monetary policy, without considering a wider range of macroeconomic factors such as endogenous physical capital accumulation and asset-price fluctuations on investment.

This paper is also related to the bank capital literature. Markovic (2006) and Meh and Moran (2010) provide evidence on the importance of bank capital for bank lending and funding, and the need to entrench the bank capital channel in the financial frictions paradigm. In addition, Van den Heuvel (2008) finds that bank capital requirements limit the ability of banks to satisfy households' liquidity preferences which, in turn, significantly hinder real economic activity. Indeed, only recently did Markovic (2006), Van den Heuvel (2008), and Christiano et al. (2010) support the idea of including equity in bank capital accumulation.

[3] See Christiano et al. (2010, p.10) for comments on the important counterfactual responses from the model.

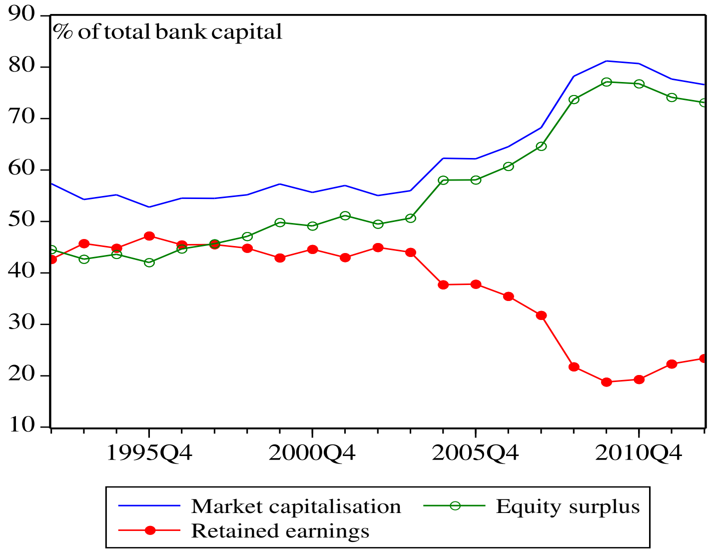

Figure 2: Bank capital structure: all commercial banks (1992Q04 - 2012Q01)

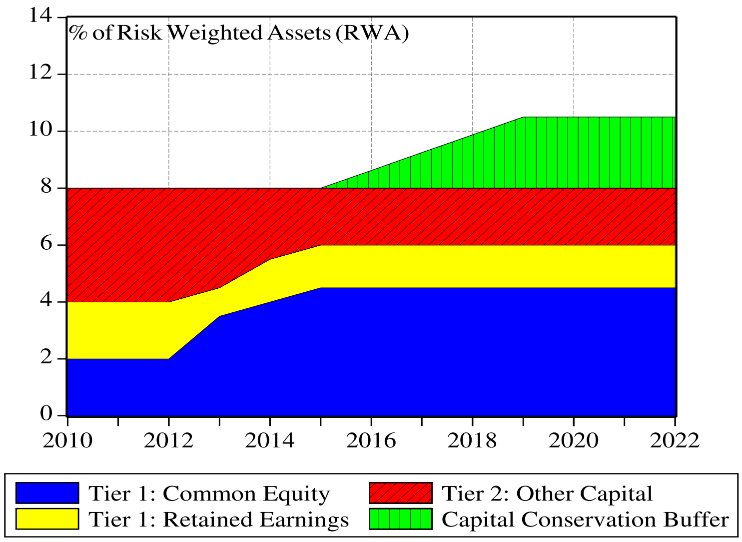

Figure 3: Basel III minimum capital requirements

However, none of these studies consider the demand-side effect of the equity market on banking operations. In our study, we introduce an equity price channel to close these gaps in the interaction between equity prices and the real economy in the literature.

The contribution of our paper is two-fold. Firstly, by addressing the gaps in the literature we highlight the equity price channel as a different aspect to general equilibrium models with financial frictions. This equity price channel links consumption, production and banking activities, whereby equity prices affect both households' and entrepreneurs' financial wealth, and bank assets are partially financed by equity. Secondly, we estimate the model with Bayesian techniques, using U.S. data over the sample period $1982Q01-2012Q01$. We show that a New-Keynesian DSGE model with an equity price channel well mimics the U.S. business cycle over the sample period. The model also does well in terms of reproducing the strong procyclicality of the equity market.

The main findings of this paper are as follows. The equity price channel amplifies and propagates shocks to the real economy through both financial accelerator and bank capital channels. Equity plays a significant role in amplifying the financial accelerator effect for interest and inflation rates, and household loans. Due to the direct wealth effect, a negative equity price shock decreases households' consumption and, hence, output. The equity price channel weakens the counter-cyclicality of capital-asset ratio, which supports the increasing emphasis on common equity capital in Basel III regulations. This is beneficial in terms of financial stability, but amplifies and propagates shocks to the real economy. Finally, sticky interest rates have a negligible pass-through effect on the real economy.

The rest of the paper proceeds as follows. Section 2 defines the equity price channel. Section 3 develops the New-Keynesian DSGE model with financial frictions and the equity price channel. Sections 4 and 5 present the Bayesian estimation results, and discuss the role of the equity price channel in business cycle fluctuations. Section 5.2 performs the robustness analysis, and reports the cyclical properties of the model. Section 6 concludes.

2 The equity price channel in business cycles

The nexus of the equity price channel in the real economy is as follows. Equity prices are endogenously determined by the aggregation of buying and selling shares between market participants. That is, households can adjust their portfolio (bank and entrepreneur) equity investment to either liquidate shares to finance current consumption or increase their equity holdings for future consumption. This is the direct wealth effect on consumption. As a result, the demand-side determination of equity prices will affect financial contracts between creditors and debtors. Specifically, the extension of credit to households is based on their ability to service debt with wage income and their financial wealth (equity investment), whereas entrepreneurs—who manage firm production—obtain loans based on their market capitalization and their redeemable physical capital assets. Hence, the current market value of the entrepreneur initial stock of equity affects their ability to finance production with loans.

Not only does the equity price channel affect real economic activity through the financial accelerator channel, it also influences credit supply through bank capital requirements and bank funding. Firstly, banks finance assets with deposits and bank capital (equity and retained earnings), where bank equity capital functions as a shock-absorber for loan defaults or deficiencies. Secondly, we adopt the quadratic adjustment cost structure from Gerali et al. (2010) as the core framework for credit supply frictions in financial intermediation: a monopolistically competitive banking sector with sticky retail loan rate adjustments and a target capital-asset ratio for the interbank rate.

3 The model economy

The basic framework of the model is a medium-scale New Keynesian DSGE model, in which a monopolistically competitive retail goods sector introduces Calvo-type sticky prices. For simplicity purpose, wages are flexible in the model. We augment the model with a heterogeneous banking sector along the lines of Gerali et al. (2010). The model is closed by assuming that the monetary authority follows a Taylor-type interest rate rule.

We introduce the equity price channel in the model as follows. Both borrower and saver households invest in the equity market, where equity serves as collateral for borrower households. Analogously the market value of the initial stock of entrepreneur equity serves as part of collateral when entrepreneurs borrow bank loans. For banks, bank capital is accumulated by previous bank capital, bank equity and retained earnings.

3.1 Households

There are two types of representative households, namely saver and borrower households. Both types of households, indexed by $\Gamma = b, s$ for borrowers and savers, maximize their expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_{\Gamma}^t \Big[\frac{(\tilde{C}_t^{\Gamma})^{1-\gamma^{\Gamma}}}{1-\gamma^{\Gamma}} - \frac{(H_t^{\Gamma})^{1+\eta}}{1+\eta} + aln(\frac{D_t^{\Gamma}}{P_t}) + \xi_{\psi,t} ln(\frac{Q_t^{\psi}\Psi_t^{\Gamma}}{P_t}) \Big], \tag{1}$$

where the discount factor $\beta_b^t < \beta_s^t$. Consumption ($\tilde{C}_t^{\Gamma} = C_t^{\Gamma} - \phi C_{t-1}^{\Gamma}$) includes habit formation parameterized by ϕ. Households' financial wealth is made up of deposits (D_t^{Γ}) and equity investments (Ψ_t^{Γ}). Q_t^{Ψ} is the equity price in current period t. $\xi_{\psi,t}$ is an exogenous shock to the current market value of equity holdings. H_t^{Γ} is labor, where η measures the Frisch elasticity of labor supply. γ^{Γ} is the coefficient of relative risk aversion for each household type ($\Gamma = b, s$). Parameter a equals 0 for borrowers and 1 for savers. That is, only savers hold deposits.

3.2 Savers

Compared with borrowers, savers have a lower marginal propensity to consume, hold risk-free deposits ($a = 1$), and do not borrow from banks at all. Savers allocate periodic income from wages (W_t), deposits ($I_{t-1}^d D_{t-1}^s$), capital gains/losses ($Q_t^{\psi}\Psi_{t-1}^s$) and dividends ($\Pi_{\psi,t}^s$) to current consumption and new financial wealth holdings. Eq. 2 gives the budget constraint for savers:

$$\tilde{C}_t^s + \frac{D_t^s}{P_t} + \frac{Q_t^\psi}{P_t}\Psi_t^s = \frac{W_t}{P_t}H_t^s + \frac{I_{t-1}^d D_{t-1}^s}{P_t} + \frac{(Q_t^\psi + \Pi_{\psi,t}^s)}{P_t}\Psi_{t-1}^s. \tag{2}$$

The dividend policy is characterized by periodic rebated profits from entrepreneurs and banks to shareholders. For banks, dividend payments are endogenously determined by profits, whereas entrepreneurs follow a dividend policy rule defined as a proportion r^ψ (the steady-state net dividend yield) of each household's equity holdings.

$\Psi_t = \Psi_t^s + \Psi_t^b$ is the total aggregate equity stock. The total aggregate equity stock is equal to the total supply of equity from banks Ψ_t^B and entrepreneurs Ψ_t^e, which is constant (i.e., no new equity shares are issued). Therefore, in equilibrium $\Psi_t^s + \Psi_t^b \equiv \Psi = \Psi^B + \Psi^e$.

The representative saver household's first-order conditions for deposits, labor and equity holdings are the following:

$$\frac{P_t}{D_t^s} = (\tilde{C}_t^s)^{-\gamma^s} - \beta_s E_t\Big[(\tilde{C}_{t+1}^s)^{-\gamma^s}\frac{I_t^d}{P_{t+1}/P_t}\Big], \tag{3}$$

$$\frac{W_t}{P_t} = (\tilde{C}_t^s)^{\gamma^s}(H_t^s)^\eta, \tag{4}$$

$$\xi_{\psi,t}\frac{P_t}{Q_t^\psi \Psi_t^s} = (\tilde{C}_t^s)^{-\gamma^s} - \beta_s E_t\Big[(\tilde{C}_{t+1}^s)^{-\gamma^s}\Big(\frac{Q_{t+1}^\psi + \Pi_{\psi,t+1}^s}{Q_t^\psi}\Big)\frac{P_t}{P_{t+1}}\Big]. \tag{5}$$

Eq. 3 indicates that the demand for deposits depends on households' consumption and the real return on deposits. Eq. 4 gives the standard real wage equation: the real wage equals the marginal rate of substitution of leisure for consumption. Eq. 5 gives the demand for equity investment. Assuming no direct utility from equity holdings, the first order condition for equity holdings collapses to the standard consumption-based asset pricing equation,

$$1 = \beta_s E_t\Big[(\frac{\tilde{C}_t^s}{\tilde{C}_{t+1}^s})^{\gamma^s}\Big(\frac{Q_{t+1}^\psi + \Pi_{\psi,t+1}^s}{Q_t^\psi}\Big)\frac{P_t}{P_{t+1}}\Big]. \tag{6}$$

3.3 Borrowers

Borrowers do not invest in risk-free deposits ($a = 0$) and, instead, borrow bank loans to finance their current consumption and investment in the equity market. Borrowers' budget constraint is given by:

$$\tilde{C}_t^b + \frac{I_{t-1}^h L_{t-1}^h}{P_t} + \frac{Q_t^\psi}{P_t}\Psi_t^b = \frac{W_t}{P_t}H_t^b + \frac{L_t^h}{P_t} + \frac{(Q_t^\psi + \Pi_{\psi,t}^b)}{P_t}\Psi_{t-1}^b. \tag{7}$$

The household allocates periodic income from wages, capital gains/losses, dividends, and new loans (L_t^h) to current consumption, new financial wealth holdings and the repayment of previous loans ($I_{t-1}^h L_{t-1}^h$). In addition to the budget constraint, borrowers also face the following borrowing constraint:

$$I_t^h L_t^h \leq \nu_{h,t}\big[\phi_w W_{t+1}H_t^b + (1-\phi_w)(Q_{t+1}^\psi + \Pi_{\psi,t+1}^b)\Psi_t^b\big]. \tag{8}$$

The representative borrower's wage income together with her investment in the equity market serve as collateral, where $0 \leq \phi_w \leq 1$ is the weight on wage income. $\nu_{h,t}$ is the loan-to-value ratio and, correspondingly, $1-\nu_{h,t}$ can be interpreted as the proportional transaction cost for banks of repossessing collateral assets in cases of borrower defaults. Following the literature (eg. Iacoviello, 2005), we assume the size of shocks is small enough so that the borrowing constraint is always binding.

The representative borrower household's first-order conditions for labor , household loans and equity holdings are the following:

$$\frac{W_t}{P_t} = (\tilde{C}_t^b)^{\gamma^b}(H_t^b)^{\eta} - \lambda_t^h(\tilde{C}_t^b)^{\gamma^b}\nu_{h,t}\phi_w\frac{W_{t+1}}{P_t}, \tag{9}$$

$$1 = \beta_b E_t\left[\frac{(\tilde{C}_t^b)^{\gamma^b}}{(\tilde{C}_{t+1}^b)^{\gamma^b}}\frac{I_t^h}{P_{t+1}/P_t}\right] + \lambda_t^h(\tilde{C}_t^b)^{\gamma^b}I_t^h, \tag{10}$$

$$\begin{aligned}\xi_{\psi,t}(\frac{P_t}{Q_t^{\psi}\Psi_t^b}) &= (\tilde{C}_t^b)^{-\gamma^b} - \beta_b E_t\left[(\tilde{C}_{t+1}^b)^{-\gamma^b}\frac{R_{t+1}^{\psi}}{P_{t+1}/P_t}\right] \\ &\quad - \lambda_t^h\nu_{h,t}(1-\phi_w)\frac{R_{t+1}^{\psi}}{P_{t+1}/P_t},\end{aligned} \tag{11}$$

where $R_{t+1}^{\psi} = (Q_{t+1}^{\psi} + \Pi_{\psi,t+1}^b)/Q_t^{\psi}$ is the gross nominal return to equity, and λ_t^h is the Lagrangian multiplier of the borrowing constraint. Eq. 9 is the first-order condition for borrowers' labor supply. Eq. 9 and Eq. 4 give the aggregate labor supply schedule. Eq. 10 is the borrower household consumption Euler equation. Eq. 11 gives borrowers' demand for equity holdings.

By introducing heterogeneity in households and equity holdings in the households' utility function, we are able to model the demand-side interplay in the equity market. Indeed, given the assumption of a constant total stock of equity, the net effect of the realized demand for equity holdings for different types of households is equivalent, $|\triangle\ \Psi_t^b| = |\triangle\ \Psi_t^s|$.

3.4 Retailers

The retail sector is characterized by monopolistically competitive branders and acts as a modelling device to introduce Calvo-type sticky prices into the model (Bernanke et al., 1999; Iacoviello, 2005). Retailers purchase intermediate goods $Y_{j,t}$ from entrepreneurs at the wholesale price $P_{j,t}^W$ in a competitive market, and differentiate them at no cost into $Y_{k,t}$. Each retailer sells with a markup over $P_{j,t}^W$ at price $P_{k,t}$, taking into account their individual demand curves from consumers. Following Calvo (1983), we assume that the retailer can only adjust the retail price with probability $1-\theta_R$ in each period. Therefore, the decision problem for the retailer is

$$\max_{\{P_{k,t}^*\}} E_t\sum_{z=0}^{\infty}\theta_R^z\Lambda_{t,z}\left[P_{k,t}^*Y_{k,t+z} - P_{j,t+z}^W XY_{k,t+z}\right] \tag{12}$$

subject to the consumer demand schedule for goods

$$Y_{k,t+z} = (\frac{P_{k,t}^*}{P_{t+z}})^{-\varepsilon_t^p}Y_{t+z}, \tag{13}$$

where $\Lambda_{t,z}$ is the consumption-based relevant discount factor and $P_{k,t}^*$ denotes the price set by the retailers, who are able to adjust the price in period t. $X_t \equiv \frac{P_t}{P_t^W}$ is the aggregate markup of the retail price over the wholesale price. In steady state, $X = \frac{\varepsilon^p}{(\varepsilon^p - 1)}$, where ε^p is the steady state price elasticity of demand for intermediate good $Y_{j,t}$.

The aggregate price level is determined by

$$P_t^{1-\varepsilon_t^p} = \theta_R \left((\frac{P_{t-1}}{P_{t-2}})^{\gamma_p} P_{t-1} \right)^{1-\varepsilon_t^p} + (1-\theta_R)(P_t^*)^{1-\varepsilon_t^p}, \tag{14}$$

where γ_p determines the degree of price indexation. Combining and linearizing Eq. 12 and Eq. 14 gives the forward-looking Phillips Curve, where current inflation is positively related to expected inflation and negatively related to the markup.

3.5 Entrepreneurs

Entrepreneurs produce the wholesale good using a standard Cobb-Douglas production function described by

$$Y_{j,t} = \xi_{z,t} K_{j,t-1}^{\alpha} H_{j,t}^{1-\alpha}, \tag{15}$$

where $K_{j,t-1}$ is physical capital, $H_{j,t}$ is labor, and $\xi_{z,t}$ is the technology.

We assume that in each period the representative entrepreneur chooses the desired amount of physical capital, bank loans and labor to maximize

$$E_0 \sum_{t=0}^{\infty} \beta_e^t \; [\; \Omega_{j,t}^e \;] \tag{16}$$

subject to the production technology (Eq. 15) and the flow of funds constraint

$$\Omega_{j,t}^e = \frac{Y_{j,t}}{X_{j,t}} + \frac{L_{j,t}^e}{P_t} - \frac{I_{j,t-1}^e L_{j,t-1}^e}{P_t} - \frac{W_t}{P_t} H_{j,t} - (K_{j,t} - (1-\delta_e) K_{j,t-1}) - Adj_{j,t}^e - \Pi_{\psi,jt}^e. \tag{17}$$

$Adj_{j,t}^e$ captures the adjustment cost of capital installation:

$$Adj_{j,t}^e = \kappa_v (\frac{V_{j,t}}{K_{j,t-1}} - \delta_e)^2 \frac{K_{j,t-1}}{(2\delta_e)}, \tag{18}$$

where $V_{j,t}$ is the investment used to accumulate capital and κ_v is the capital adjustment cost parameter. $\Pi_{\psi,jt}^e = (r^{\psi} Q_{j,t}^{\psi} \Psi_j^e)/P_t$ is the real dividend paid out. We assume entrepreneurs are more impatient than saver households ($\beta_e^t < \beta_s^t$), as in Iacoviello (2005).[4]

In addition to the flow of funds constraint, the representative entrepreneur also faces the following borrowing constraint:

$$I_{j,t}^e L_{j,t}^e \leq \nu_{e,jt} [\phi_k Q_{j,t+1}^k K_{j,t} + (1-\phi_k) Q_{j,t+1}^{\psi} \Psi_j^e], \tag{19}$$

where $Q_{j,t}^k$ is the nominal price of physical capital, $\nu_{e,jt}$ is the exogenous stochastic loan-to-value ratio, and $I_{j,t}^e$ is the gross nominal interest rate on entrepreneur bank loans ($L_{j,t}^e$). The value of physical capital

[4]The usual binding constraint conditions apply (see Iacoviello, 2005, p. 743-4), while $(1/R^e - \beta_e) > 0$ must hold.

$(Q^k_{j,t}K_{j,t})$ and the market value of the initial stock of entrepreneur equity $(Q^{\psi}_{j,t}\Psi^e_j)$ serves as collateral. $\phi_k \in [0,1]$ is the weight on physical capital stock.

The first order conditions for labor, bank loans, and physical capital are the following:

$$\frac{W_t}{P_t} = \frac{(1-\alpha)Y_{j,t}}{H_{j,t}X_{j,t}}, \tag{20}$$

$$\lambda^e_{j,t} = \frac{1}{I^e_{j,t}} - \beta_e E_t\left[\frac{P_t}{P_{t+1}}\right], \tag{21}$$

$$\begin{aligned}\frac{Q^k_{j,t}}{P_t} &= \beta_e E_t\Bigg[\left(\frac{\kappa_v}{\delta_e}\left(\frac{V_{j,t+1}}{K_{j,t}} - \delta_e\right)\frac{V_{j,t+1}}{K_{j,t}} - \frac{\kappa_v}{2\delta_e}\left(\frac{V_{j,t+1}}{K_{j,t}} - \delta_e\right)^2\right) \\ &\quad + \frac{Q^k_{j,t+1}}{P_{t+1}}(1-\delta_e) + \frac{\alpha Y_{j,t+1}}{X_{j,t+1}K_{j,t}} + \lambda^e_{j,t}\nu_{e,jt}\phi_k\frac{Q^k_{j,t+1}}{P_{t+1}}\Bigg],\end{aligned} \tag{22}$$

where $\lambda^e_{j,t}$ is the Lagrangian multiplier of the borrowing constraint. Eq. 20 is the standard labor demand schedule. Eq. 22 is the investment schedule, indicating that the shadow price of capital must equal the expected marginal product of capital plus the discounted expected shadow price and capital adjustment costs.

3.6 Loan and deposit demand

Following Gerali et al. (2010), we adopt a Dixit-Stiglitz framework for the credit market. The retail branch of bank j provides a basket of differentiated deposits $(D_{j,t})$ and loan contracts with households $(L^h_{j,t})$ and entrepreneurs $(L^e_{j,t})$. The deposit and loan demand schedules are

$$D_{j,t} = \left(\frac{i^d_{j,t}}{i^d_t}\right)^{-\varepsilon^d_t} D_t, \tag{23}$$

$$L^h_{j,t} = \left(\frac{i^h_{j,t}}{i^h_t}\right)^{-\varepsilon^h_t} L^h_t, \qquad L^e_{j,t} = \left(\frac{i^e_{j,t}}{i^e_t}\right)^{-\varepsilon^e_t} L^e_t, \tag{24}$$

where $D_t = D^s_t \; \forall\, j \in [0,1]$. ε^d_t, ε^h_t, and ε^e_t are the stochastic elasticities of substitution for deposits, household loans, and entrepreneur loans respectively. The interest rates are set by bank j. When setting interest rates the stochastic elasticities influence the aggregate markups for deposits and loans, which in turn, attenuate or exacerbate the pass-through effect of monetary policy.

3.7 Banking sector

The banking sector setup is along the lines of Gerali et al. (2010), in which there is a continuum of monopolistically competitive commercial banks. Each bank $j \in [0,1]$ consists of a perfectly competitive wholesale branch and two monopolistically competitive retail branches, namely a loan branch and a deposit branch. Banks issue loans to households and entrepreneurs. Assets (both household and entrepreneur loans) are funded by deposits and bank capital. Banks have the market power to set interest rates subject to a quadratic cost.

We introduce the equity price channel into the banking sector in the following way: bank capital is accumulated through previous period bank capital, changes in market capitalization of bank equity and retained earnings (see Eq. 27). The equity price channel therefore plays a key role in determining credit supply through bank capital channel and bank capital requirements. For example, a negative shock to equity price adversely affects the total bank capital, and reduces credit extension through two mechanisms. Firstly, banks raise the cost of credit to bring their capital-asset ratios back to the target capital requirement ratio, resulting in a downward pressure on credit demand. Secondly, the binding bank balance sheet automatically reduces the feasible supply of credit—equivalent to a leftward shift in the credit supply schedule which, in turn, adversely affects household consumption and entrepreneur production. This is, indeed, how variations in the market value of bank equity affect the real economy through the bank capital channel.

It is worth noting that in the model developed here, bank deposits are not only one form of financial wealth for households, but also one form of bank funds on the liability side of banks' balance sheets. Therefore, changes in deposits affect households' utility and banks' ability to extend credit.

Wholesale branch

The mandate of the wholesale branch is to manage the consolidated balance sheet of bank j. The movement of funds between the branches of bank j are as follows. The wholesale branch of bank j accepts deposits from the retail deposit branch at the wholesale deposit rate i_t^D. The retail loan branch receives wholesale loans and remunerates the wholesale branch at i_t^l. The wholesale branch therefore chooses wholesale loans (L_t) and deposits (D_t) to maximize

$$E_0 \sum_{t=0}^{\infty} \beta_B^t \left[i_t^l L_t - i_t^D D_t - \frac{\kappa_k}{2} \left(\frac{K_t^B}{L_t} - \tau \right)^2 K_t^B \right] \tag{25}$$

subject to the binding balance sheet identity

$$L_t = K_t^B + D_t, \tag{26}$$

where K_t^B is the total bank capital. The coefficient κ_k captures the quadratic adjustment cost of the deviation of the current capital-to-asset ratio (K_t^B/L_t) from a target minimum capital requirement ratio (τ), according to the Basel regulations.

The bank capital accumulation equation is as follows:

$$K_t^B = (1-\delta_B)K_{t-1}^B + \phi_B(Q_t^\psi - Q_{t-1}^\psi)\Psi^B + (1-\phi_\psi)\omega_{B,t-1}, \tag{27}$$

where, analogous to entrepreneurs, the initial stock of bank equity (Ψ^B) remains unchanged. What matters here is the market capitalization of bank equity ($Q_t^\psi \Psi^B$). The higher the market capitalization of bank equity is, the more bank capital will be accumulated and, in turn, the more credit banks will be able to supply. ϕ_B measures the pass-through effect of equity price changes on total bank capital. Retained earnings are the consolidated profits ($\omega_{B,t-1}$) of bank j net of dividend payments, where ϕ_ψ captures the share of bank profits paid out as dividends to households. δ_B captures sunk costs for bank capital management.

The first-order conditions for loans and deposits give the spread between the competitive wholesale loan rate and the wholesale deposit rate,

$$i_t^l = i_t^D - \kappa_k \left(\frac{K_t^B}{L_t} - \tau \right) \left(\frac{K_t^B}{L_t} \right)^2. \tag{28}$$

The banking sector is closed by assuming that wholesale banks have access to unlimited funds from the central bank at the policy rate i_t. Arbitrage in the interbank market will then drive the wholesale deposit rate i_t^D towards i_t.

Retail branches

Wholesale loans L_t collected by the retail loan branch of bank j are differentiated at zero cost and resold to households and entrepreneurs at their individual rates. The coefficients κ_h and κ_e capture the quadratic adjustment costs for household and entrepreneur loan rates. The retail loan branch's objective function is

$$\max_{\{i_t^h, i_t^e\}} E_0 \sum_{t=0}^{\infty} \beta_B^t \left[i_t^h L_t^h + i_t^e L_t^e - i_t^l L_t - \frac{\kappa_h}{2} \left(\frac{i_t^h}{i_{t-1}^h} - 1 \right)^2 i_t^h L_t^h - \frac{\kappa_e}{2} \left(\frac{i_t^e}{i_{t-1}^e} - 1 \right)^2 i_t^e L_t^e \right] \tag{29}$$

subject to demand schedules (24), with $L_t^h + L_t^e = L_t$.

In the symmetric equilibrium (for all loan types indexed $z = e, h$ and banks $j \in [0, 1]$), the first-order conditions give the borrower households' and entrepreneurs' bank loan rates. With flexible interest rates, the loan rate is a markup over the marginal cost:

$$i_t^z = \frac{\varepsilon_t^z}{\varepsilon_t^z - 1} i_t^l. \tag{30}$$

The log-linearized equation for the loan rate can be written as

$$\begin{aligned} \hat{i}_t^z &= \frac{\kappa_z}{\varepsilon^z - 1 + (1+\beta_B)\kappa_z} \hat{i}_{t-1}^z + \frac{\beta_B \kappa_z}{\varepsilon^z - 1 + (1+\beta_B)\kappa_z} E_t \hat{i}_{t+1}^z \\ &\quad + \frac{\varepsilon^z - 1}{\varepsilon^z - 1 + (1+\beta_B)\kappa_z} \hat{i}_t^l - \frac{\varepsilon_t^z}{\varepsilon^z - 1 + (1+\beta_B)\kappa_z}. \end{aligned} \tag{31}$$

Eq. 31 shows that the loan rate setting depends on the stochastic markup, the past and expected future loan rates, and the marginal cost of the loan branch (the wholesale loan rate $\hat{i}_t^l$), which depends on the policy rate and the balance sheet position of the bank.

The log-linearized equation for the deposit rate is

$$\hat{i}_t^d = \frac{\kappa_d}{1 - \varepsilon^d + (1+\beta_B)\kappa_d} \hat{i}_{t-1}^d + \frac{\beta_B \kappa_d}{1 - \varepsilon^d + (1+\beta_B)\kappa_d} E_t \hat{i}_{t+1}^d + \frac{1 - \varepsilon^d}{1 - \varepsilon^d + (1+\beta_B)\kappa_d} \hat{i}_t. \tag{32}$$

With flexible interest rates, Eq. 32 implies $\hat{i}_t^d = \hat{i}_t$. Gerali et al. (2010) show that the deposit rate is a markdown of the policy rate. However, based on the inspection of U.S. deposit rate data over the sample period $1982Q01 - 2012Q01$, we find an aggregate steady-state markup of 0.16 percentage points over the federal funds rate. This implies that the retail deposit branch is indeed making a negligible loss based on the model's setup.

3.8 Monetary policy and market clearing conditions

The monetary authority follows a Taylor-type interest rate rule

$$I_t = (I_{t-1})^{\kappa_i} \left(\frac{\Pi_t}{\Pi^{target}} \right)^{\kappa_\pi (1-\kappa_i)} \left(\frac{Y_t}{Y_{t-1}} \right)^{\kappa_y (1-\kappa_i)} \xi_{i,t}, \tag{33}$$

where κ_i is the weight on the lagged policy rate, κ_π is the weight on inflation (Π_t), and κ_y is the weight on output growth. $\xi_{i,t}$ is the monetary policy shock following an AR(1) stochastic process.

The aggregate resource constraint for the economy is

$$Y_t = \tilde{C}_t + V_t + \delta_B \frac{K^B_{t-1}}{\Pi_t}, \tag{34}$$

where $\tilde{C}_t = \tilde{C}^s_t + \tilde{C}^b_t$ is aggregate consumption. In the equity market, as discussed in Section 3.2, $\Psi^s_t + \Psi^b_t \equiv \Psi = \Psi^B + \Psi^e$. The usual market aggregation applies for loans ($L_t = L^h_t + L^e_t$) and labor ($H_t = H^s_t + H^b_t$).

In a symmetric equilibrium, all entrepreneurs and bank retail branches make identical decisions, so that $Y_{j,t} = Y_t$, $K_{j,t} = K_t$, $H_{j,t} = H_t$, $V_{j,t} = V_t$, $P_{j,t} = P_t$, $Q^k_{j,t} = Q^k_t$, $D_{j,t} = D_t$, $L^e_{j,t} = L^e_t$, $L^h_{j,t} = L^h_t$ for j $\in$ [0,1] and $t = 0, 1, 2$ ....

4 Estimation

We estimate the model with Bayesian techniques using U.S. data over the sample period $1982Q01-2012Q01$.[5] Since the model has a total of nine shocks, our data set contains nine observable variables: output, inflation (GDP deflator), equity price, household loans, entrepreneur loans, deposits, the Fed funds rate, the mortgage rate, and the Baa corporate rate. All variables except inflation and interest rates are converted in real terms using the GDP deflator. We take the log-difference of real variables prior to estimation.

4.1 Calibrated parameters

Table 1 lists the parameters that are calibrated prior to estimation. In the first block, the discount factor for saver households (β_s) is the reciprocal of the benchmark steady-state rate ($R = 1.01$). To guarantee that the borrowing constraints are binding, we fix the discount factors for borrower households (β_b) and entrepreneurs (β_e) to 0.96 and 0.95, respectively. As in Gerali et al. (2010), we assume that the bank's discount factor (β_B) and the retailers discount factor (β_R) equal β_s. The inverse of the Frisch elasticity (η) is set to 1. The capital-output share α is set to 0.33, and the physical capital depreciation rate δ_e is set to 0.025. The parameter governing capital installation costs (κ_v) is set to 2 (see, for example, Iacoviello, 2005). A steady-state gross markup of $X = 1.10$ implies a price elasticity of demand for retail goods of $\varepsilon^p = 11$. The steady-state return to equity is calibrated from S&P500 dividend yield data (Shiller, 2005).

The second block reports the relevant conditions of the U.S. banking sector and the steady-state ratios of the main aggregates. The elasticities of substitution for entrepreneur loans (ε^e) and household loans (ε^h) equal 1.352 and 1.436 respectively. The target capital requirement ratio τ equals 11%, reflecting the recent

[5]The model is estimated using Dynare, developed by Michel Juillard and his collaborators at CEPREMAP.

Table 1: Calibrated parameters

Parameter	Description	Value
β_s	Discount factor for saver households	0.99
β_b	Discount factor for borrower households	0.96
β_e	Discount factor for entrepreneurs	0.95
η	Inverse of the Frisch elasticity	1
α	Capital share in the production function	0.33
δ_e	Capital depreciation rate	0.025
κ_v	Capital installation costs	2
ε^p	Price elasticity of demand for goods	11
R^ψ	Steady-state gross dividend yield	1.026
ε^e	Elasticity of substitution for entrepreneur loans	1.352
ε^h	Elasticity of substitution for household loans	1.436
τ	Capital requirement ratio	0.11
δ_B	Sunk costs for bank capital management	0.4
ϕ_ψ	Share of bank profits paid out in dividends	0.68
L^h/L	Households' share of total loans	0.45
L^e/L	Entrepreneurs' share of total loans	0.55
L/Y	Total loans-output ratio	1.5
C/Y	Consumption-output ratio	0.679
$Q^\psi\Psi/Y$	Total equity-output ratio	0.849

Note: Bank and retailer discount factors are equal to the saver household discount factor.

U.S. commercial banks' balance sheet condition. Based on Eq. 27, we equate bank capital management costs (δ_B) with the steady-state ratio of retained earnings to bank capital over the sample period 1982−2012 (FDIC, 2012). From 1982 to 2012, the average dividend to net income ratio for all U.S. commercial banks $\phi_\psi = 0.68$ (FDIC, 2012). Shares of household and entrepreneur loans to total bank loans, the total loans-output ratio, the consumption-output ratio, and the equity-output ratio are calculated using the data means over the sample period. We restrict any other steady-state ratios in the banking sector to be consistent with the balance sheet identity and the capital requirement.

4.2 Prior distributions and posterior estimates

The prior distributions of the structural parameters are reported in columns 3-5 in Tables 2 and 3. We assume that the coefficients of relative risk aversion for savers and borrowers $\{\gamma^s, \gamma^b\}$ follow an inverse-gamma distribution with a mean of 3 and a standard deviation of 0.5. The prior on habit formation parameter ϕ is set at 0.5 with a standard deviation of 0.1. Prior means and standard deviations of the parameters in the Phillips Curve and the monetary policy rule are based on the estimates from Smets and Wouters (2007) and Christiano et al. (2010). The interest rate adjustment cost parameters $\{\kappa_k, \kappa_h, \kappa_e\}$ are assumed to follow a gamma distribution with a mean of 4 and a standard deviation of 2 (see also, Gerali et al., 2010). Based on recent data from the Federal Housing Finance Board, we choose a reasonable value of 0.75 as the prior mean for households' LTV (ν_h) and a more modest prior mean of 0.55 for entrepreneurs' LTV (ν_e) (see also, Gerali et al., 2010; Iacoviello and Neri, 2010). The weight on wages (ϕ_w) in the household borrowing constraint is set to 0.5 with a standard deviation of 0.05. This implies that the amount households can borrow depends

Table 2: Structural parameters

	Parameter	Prior distribution Type	Mean	Std.dev	Posterior distribution Mean	2.5%	Median	97.5%
Preferences								
γ_s	Saver relative risk aversion	Inv.Gamma	3	0.5	4.21	3.08	4.17	5.27
γ_b	Borrower relative risk aversion	Inv.Gamma	3	0.5	2.69	2.06	2.64	3.27
ϕ	Habit formation	Beta	0.5	0.1	0.75	0.70	0.75	0.79
Prices and wages								
θ_R	Price stickiness	Beta	0.7	0.05	0.86	0.84	0.86	0.88
γ_p	Degree of price indexation	Beta	0.5	0.05	0.62	0.54	0.62	0.70
Monetary policy rule								
κ_i	Coefficient on lagged policy rate	Beta	0.5	0.05	0.49	0.42	0.49	0.56
κ_π	Coefficient on inflation	Gamma	2	0.05	2.07	1.99	2.07	2.16
κ_y	Coefficient on output change	Beta	0.25	0.05	0.25	0.18	0.25	0.33
Credit and banking								
κ_h	HH loan rate adjust. cost	Gamma	4	2	3.59	1.58	3.40	5.84
κ_e	Entrep. loan rate adjust. cost	Gamma	4	2	0.87	0.45	0.83	1.23
κ_k	Leverage deviation cost	Gamma	4	2	9.11	6.44	8.93	12.1
ν_h	Households' LTV ratio	Beta	0.75	0.05	0.73	0.64	0.73	0.80
ν_e	Entrepreneurs' LTV ratio	Beta	0.55	0.05	0.51	0.42	0.51	0.60
ϕ_w	Weight on wages in borr. constraint	Beta	0.5	0.05	0.43	0.38	0.43	0.48
ϕ_k	Weight on physical capital in borr. constraint	Beta	0.8	0.05	0.91	0.87	0.91	0.94
ϕ_B	Equity price pass-through	beta	0.35	0.05	0.35	0.28	0.35	0.42

equally on their wage income and on the market value of their equity holdings. A relatively higher weight on physical capital assets ($\phi_k = 0.8$) is imposed in the entrepreneur borrowing constraint. The prior mean of ϕ_B is set to 0.35 with a standard deviation of 0.05. Lastly, the prior distributions for the AR(1) coefficients and the standard deviations of the shocks are reported in columns 3-5 in Table 3.

The estimated posterior means and standard deviations for the structural parameters are reported in columns 6-9 in Tables 2 and 3. The estimated relative risk aversion coefficient for saver households (4.21) is higher than that for borrower households (2.69). This implies that saver households are less sensitive to financial market conditions and have a stronger preference for smoothing their lifetime consumption. The estimated consumption habit formation parameter ($\phi = 0.75$) is consistent with those in the literature (e.g., Uhlig, 2007; Christiano et al., 2010). The estimated parameters for price-setting and the monetary policy rule all conform well to the literature.

The estimated parameter capturing entrepreneur loan rate adjustment cost (0.87) is smaller than that of the household loan rate adjustment cost (3.59), reflecting more frequent adjustments of the Baa corporate rate to the changes in credit market condition, compared to that of the mortgage rate. Interestingly, both estimates in our paper (for the U.S. data) are all lower than those in Gerali et al. (2010) for the Euro area. Yet, as we find in the following section, both our paper and theirs allude to the limited relevance of the sticky interest rate structure in banking. The estimated parameter measuring the cost of deviating from targeted leverage is 9.11. The LTV ratio for entrepreneurs (0.51) is lower than that of households (0.73), which suggests that households can more easily collateralize their loans. In fact, high estimates for ν_h and

Table 3: Exogenous processes

	Parameter	Prior distribution Type	Mean	Std.dev	Posterior distribution Mean	2.5%	Median	97.5%
AR(1) coefficients								
ρ_z	Technology	beta	0.5	0.1	0.975	0.964	0.976	0.985
ρ_i	Monetary policy	beta	0.5	0.1	0.487	0.402	0.489	0.567
ρ_d	Deposit	beta	0.5	0.1	0.977	0.961	0.978	0.991
ρ_e	Entrepreneur loan markup	beta	0.5	0.1	0.672	0.598	0.677	0.746
ρ_h	Household loan markup	beta	0.5	0.1	0.558	0.451	0.555	0.675
ρ_{ν_h}	Households' LTV	beta	0.5	0.1	0.922	0.892	0.922	0.951
ρ_{ν_e}	Entrepreneurs' LTV	beta	0.5	0.1	0.972	0.957	0.973	0.988
ρ_ψ	Equity	beta	0.5	0.1	0.938	0.921	0.938	0.953
ρ_p	Price markup	beta	0.5	0.1	0.584	0.495	0.589	0.666
Standard deviations								
ϵ_z	Technology	Inv.Gamma	0.01	inf	0.024	0.019	0.023	0.028
ϵ_i	Monetary policy	Inv.Gamma	0.01	inf	0.009	0.008	0.009	0.011
ϵ_d	Deposit	Inv.Gamma	0.01	inf	0.007	0.007	0.007	0.008
ϵ_e	Entrepreneur loan markup	Inv.Gamma	0.01	inf	0.006	0.004	0.005	0.007
ϵ_h	Household loan markup	Inv.Gamma	0.01	inf	0.014	0.007	0.014	0.021
ϵ_{ν_h}	Households' LTV	Inv.Gamma	0.01	inf	0.012	0.010	0.012	0.013
ϵ_{ν_e}	Entrepreneurs' LTV	Inv.Gamma	0.01	inf	0.013	0.011	0.013	0.015
ϵ_ψ	Equity	Inv.Gamma	0.01	inf	0.003	0.002	0.003	0.004
ϵ_p	Price markup	Inv.Gamma	0.01	inf	0.001	0.001	0.001	0.001

ν_e means that changes to household creditworthiness and entrepreneur net worth have strong effects on aggregate demand and output. With respect to the pass-through of equity price changes on bank capital accumulation, an estimate of 0.35 for ϕ_B implies that, *ceteris paribus*, a 1% decrease in the equity price causes a 0.35% decline in bank equity capital.

5 Results

In this section, we first assess the baseline New-Keynesian DSGE model with the equity price channel (BEP hereafter) by examining the dynamics of the model in response to a technology shock, a monetary policy shock, an equity price shock and a price markup shock. In order to draw more valuable insights from the model, we compare the BEP model with two alternative versions of the model: the model without the equity price channel (NEP hereafter) and the flexible interest rate model (FI hereafter). For the NEP model, the equity market is taken out of the model completely. That is, equity assets are no longer part of households' financial wealth and the redeemable collateral for borrower households and entrepreneurs, whereas bank equity is not being used to accumulate bank capital. For the FI model, there are no quadratic interest rate adjustment costs, i.e. $\kappa_h = \kappa_e = 0$. The main focus here is on how the equity price channel affects the business cycle through the direct wealth effect on consumption, the financial accelerator channel and the bank capital channel. We then study the role of equity in borrower creditworthiness and bank capital accumulation. Finally, in order to complement our quantitative analysis, we perform the robustness analysis for the model, and report the cyclical properties of the equity price.

5.1 The equity price channel

As shown in Figs. 4 and Fig. 5, it is clear that the equity price channel amplifies and propagates shocks to the real economy through both financial accelerator and bank capital channels.[6] In response to a positive technology shock, equity price arises. On the one hand, a bullish equity market raises the creditworthiness of borrower households and entrepreneurs and, in turn, raises credit demand (the financial accelerator channel). On the other hand, banks are able to meet the increase in credit demand because the bullish equity market raises bank capital and, hence, the feasible quantity of credit supply (the bank capital channel). The upward shift of the credit demand and supply schedules increases total loans, which stimulates entrepreneurs' investment in production activities and allows households to increase their current consumption.

The equity price channel weakens the counter-cyclicality of capital-asset ratio. The technology shock produces a counter-cyclical capital-asset ratio for the U.S. economy (see also, Meh and Moran, 2010). As the capital-asset ratio falls below the capital requirement over-leveraged banks put upward pressure on retail loan rates, which raises the cost of credit and, at the same time, increases the profitability of the marginal loan (that is, a widening of credit spreads). Banks therefore adjust their capital-asset ratios back to the regulatory requirement, dampening the credit expansion. Including common equity in bank capital accumulation weakens the counter-cyclicality of capital-asset ratio (BEP versus NEP, first row in Fig. 5). Equity serves as a shock absorber for capital deficiencies, which supports the increasing emphasis on common equity capital in Basel III regulations. This is beneficial in terms of financial stability, but amplifies and propagates shocks to the real economy.

For a positive monetary policy shock and price markup shock, we observe similar dynamics for the real economy: a decline in output. Moreover, the decline in output is greater with the BEP model than that with the NEP model. For the credit market, on the demand side, the equity price channel significantly influences the creditworthiness of borrowers. On the supply side, equity price movements have a strong influence on bank funding through bank equity capital. As a result, the equity price channel amplifies and propagates shocks to bank loans: the decrease in entrepreneur loans is more severe with the BEP mode than that with the NEP model.

The dynamics of the model in response to a negative equity price shock mimics that of a negative technology shock (see also, Castelnuovo and Nisticò, 2010). Due to the direct wealth effect, a negative equity price shock decreases households' consumption and, hence, output. Finally, flexible retail loan rate adjustment (the FI model) has a minimal effect on the business cycle, indicating that sticky interest rates have a negligible pass-through effect on the real economy (see also, Gerali et al., 2010).

[6]Fig. 4 reports the impulse responses of output, policy rate, equity price and inflation to each shock listed from column one to four, whereas Fig. 5 reports the impulse responses of the banking sector variables. As the impulse responses of household loans are qualitatively similar to entrepreneur loans, we report the results for entrepreneur loans only.

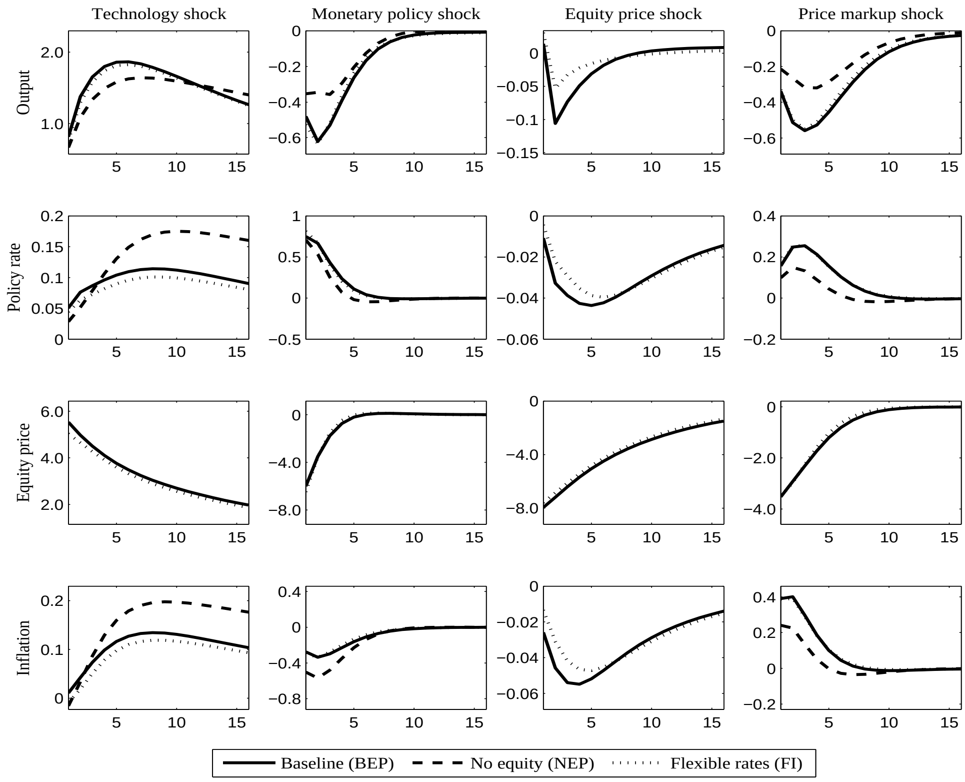

Figure 4: IRFs for main macroeconomic aggregates

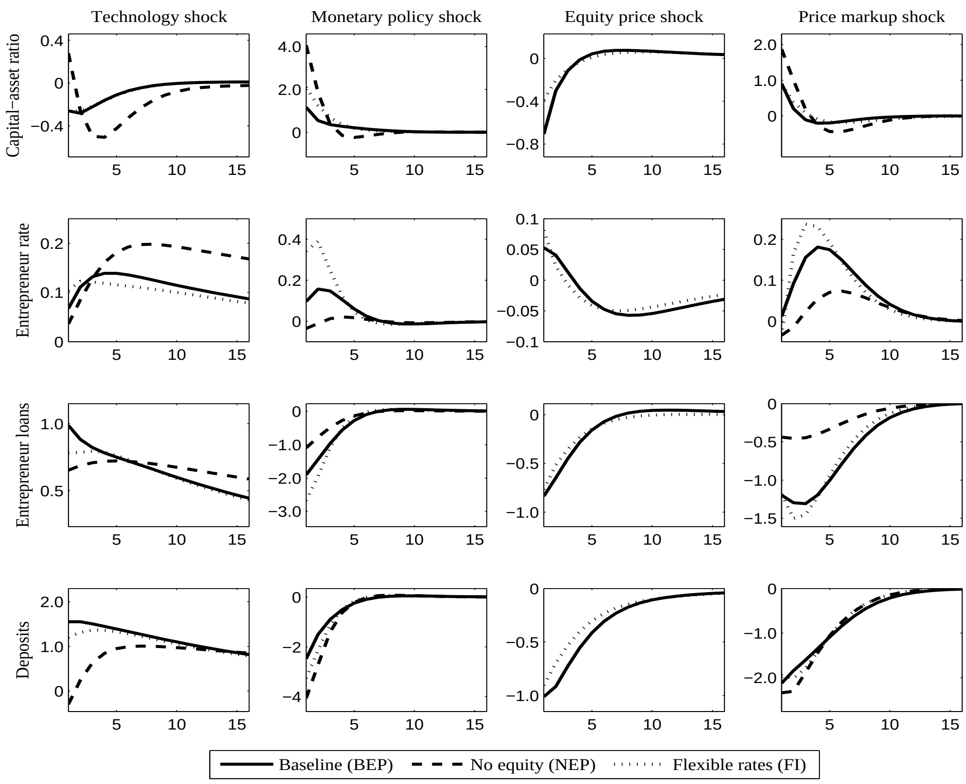

Figure 5: IRFs for the banking sector variables

5.2 The role of equity in borrower creditworthiness and bank capital accumulation

In this section we do a further investigation on the role of equity in borrower creditworthiness and bank capital accumulation. To do so, we estimate and compare two alternative models to our baseline BEP model. In the first alternative model (ALT1 hereafter) we take equity out of the household's and entrepreneur's borrowing constraints (i.e., $\phi_k = \phi_w = 1$). In the second alternative model (ALT2 hereafter) there is no equity in bank capital accumulation (i.e., $\phi_B = 0$). Fig. 6 displays the estimated impulse responses to a negative equity price shock for ALT1, ALT2 and BEP models.

Based on the results, we conclude that the equity price channel amplifies and propagates the shock to the real economy mainly through the bank capital channel: the impulse responses of output are the same with ALT1 and BEP models, and are stronger than that with the ALT2 model, in which equity plays no role in bank capital accumulation. This conclusion is supported by the results for both entrepreneur and household loans: the decline in both loans in response to the shock with the BEP model is larger than that with the ALT2 model. Without equity in bank capital accumulation (in ALT2), the response of loan rates is much stronger than that with the BEP model and, in return, resulting in a less severe decline in bank loans. This finding supports the emphasis of the Basel III regulations for more common equity in bank leverage, as well as the recent structural change in banks' balance sheet.

The opposite response to the shock in the capital-asset ratio with ALT2 and BEP models also supports higher requirement for common equity in Basel III regulations. Without equity in bank capital accumulation (in ALT2), the capital-asset ratio increases in response to a negative equity price shock, as opposed to a decline with the BEP model. Without the equity cushion, the net effect of a negative equity price shock results in an increase in the capital-asset ratio. This forces banks to adjust loan rates more heavily than otherwise (ALT2 verse BEP). The same applies to the monetary authority in adjusting the policy rate. Compared to the ALT2 model, the opposite response of the policy and loan rates with the ALT1 model is due to the decline in the capital-asset ratio, which is explained in Section 5.1.

Equity plays a significant role in borrower creditworthiness in affecting interest and inflation rates. In other words, the equity price channel amplifies and propagates the shock to the policy rate, both loan rates and the inflation rate mainly through the financial accelerator channel. It is worth noting that, compared to entrepreneur loans, equity plays a more significant role in amplifying the financial accelerator effect for household loans. This is due the estimated weight on equity assets in the household's borrowing constraint is much higher than that in the entrepreneur's borrowing constraint.[7]

To provide an additional frame of reference, we estimate a vector autoregression (VAR) with the same data set and sample period used in the DSGE model estimation.[8] Fig. 7 displays the VAR impulse responses to a negative equity price shock. The responses of output, interest rates from the estimated BEP are all quantitatively and qualitatively similar to those from the estimated VAR. A few points are worth noting here. Firstly, in response to a negative equity price shock, the contraction of loans to households and entrepreneurs

[7]See table 2.
[8]The VAR contains two lags of each variable.

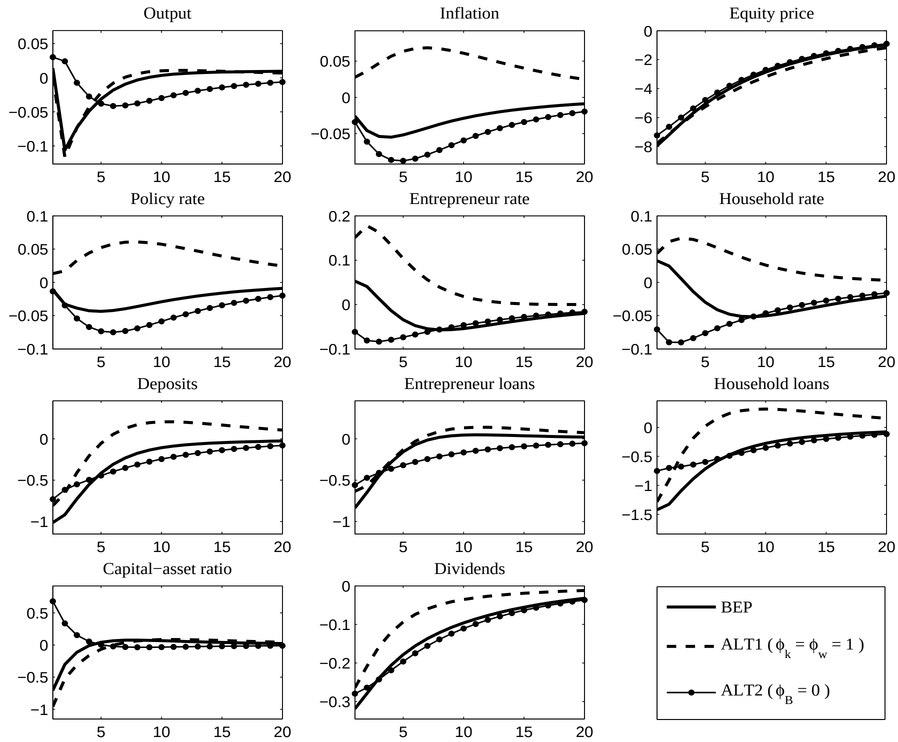

Figure 6: IRFs to a negative equity price shock

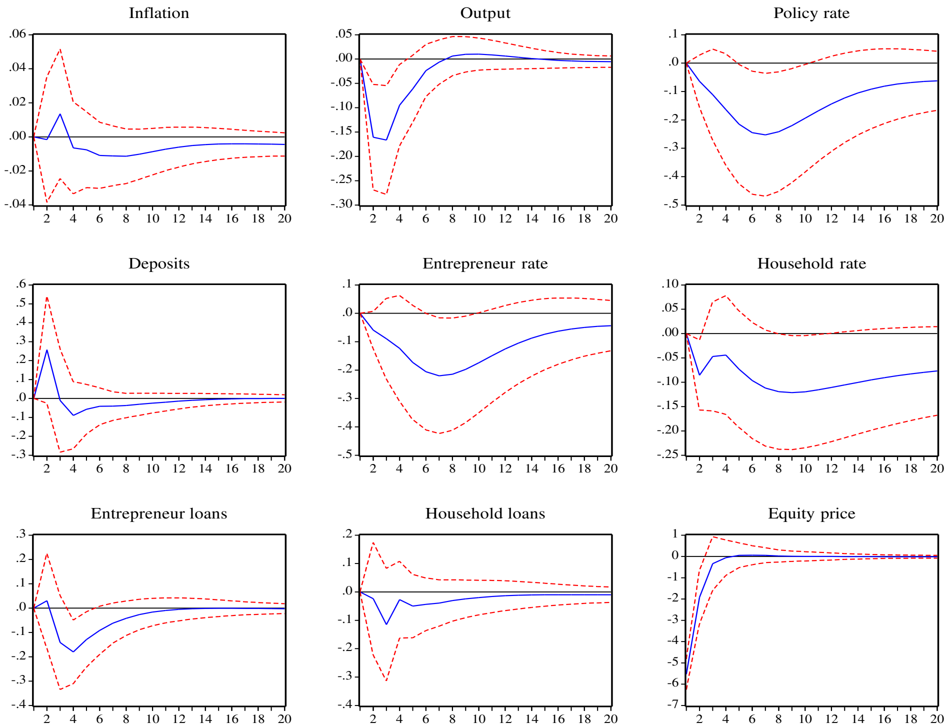

Figure 7: VAR IRFs to a negative equity price shock

reflects the important role of equity in borrower creditworthiness. Secondly, the strong positive correlation between output and equity prices highlights the direct financial wealth effect on consumption and, hence, output. Thirdly, the impulse responses of deposits from the estimated DSGE models are inconsistent with that from the estimated VAR. Neither the BEP model nor the two alternative models capture the initial substitution effect between deposits and equity.[9] This is because, in the DSGE model setup, the binding bank balance sheet identity constrains the substitutability of equity assets with deposit holdings.

5.3 Robustness analysis

To perform the robustness analysis, we compare the posterior estimates of the parameters of each alternative model. Overall, as reported in Table 4, most of the parameter estimates are consistent across models. Some interesting points are worth noting here. The estimated relative risk aversion coefficients for both borrowers and savers for the BEP model are greater than those for the NEP model. This reflects the fact that households are more risk averse if they invest in the equity market. As argued by Cochrane (2008), a high degree of risk aversion is needed to explain the high risk premium. The estimated κ_k for the NEP model is 5.27, whereas the estimate is 9.11 for the BEP model. This decline in the capital adjustment cost parameter in the NEP model reflects the significance of the equity price channel on bank capital. The same is observed in the FI model. The estimated LTV ratios for entrepreneurs (ν_e) and households (ν_h) are consist with the findings in the literature, and vary slightly across the models.

[9]That is, in response to a collapse in equity prices, households initially shift from equity assets to risk-free deposit holdings.

Table 4: Alternative model estimated parameter comparisons

	Posterior distribution means				Posterior distribution means		
	Benchmark BEP	No equity NEP	Flexible rates FI		Benchmark BEP	No equity NEP	Flexible rates FI
Parameters				AR(1) processes			
γ_s	4.215	3.881	3.349	ρ_z	0.975	0.976	0.952
γ_b	2.691	2.000	2.458	ρ_i	0.487	0.463	0.464
ϕ	0.746	0.707	0.693	ρ_d	0.977	0.935	0.946
θ_R	0.861	0.819	0.867	ρ_e	0.672	0.451	0.724
γ_p	0.623	0.691	0.644	ρ_h	0.558	0.533	0.747
κ_i	0.493	0.496	0.446	ρ_{ν_h}	0.922	0.928	0.905
κ_π	2.071	2.088	2.082	ρ_{ν_e}	0.972	0.935	0.936
κ_y	0.253	0.247	0.260	ρ_ψ	0.938	-	0.899
κ_h	3.592	3.617	-	ρ_p	0.584	0.545	0.533
κ_e	0.869	2.939	-	ϵ_z	0.024	0.016	0.019
κ_k	9.111	5.274	4.095	ϵ_i	0.009	0.010	0.010
ν_h	0.728	0.739	0.781	ϵ_d	0.007	0.008	0.008
ν_e	0.508	0.295	0.526	ϵ_e	0.006	0.013	0.003
ϕ_w	0.428	-	0.430	ϵ_h	0.014	0.014	0.003
ϕ_k	0.907	-	0.897	ϵ_{ν_h}	0.012	0.022	0.010
ϕ_B	0.352	-	0.228	ϵ_{ν_e}	0.013	0.008	0.012
				ϵ_ψ	0.003	-	0.004
				ϵ_p	0.001	0.001	0.001

Note: We exclude parameter descriptions, prior means and standard deviations (see Tables 2 and 3), and statistical confidence intervals in the table, due to the limited space.

The dynamics of the model reported in Section 5.1 also shows that the model developed in this study (BEP) is robust. Overall, the BEP model with the equity price channel performs well. The responses of the main macroeconomic variables to each of the shocks are intuitive, and conform to the findings in the literature (eg. Castelnuovo and Nisticò, 2010).

5.4 Cyclical properties of the equity price

In this section, we study the cyclical properties of the equity price. We first compare the second moment of a variable, $\sigma(X)$, relative to that of output from the data and those from the model. We then compare correlations of equity price with interested variables from the data and those from the model.

Panel A in Table 5 reports the results for the U.S. data. Over the sample period $1982Q01 - 2012Q01$, equity prices are nine times as volatile as output, while investment and bank capital are 4 and 2 times as volatile. The relative variation of consumption to output is slightly less than one. Equity prices are persistent at one-step and two-step autocorrelations, and are positively correlated with all the variables. In addition, equity prices tend to be a leading indicator of the other variables.

Panel B reports the results from the model. Firstly, the generated volatilities of the variables are consistent with those from the data. Secondly, for all the variables we find that the model replicates the strong positive correlation with equity price observed from the U.S. data.

Overall, the model does well in terms of reproducing the strong procyclicality of the equity market. Furthermore, for both the data and the model equity price is shown to be a leading indicator of the other variables. These results reaffirm the relevance of equity price channel in general equilibrium model.

Table 5: Cyclical properties of equity price

Variable	$\frac{\sigma(X)}{\sigma(Y)}$	*Correlation of equity price with*				
		X_{t-2}	X_{t-1}	X_t	X_{t+1}	X_{t+2}
Panel A: U.S. data						
Equity price	9.29	0.59	0.83	1	0.83	0.59
Consumption	0.79	0.28	0.42	0.57	0.60	0.56
Investment	4.04	0.21	0.33	0.47	0.57	0.61
Bank Capital	2.01	0.23	0.15	0.31	0.37	0.38
GDP	1	0.27	0.41	0.55	0.61	0.56
Panel B: Model economy						
Equity price (Q_t^{ψ})	6.87	0.87	0.94	1	0.94	0.87
Consumption (C_t)	1.14	0.68	0.75	0.82	0.80	0.77
Investment (V_t)	2.64	0.42	0.45	0.48	0.48	0.49
Bank Capital (K_t^B)	1.43	0.46	0.56	0.66	0.61	0.58
Output (Y_t)	1	0.68	0.76	0.83	0.82	0.79

Notes: For the U.S. data, all series are detrended using the HP filter. For the model, we use the smoothed variables predicted from the posterior estimates. Equity price and output are observable variables in estimation though.

6 Concluding remarks

This paper highlights the equity price channel as a different aspect to general equilibrium models with financial frictions. We acknowledge that the model developed here, as with other general equilibrium models in the literature, lacks a comprehensive description of complex stock price dynamics. Our focus here is on the implication of introducing the equity price channel into a general equilibrium model: how the equity price channel affects consumption, production and banking activities. We show that a New-Keynesian DSGE model with an equity price channel reproduces the U.S. business cycle well. The model also does well in terms of reproducing the strong procyclicality of the equity market.

The equity price channel amplifies and propagates shocks to the real economy through both financial accelerator and bank capital channels. Equity plays a significant role in amplifying the financial accelerator effect for interest and inflation rates, and household loans. Due to the direct wealth effect, a negative equity price shock decreases households' consumption and, hence, output. The equity price channel weakens the counter-cyclicality of capital-asset ratio. Equity serves as a shock absorber for capital deficiencies, which supports the increasing emphasis on common equity capital in Basel III regulations. This is beneficial in terms of financial stability, but amplifies and propagates shocks to the real economy. Finally, sticky interest rates have a negligible pass-through effect on the real economy.

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7 Appendix: Data and sources

Data source from the St. Louis Federal Reserve Economic Data (FRED).

1. RGDP: Real Gross Domestic Product, 1 Decimal (GDPC1), Billions of Chained 2005 Dollars, Quarterly, Seasonally Adjusted Annual Rate.

2. Inflation: Gross Domestic Product: Implicit Price Deflator (GDPDEF), Index 2005=100, Quarterly, Seasonally Adjusted.

3. Nominal interest rate: Effective Federal Funds Rate (FEDFUNDS), Percent, Quarterly, Not Seasonally Adjusted.

4. Deposit rate: US CD secondary market − 1-month, 3-month, 6-month middle rate, arithmetic average of DCD1M, CD3M and CD6M respectively (see also, Pesaran and Xu, 2011, p.46).

5. Loan rate to entrepreneurs: Moody's seasoned Baa corporate bond yield (BAA), Percent, Quarterly, Not Seasonally Adjusted.

6. Loan rate to households: 30-Year Conventional Mortgage Rate (MORTG), Percent, Quarterly, Not Seasonally Adjusted.

7. Loans to households: Total Liabilities − Balance Sheet of Households and Nonprofit Organizations (TLBSHNO), Billions of Dollars, Quarterly, Not Seasonally Adjusted - includes mortgage sector and consumer credit sector (equivalent to CMDEBT).

8. Loans to entrepreneurs: Total Liabilities − Balance Sheet of Non-farm Nonfinancial Corporate Business (TLBSNNCB), Billions of Dollars, Quarterly, Not Seasonally Adjusted.

9. Deposits: Deposits − Assets − Balance Sheet of Households and Nonprofit Organizations (DABSHNO), Billions of Dollars, Quarterly, Not Seasonally Adjusted (closely related to M2SL).

10. Equity: Standard and Poor 500 Index (SP500), Index, Quarterly, Not Seasonally Adjusted.

11. US population: Civilian Noninstitutional Population (CNP16OV), Thousands of Persons, Quarterly, Not Seasonally Adjusted.