Financial Frictions and Monetary Policy Tradeoffs

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Abstract

In the wake of recent global financial crisis, financial frictions appear to be a significant source of inefficiency in the economy. This paper builds on the recent generation of estimated New Keynesian models that include financial frictions. We investigate monetary policy stabilization in an environment where financial frictions are a relevant source of macroeconomic fluctuation. We make two contributions to the literature. First, we derive a measure of output gap that accounts for financial frictions in the data. Second, we compute the trade-offs between nominal and real stabilization that

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arise when the monetary policy authority behaves optimally. The presence of financial frictions implies that the central bank faces an additional source of inefficiency, besides the presence of monopolistic competition and nominal rigidities in the goods and labor markets. We find that policy trade-offs are substantial; price and wage inflation are significantly less volatile under the optimal policy, but stabilization policy fails to counteract the fluctuation in output gap.

**Keywords:** Financial Frictions, Optimal Monetary Policy, Output Gap.

**JEL codes:** C51, E12, E24, E31, E32, E44, E52

1 Introduction

Potential output and output gap are not observable economic variables. Yet they are crucial variables for policy makers in helping them to gauge the stance of policy, be it in setting interest rates or the size of fiscal balance. Yet, the recent financial crisis has been a sobering experience for economic analysts and policy makers as it has put in serious doubt previous estimates of potential output and output gap. Crucially, most estimates of potential output simply focus on the role of labour, capital, technology and sometimes trade variables, and ignore the role of financial variables. A key motivation behind this study is to introduce the missing link of financial variables to models used to analyze the implications for optimal policy making.

In the Federal Reserve Act the statutory objectives for monetary policy are: maximum employment, stable prices, and moderate long-term interest rates. Central bank achieves this by setting the interest rate to counteract deviation of inflation from its desired outcome and minimize fluctuations in output gap. Within this framework, sustainability is a defining feature of economy’s efficient frontier. However, considering potential output as a non-inflationary component of output is too simplistic; the recent financial crisis illustrates that financial imbalances can build up in a relatively stable inflation environment and ultimately lead to a disruptions in the real economy. What are the sources of inefficiencies in the economy? How do financial frictions affect stabilization policies? These are the questions that we try to answer here.

In this paper we build on the recent generation of estimated models with financial frictions and financial shocks. We make two contributions to the literature. First, we derive a measure of output gap that accounts for financial frictions in the data. We further quantify the degree of inefficiency in an economy that is
perturbed by inefficient financial shocks in addition to the standard inefficient shocks to price and wage mark-ups that have been so far considered in the New Keynesian literature (see, Rotemberg and Woodford (1995), and Gali, Gertler and López-Salido (2007)). Second, we compute the trade-offs between nominal and real stabilization that emerge when the monetary policy authority behaves optimally. The presence of financial frictions implies that the central bank faces an additional source of inefficiency, besides the presence of monopolistic competition and nominal rigidities in goods and labor markets as in the standard New Keynesian model.

We conduct our analysis in the context of an estimated New Keynesian model that is extended to include a financial accelerator mechanism along the lines of Bernanke, Gertler and Gilchrist (1999). The New Keynesian core of the model is taken from Justiniano, Primiceri and Tambalotti (JPT, henceforth) (2012) that constitutes the state of the art reference on monetary policy trade-offs in New Keynesian models without financial frictions. As in Christiano, Motto and Rostagno (2013) financial frictions modify the propagation of standard disturbances by amplifying demand shocks and attenuating supply shocks. Moreover, financial frictions are also a source of shocks. We include two inefficient financial shocks as in Gilchrist, Yankov and Zakrasjek (2009): a shock to the net worth of firms, that directly affects the availability of credit for the production sector, and a shock to the external finance premium that reflects possible tensions in the financial markets.

We define the output gap as the difference between actual output and potential output. Potential output in our economy is unobserved and it is the counterfactual level of output that emerges if prices and wages have been flexible and there are no financial shocks, but firms maintain constant monopoly power in the goods and labor markets. Therefore, the markups are constant at their steady state level. Moreover, the financial wedge is in place and absent financial shocks, it depends on the leverage ratio in equilibrium. In our economy inefficiencies stem from several sources, namely price and wage rigidities, habit persistence, capital accumulation, financial frictions and cost push shocks. Financial frictions act through two channels in affecting output: the accelerator and financial shocks. Financial shocks are inefficient shocks and explain 21.56% of the volatilities in output in our model. The presence of the accelerator implies a wedge between the expected return on capital and the risk-free rate distorting households’ intertemporal decision-making. The financial wedge depends on the aggregate financial conditions in the economy.

The evidence presented in this paper underlines the role of financial frictions as the fundamental in the models used for monetary policy formulation; the presence
of financial frictions enrich the plausibility of implied potential output and output gap. Using our estimated model, we find that output gap has been positive during the great moderation, up to the onset of the financial crisis. This indicates that policy was loose during this time. We also construct a time varying measure of financial frictions and further show that this measure is countercyclical and highly correlated with the default risk spread and proxies of financial condition. The monetary policy authority, who wish to stabilize all its intermediate targets at the same time, faces a substantial trade-offs due to financial frictions together with nominal and real rigidities. We find that under optimal monetary policy the central bank can considerably stabilize price inflation and (especially) wage inflation at the cost, however, of non-negligible fluctuations in the output gap. Putting it differently, the optimal policy prioritizes nominal objectives (price and wage inflation), even if it involves undermining output gap stabilization. Finally turning to the financial stabilization, we show that the paths of financial variables under the optimal and historical rule somewhat track each other. However, spread and asset price inflation have been slightly more stationary under the historical interest rate rule.

We contribute to two strands of the literature. The first relates to the behavior of the output gap in DSGE models. Earlier contributions include Levin, Onatski, Williams and Williams (2005), Andrés, López-Salido and Nelson (2005) and Edge, Kiley and Laforte (2008). Sala, Söderström and Trigari (2008) were the first to obtain a cyclical output gap in an estimated DSGE model with unemployment; their model based output gap exhibits cyclical properties that resembles to measures of the output gap obtained using statistical methods. JPT (2012) and Gali, Smets and Wouters (2011) relate the model implied output gap to the stochastic processes driving labor supply shocks and wage mark-up shocks. To the best of our knowledge, our paper is the first that derives the output gap from a model with financial frictions. A relevant empirical work is Borio, Disyatat and Juselius (2012), which emphasize on the relevance of financial factors for output gap dynamics. They use a statistical estimation approach to draw attention on effects of financial cycle on potential output and hence the output gap.

This work also belongs to the strand of literature investigating monetary policy tradeoffs using structural models. Most central banks perceive a trade-off between stabilizing inflation and stabilizing the gap between output and potential. However, Blanchard and Gali (2007) show that within small size NK models, there is no trade-off between output gap stabilization and inflation stabilization. This is called "Divine Coincidence". In this world only cost-push shocks in New Keynesian Phillips curve, price and wage-markup shocks, can generate trade-offs.
As discussed in Gali, Gertler and Lopez-Salido (2009) and Blanchard and Gali (2007), however, the divine coincidence holds only under strong assumptions: no capital accumulation and no real rigidities in the form of habit persistence or real wage rigidities. Therefore, in medium-scale DSGE models, like Smets and Wouters (2007) where real rigidities and capital accumulation play an important role, the divine coincidence does not hold anymore and all shocks have cost-push effects and generate trade-offs. JPT (2012) provide a quantitative setup to estimate the magnitude of policy trade-offs in a medium size DSGE; and they find that the policy trade-offs are negligible;  
that is to say, policymaker is able to stabilize almost completely price inflation, wage inflation and the output gap as long as wage markup shocks are small.

In our model financial frictions act as a new source of inefficiencies affecting the frontier of the economy. We compute the counterfactual level of output under the Ramsey optimal monetary policy, in spirit of JPT (2012). We are not the first looking at the optimal monetary policy in a model with financial frictions. Fendoglu (2011) computes the Ramsey monetary policy in a calibrated financial accelerator model driven by three disturbances namely, productivity, government spending and risk. Other papers that look at the optimal monetary policy in models with financial frictions are Curdia and Woodford (2009), De Fiore and Tristani (2009) and Ravenna and Walsh (2006). In a similar set-up Faia and Monacelli (2007) look at the optimal monetary policy rules in a financial accelerator model driven by technology and government spending shocks. We contribute to this literature by conducting our analysis in an estimated (rather than calibrated model) model driven by eleven exogenous disturbances, including two financial shocks, which differentiate our paper from JPT (2012).

The rest of the paper is organized as follows. Section 2 provides the details of the theoretical model and section 3 describes the empirical evaluation of the model and variance decomposition analysis. Section 4 discusses the impact of financial frictions on potential output and output gap. Optimal monetary policy is described in section 5. Section 6 concludes.

1this is called "Trinity" in their terminology.
2The presence of financial shocks is particularly important because these shocks are inefficient. It is well known since JPT (2010) and Christiano, Motto and Rostagno (2013) that financial shocks absorb a large part of the explanatory power of shocks to the marginal efficiency of investment once financial variables are used in the estimation.
2 Model

This section describes our model of the US business cycle. This is a quantitative DSGE model, which contains many frictions that affect nominal, real and financial decisions of households, entrepreneurs and rms. The model nests the standard New Keynesian model of Justiniano, Primiceri and Tambalotti (2012). The baseline NK model is essentially Christiano, Eichenbaum and Evans (2005), and Smets and Wouters (2007), which we augment by financial accelerator block of Bernanke, Gertler and Gilchrist (1998). The economy consists of six classes of agents: households, entrepreneurs, intermediate good producer firms, final good producer firms, the employment agency, and the government. In what follows we explain the underlying function of each sector in the economy.

2.1 Final Good Producers

Perfectly competitive final good producers combine a continuum of intermediate goods $Y_t(i)$, indexed with $i \in [0, 1]$, according to a Dixit-Stiglitz technology to produce the homogenous good $Y_t$:

$$Y_t = \left[ \int_0^1 Y_t(i) \frac{1}{1+\Lambda_{p,t}} \, di \right]^{1+\Lambda_{p,t}} \tag{1}$$

$\Lambda_{p,t}$ is the curvature of the aggregator. It is related to the degree of substitutability across different intermediate goods in the production of the final good. $\Lambda_{p,t}$ varies exogenously over time in response to price mark-up shocks ($\epsilon_{p,t}$). The stochastic process of this shock is as follow:

$$\log(1 + \Lambda_{p,t}) \equiv \lambda_{p,t} = (1 - \rho_p)\lambda_{p,t} + \rho_p\lambda_{p,t-1} + \epsilon_{p,t} \tag{2}$$

Where $\epsilon_{p,t} \sim i.i.d. N(0, \sigma_p^2)$. With the monopolistic competition, price is a markup over marginal cost. The natural level of output, which prevails in the steady state, is the level of output when the markup is at its constant steady state value. Natural output would be a function of productivity and, as we will see later, because of the price indexation scheme that we adopt, there is no price dispersion in steady state. Hence the steady state level of inflation does not affect welfare. Inflation on the other hand would be a function of expected inflation, the output
gap, and the markup shock. The variation in the markup, affects the competitiveness in the intermediate goods market; hence the central bank faces a tradeoff between inflation stabilization and output stabilization at its natural level, which does not change in response to the markup.

The price of the final good \( P_t \) is obtained from profit maximization and zero profit condition of the final good producer firm. It is an aggregate of the prices of intermediate goods \( P_t(i) \)

\[
P_t = \left[ \int_0^1 P_t(i)^{-\Lambda_{p,t}} \, di \right]^{-\Lambda_{p,t}}
\]

(3)

The demand function for each intermediate good \( i \) is given by:

\[
Y_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{1+\Lambda_{p,t}} Y_t
\]

(4)

2.2 Intermediate Good Producers

The intermediate goods are produced by monopolists using the following production function

\[
Y_t(i) = A_t^{1-\alpha} K_t(i)^{\alpha} L_t(i)^{1-\alpha} - A_t F
\]

(5)

Where \( K_t(i) \) and \( L_t(i) \) represent the quantity of capital and labor used by firm \( i \) in the production sector. \( F \) is a fixed cost of production, indexed to technology, so that profits are zero in steady state. \( A_t \) is the Solow residual of the production function. Its growth rate \( z_t \) \( (z_t \equiv \Delta \log A_t) \) is stationary and varies exogenously over time in response to technology shocks \( (\varepsilon_{z,t}) \). The dynamic of technology shock follows an AR(1) process with \( \varepsilon_{z,t} \sim i.i.d. N(0, \sigma_z^2) \)

\[
z_t = (1 - \rho_z) \gamma + \rho_z z_{t-1} + \varepsilon_{z,t}
\]

(6)

Each monopolist chooses its price subject to a Calvo (1983) mechanism. Every period a fraction \( \xi_p \) do not choose prices optimally but simply index their current
price according to the rule

\[ P_t (i) = P_{t-1} (i) \pi_{t-1} \pi^{1-t_p} \]  

(7)

\[ \pi_t \equiv \frac{P_t - P_{t-1}}{P_{t-1}} \]  

(8)

Where \( \pi_t \) is the gross inflation rate and \( \pi \) represents its steady state value. Note that this steady state value does not depend on the \( i \), therefore there is no price dispersion in steady state. As explained in Justiniano, Primiceri and Tambalotti (2013), this indexation scheme has the desirable property that the level of steady state inflation does not affect welfare and the level of output in steady state. Remaining firms set their price \( \tilde{P}_t (i) \) by maximizing profits intertemporally

\[
E_t \sum_{s=0}^{\infty} \xi^s \frac{\beta^s \Lambda_{t+s}}{\Lambda_t} \left\{ \left[ \tilde{P}_t (i) \left( \prod_{j=0}^{s} \pi_{t-1+j} \pi^{1-t_p} \right) \right] Y_{t+s} (i) - \left[ W_t L_t (i) + r^k_t K_t (i) \right] \right\}
\]  

(9)

Where \( \frac{\beta^s \Lambda_{t+s}}{\Lambda_t} \) represents the household’s discount factor, being \( \Lambda_t \) the marginal utility of consumption, whereas \( W_t \) and \( r^k_t \) indicate the nominal wage and nominal rental rate of capital, respectively.

### 2.3 Employment Agencies

Perfectly competitive employment agencies, or labor packers, combine differentiated labor services, indexed with \( j \in [0,1] \), into homogeneous labor using the following technology

\[
L_t = \left[ \int_0^1 L_t (j) \frac{1}{1+\lambda_{w,t}} \right]^{1+\lambda_{w,t}}
\]  

(10)

\[ \lambda_{w,t} \equiv \log (\Lambda_{w,t} + 1) \]

Where \( \lambda_{w,t} \) is the elasticity of substitution across different labor varieties. The real wage can be obtain by multiplying the markup \( (\Lambda_{w,t} + 1) \) by the ratio of the marginal utility of leisure over the marginal utility of consumption. \( \lambda_{w,t} \) is an
\( i.i.d. \mathcal{N}(0, \sigma_w^2) \) wage mark-up shock. Employment agencies maximize profits in a perfectly competitive environment. The demand function for labor of type \( j \) is given by:

\[
L_t(j) = \left( \frac{W_t(j)}{W_t} \right)^{1+\Lambda_{w,t}} L_t
\]  

(11)

Profit maximization combined with the zero profit condition would lead to the optimal wage paid by intermediate good producer firms. This aggregate wage is as follow:

\[
W_t = \left[ \int_0^1 W_t(j) \frac{1}{\Lambda_{w,t}} d\mu \right]^{-\Lambda_{w,t}}
\]  

(12)

For each labor type, we assume the existence of a union, which represents all workers of that type. Wages are set subject to Calvo lotteries. In parallel with the goods market, every period a fraction \( \xi_w \) of unions index the wage according to the rule

\[
W_t(j) = W_{t-1}(j) \left( \pi_{t-1} e^{\gamma_{w-1}} \right)^{1-\xi_w} \left( \pi e^{\gamma} \right)^{1-\xi_w}
\]  

(13)

Where \( \gamma \) represents the growth rate of the economy along a balanced growth path. This indexation scheme implies that output is independent of the steady state value of wage inflation. The remaining unions choose the wage optimally by maximizing utility of their members subject to labor demand.

2.4 Households

The household sector is composed of a large number of identical households, each composed by a continuum of family members indexed by \( j \). All labor types are represented in each household, and family members pool wage income and share the same amount of consumption as in Andolfatto (1996) and Merz (1995). Capital is produced within the household by combining investment goods \( (I_t) \) and undepreciated capital \( (\overline{K_t}) \) according to the following technology

\[
\overline{K}_{t+1} = (1-\delta) \overline{K}_t + \mu_t \left( 1 - S \left( \frac{I_t}{I_{t-1}} \right) \right) I_t
\]  

(14)
Where $\delta$ is the depreciation rate and the function $S\left(\frac{I_t}{I_{t-1}}\right) = \frac{1}{2} \left(\frac{I_t}{I_{t-1}} - e^\gamma\right)^2$ captures investment adjustment costs, as in Christiano, Eichenbaum and Evans (2005). In steady state $S = S' = 0$ and $S'' = \zeta$. $\mu_t$ varies exogenously over time in response to shocks to the marginal efficiency of investment ($\varepsilon_{\mu,t}$) following Greenwood, Hercowitz and Hufmann (1988) and Justiniano, Primiceri and Tambalotti (2011):

$$\log \mu_t = \rho_\mu \log \mu_{t-1} + \varepsilon_{\mu,t}, \quad \varepsilon_{\mu,t} \sim i.i.d. N(0, \sigma_{\mu}^2)$$ (15)

The representative household takes the price of capital ($Q_t$) and the price of investment goods ($P_t$), as well as labor income, as given and maximizes the utility function

$$E_t \left\{ \sum_{s=0}^{\infty} \beta^s b_{t+s} \left[ \log \left( C_{t+s} - hC_{t+s-1} \right) - \varphi_t \int_0^1 \frac{L_{t+s}(j)^{1+\nu}}{1+\nu} dj \right] \right\}$$ (16)

Log utility ensures the existence of a balanced growth path, as the technological progress is non-stationary. $C_t$ stands for consumption, $h$ for the degree of habit formation, $\nu$ for the inverse of the labor supply elasticity. $b_t$ varies exogenously over time in response to intertemporal preference shocks $\varepsilon_{b,t}$ as does $\varphi_t$ in response to intertemporal labor supply shocks $\varepsilon_{\varphi,t}$.

$$\log b_t = \rho_b \log b_{t-1} + \varepsilon_{b,t}, \quad \varepsilon_{b,t} \sim i.i.d. N(0, \sigma_b^2)$$ (17)

$$\log \varphi_t = (1 - \rho_\varphi) \varphi + \rho_\varphi \log \varphi_{t-1} + \varepsilon_{\varphi,t}, \quad \varepsilon_{\varphi,t} \sim i.i.d. N(0, \sigma_\varphi^2)$$ (18)

Households maximize utility subject to the budget constraint

$$P_tC_t + P_tI_t + T_t + B_{t+1} + Q_t (1 - \delta) K_t = \int_0^1 W_t(j) L_t(j) dj + R_tB_t + Q_tK_{t+1} + O_t$$ (19)
Households use funds to buy consumption and investment goods, to pay lump sum taxes and to save in a one period bond \((B_{t+1})\) that pays a gross nominal return \(R_t\) in each state of nature. This bond is the source of external funds for entrepreneurs and plays a crucial role in the financial accelerator mechanism. Expenses are financed with labor income, revenues from previous period savings, revenues from selling capital to entrepreneurs, and profits from ownership of firms in the intermediate good sectors \((O_t)\).

### 2.5 Entrepreneurs

Entrepreneurs, indexed by \(l\), are essential to transform raw physical capital, produced by the household, into capital suitable for intermediate good production that can be rented to firms. At the end of period \(t\), entrepreneurs use their networth \(N_{t+1}\) to buy raw capital, \(K_{t+1}\) at price \(Q_t\). They further convert it to productive capital for production at time \(t + 1\), \((K_{t+1})\). In order to purchase the capital, the entrepreneur borrow \(Q_tK_{t+1} - N_{t+1}\) from a mutual fund or a financial intermediary. The financial intermediary transfer funds from households to entrepreneurs. In the BGG framework, households are risk averse and entrepreneurs are risk neutral; hence the entrepreneur is the only party that bares all the risk in the loan contract. Therefore, their efficient capital is \(\omega K_{t+1}\) and they choose the capital utilization rate \((u_t)\) and transform installed capital into effective capital according to

\[
K_{t+1}(l) = \omega(l) u_t(l) K_{t+1}(l) \tag{20}
\]

\(\omega(l)\) is independently drawn across time and across entrepreneurs. It is log-normally distributed with unit mean and variance \(\sigma^2\). Effective capital is then rented to firms at the competitive nominal rental rate \(\tau^k\). Therefore the return on the capital received by the entrepreneurs is \(\tau^k_{t+1}\omega u_tK_{t+1}\). As in Levin, Onatski, Williams and Williams (2005), the cost of capital utilization has the form \(a(u_t) = \rho_u^{u_t + \frac{\chi - 1}{1 + \chi}}\) such that in steady state \(u = 1\), \(a(1) = 0\) and \(\chi \equiv \frac{a''(1)}{a'(1)}\).

Finally, at the end of period \(t+1\) each entrepreneur is left with \((1-\delta)\omega(l)K_{t+1}\) used and depreciated capital. This capital is sold to households in competitive markets at the price \(Q_{t+1}\). The aggregate depreciated capital bought by household is \((1-\delta)K_{t+1}\) and they further use their technology given by Eq. 14 to build \(K_{t+2}\). Given the assumptions of the model, the optimal level of utilization is common across entrepreneurs and the nominal rate of return on capital is given by \(R^k_{t+1}(l) = \omega(l) R^k_{t+1}\) where
Following Bernanke, Gertler and Gilchrist (1999), the financial intermediary that intermediates funds between households and entrepreneurs cannot observe the idiosyncratic shock $\omega (l)$ unless it pays a monitoring cost. At the end of period $t$ the lender and the borrower agree on a gross nominal interest rate $Z_{t+1} (l)$. Let $\overline{\omega}$ the cut-off value of $\omega$ that divides entrepreneurs who cannot repay the loan from those who can. Then

$$\overline{\omega} Q_t \overline{K_{t+1} (l)} R_{t+1}^k = B_{t+1} (l) Z_{t+1} (l)$$

Entrepreneurs whose $\omega (l)$ is lower than $\overline{\omega}$ declare bankruptcy and the intermediary must pay a monitoring cost ($\mu$) proportional to the realized gross payoff to recover the remaining assets. The presence of asymmetric information and monitoring costs implies that external finance is costly so that there is a premium $S_t = E_t R_{t+1}^k$ over the risk-less rate that depends inversely on the borrower’s net worth:

$$S_t = \psi_t \tilde{S} \left( \frac{N_{t+1}}{Q_t \overline{K_{t+1}}} \right)$$

$$\log \psi_t = \rho \psi_t - 1 + \epsilon_{\psi,t}, \quad \epsilon_{\psi,t} \sim i.i.d. N(0, \sigma^2_{\psi})$$

where $\psi_t$ varies exogenously over time in response to shocks to the external finance premium ($\epsilon_{\psi,t}$) following Gilchrist, Ortiz and Zakrajsek (2009). A possible micro-foundation for this shock is studied in Christiano, Motto and Rostagno.

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3The functional form of $\tilde{S}$ is $\tilde{S} = \psi_t \left( \frac{N_{t+1}}{Q_t \overline{K_{t+1}}} \right)^\chi$, where $\chi$ is the elasticity of the external finance premium with respect to the leverage ratio derived from steady state restrictions.
Entrepreneurs are risk-neutral and have a finite horizon. The survival probability $\vartheta_t$ varies exogenously over time in response to net worth shocks ($\varepsilon_{\vartheta,t}$) as in Gilchrist and Leahy (2002). This assumption ensures that entrepreneurs will always need external finance to fund investments. Every period a fraction $1 - \vartheta_t$ of entrepreneurs exit and consume the residual assets while $\vartheta_t$ new entrepreneurs enter the market with an endowment $W^e_t$. The law of motion for net worth is given by

$$N_{t+1} = \vartheta_t \left[ R_t^e Q_{t-1} K_t - R_{t-1} B_t - F_t \right] + W^e_t$$

log $\vartheta_t = \rho_\vartheta \log \vartheta_{t-1} + \varepsilon_{\vartheta,t}$, $\varepsilon_{\vartheta,t} \sim i.i.d. N(0, \sigma_\vartheta^2)$

Where $F_t$ represents the expected monitoring cost in nominal terms.

### 2.6 Monetary and government policies.

The monetary policy authority sets the interest rate following a feedback rule

$$R_t = \left( \frac{R_{t-1}}{R^*} \right)^{\rho_R} \left[ \left( \frac{\prod_{s=0}^{3} \pi_t \left( \pi_t - \pi^* \right)^{\frac{1}{4}}}{\phi_\pi} \right)^{\frac{1}{4}} \left( \frac{(X_t/X_t-4)^{1/4}}{\phi_X} \right)^{1-\rho_R} \right] e^{\varepsilon_{R,t}} (25)$$

Where $R$ is steady state gross nominal interest rate, $\rho_R$ is the degree of interest rate smoothing, $\phi_\pi$ is the control parameter which measures the response of interest rate to the deviation of inflation from its target, $\pi^*_t$. Likewise $\phi_X$ measures the reaction to the annual GDP growth, $\frac{X_t}{X_t-4}$, from its steady state level, $e^\gamma$. $\varepsilon_{R,t}$ is an i.i.d. $N (0, \sigma_R^2)$ monetary policy shock. The inflation target, $\pi^*_t$, varies exogenously over time in response to inflation targeting shocks ($\varepsilon_{\pi,t}$) as in Ireland (2007) to account for the low frequency behavior of inflation.

$$\log \pi^*_t = (1 - \rho_\pi) \pi + \rho_\pi \log \pi^*_{t-1} + \varepsilon_{\pi,t}, \quad \varepsilon_{\pi,t} \sim i.i.d. N(0, \sigma_\pi^2)$$ (26)

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4The endowment is of a negligible size, so in the estimation we do not consider it.
5The monitoring cost are very small, so we do not consider them in the estimation.
When we compute the optimal output we ignore this monetary policy rule and we assume that the central bank maximizes the utility of the representative agent.

Government finances its expenditure, \( G_t \), by collecting the lump sum tax \( T_t \) which appears in the households budget constraint. Public spending is subject to a spending shock and is a time varying fraction of output:

\[
G_t = (1 - 1/g_t)Y_t \tag{27}
\]

\[
\log g_t = (1 - \rho_g) \log g + \rho_g \log g_{t-1} + \varepsilon_{g,t} \tag{28}
\]

\[\varepsilon_{g,t} \sim i.i.d. N(0, \sigma_g^2)\]

Where \( g \) is the steady state value of government spending. Finally, output is divided between consumption, investment, adjustment cost of investment and government consumption \( G_t \); hence the aggregate resource constraint is given by:

\[
Y_t = C_t + I_t + S(I_t/I_{t-1})I_t + G_t + F_t \tag{29}
\]

Equations (1) to (30) determine endogenous variables. The stochastic behavior of the system of linear rational expectations equations is driven by exogenous disturbances: price markup shock \( (\lambda_p,t) \), total factor productivity \( (z_t) \), wage markup shock \( (\lambda_w,t) \), labor supply shock \( (\phi_t) \), intertemporal preference shifter \( (b_t) \), marginal efficiency of investment \( (\mu_t) \), spread shock \( (\psi_t) \), net-worth shock \( (\vartheta_t) \), government spending \( (g_t) \), and monetary policy \( (\epsilon_R) \) shocks. In the next section we will explain the empirical evaluations of the model.

3 Empirical Evaluation

This section describes our empirical analysis. We first estimate the model presented in the previous section using Bayesian techniques. We then investigate the parameters’ posterior estimation and variance decompositions of the shocks.

3.1 Bayesian Estimation

The model is estimated using the Bayesian approach with ten observables. The data are quarterly from 1964QII to 2009QIV. We use eight key US macroeconomics time series, similar to JPT (2012). In addition, we use two financial series,
namely the external finance premium and the net-worth, to account for the main financial variables in the model. Our observables are as follows: GDP, consumption, investment, inflation, two measures of nominal hourly wage inflation, hours worked, net-worth, and the credit spread. The model is expressed in log deviation from steady state for the simulation purpose. The data are obtained from Federal Reserve Economic Data - FRED - St. Louis Fed, Bureau of Labor Statistics and NIPA. Appendix B describes the data and the transformation applied to each series in detail. The data feeds the models in annualized per capita log-difference, except those variables which are defined in terms of annualized rates, such as interest rates (FFR) and the credit spread (BBA-FFR) which are used in levels.

Figure 1: Brooks and Gelman’s convergence diagnostic

We estimate the posterior modes by maximizing the log posterior function, which combines the prior information on the parameters with the likelihood of the data. In the next step, the Metropolis-Hastings algorithm is used to get a complete picture of the posterior distribution and to evaluate the marginal likelihood of the model. We simulate the model for 20,000 Metropolis Hastings iterations. The model is estimated over the full sample period. Conditional on the sample information, the Kalman smoother can also be used to estimate the historical path of the model’s endogenous variables which include potential and optimal output. Figure 1 shows the multivariate convergence statistic of MCMC simulation. The red and blue lines represent within and between chain measures. Interval statistic
is constructed around parameter mean. M2 statistic is a measure of the variance and M3 is based on third moments. Simulation converges when the red and blue lines get close and settle down. As it is clear in the graph, convergence only occurs after 13000 draws. We use the methodology proposed by JPT (2012) to estimate wage inflation. This approach ensures that in the absence of financial friction, JPT’s trinity result holds and therefore our results are comparable with those in JPT.

**Wage Inflation and Trade-offs.** We estimate wage inflation using two series, compensations and earnings, in order to absorb high frequency variations in the measurement errors. Boivin and Giannoni (2006a) was the first to propose estimation of wage inflation using two series. Recently this methodology is used by JPT (2012) and Gali, Smets, and Wouters (2011). JPT (2012) provides a comprehensive discussion about the relationship between the importance of wage markup shocks in explaining business cycle fluctuation and the choice of wage observables. This approach is what essentially drives their main result, the so-called trinity trade-offs. In the New Keynesian economy of JPT (2012), without financial frictions, the monetary policy trade-offs are small when two wage series are used to estimate the model; while trade-offs are non-negligible and significant when the model is estimated using only one wage series. We estimate the model using one and two wage series but we only discuss the trade-offs in two-wage series case.

In our model, presence of financial frictions reduces the importance of wage markup shocks in explaining the macroeconomic volatilities significantly. But since we are building our analysis based on JPT (2012), we have to control for all their implementation details, in order to make sure that our results are purely driven by the presence of financial frictions. Hence we use a similar estimation approach to the one described in JPT (2012). To match the wage inflation variable in the model, $\Delta \log W_t$, with two data series, we use a simple i.i.d. observation error, using the below measurement equations:

$$
\begin{align*}
\begin{bmatrix}
\Delta \log (NHC_i) \\
\Delta \log (HE_i)
\end{bmatrix} &= \begin{bmatrix} 1 \\ \Gamma \end{bmatrix} \Delta \log W_t + \begin{bmatrix} e_{1,t} \\ e_{2,t} \end{bmatrix} \\
e_{i,t} &\sim i.i.d. N(0, \sigma_{e_{i,t}}^2) \quad i = 1, 2
\end{align*}
$$

JPT (2012)s underlying assumption is that both measures of wage series imperfectly match the notion of the wage variable in the model, and therefore one can capture this mismatch by using measurement error.
Where $\Delta \log (NHC_t)$ represents the growth rate of nominal compensation per hour in the total economy; $\Delta \log (HE_t)$ represent the growth rate of average hourly earnings of production and nonsupervisory employees. $\Gamma$ is a loading coefficient of second wage series and the first wage series loading coefficient is normalized to one. $e_{1,t}, e_{2,t}$ are observation errors which are independently and identically distributed.

<table>
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<tr>
<th>2 wage series</th>
<th>Compensations</th>
<th>Earnings</th>
</tr>
</thead>
<tbody>
<tr>
<td>$100\sigma_w$</td>
<td>0.058</td>
<td>0.283</td>
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</table>

The estimated variances of wage markup shocks are summarized in table 1. As it is seen from the table, in two wage series case, the variance is very small while when only one wage series is used the variance is almost five times larger.\(^7\)

**Prior distribution of the parameters.** In what follows, we describe the prior distributions and posterior estimations of the parameters in the model. Starting from the priors, for the parameters that are similar to the JPT (2012) model, we follow their distributional assumptions. We borrow the prior assumptions of the parameters that are related to the financial frictions block from CMR (2013) and BGG (1998). Four parameters are fixed in the estimation procedure. First, the steady state of depreciation rate of capital is fixed at 0.02. Second, the steady state ratio of government spending to GDP is set at 0.2. Third, we set the steady state net wage markup to 25 percent, as we cannot identify it. Fourth, persistence of inflation target shock is set to 0.995.\(^8\)

\(^7\)It is shown in JPT (2012), when the wage inflation is estimated using only one wage series, the variance of the wage markup shocks is almost six times larger than in their baseline case where they use two wage series as observables. Therefore when one wage series is used, the wage markup shock is implausibly large. In such case, central bank which cares about macroeconomic stabilization, faces a trade-off; they have to de-stabilize aggregate real activity (output gap), in order to reduce the volatility of price and, especially, wage inflation; and hence, the trinity doesn’t hold any more.

\(^8\)Following to JPT (2012), there is a common view that: the exogenous movements of the inflation target explain very low frequency behavior of inflation.
The standard errors for the innovations are assumed to follow an inverse-gamma distribution with a mean changing from 0.10 to 1.00 and standard deviation of 1.00—except for the inflation target equation which is set to 0.03, corresponding to a rather loose prior. The covariance matrix for the innovations is diagonal. The persistence of the AR (1) processes is beta distributed with a mean of 0.60, except for technology shock equation that is set to 0.40 and standard deviation of 0.20. The mean of the steady state probability of default, $F(\bar{\omega})$, is set to 0.007. The value of the mean in BGG (1998) is 0.75 quarterly percent and in Fisher (1999) is 0.974. The prior mean of the monitoring cost is 0.27, which is within the empirically plausible range of 0.2 - 0.36 proposed by Carlstrom and Fuerst (1997). The steady state value of spread shock, is set 0.26 following CMR (2013). The priors on the structural parameters are fairly diffuse and are set following the standard measures in the literature, see CMR (2010), SW (2007) and Del Negro, Schorfheide, Smets, and Wouters (2007). Table 2 summarizes the distributional assumptions of the priors and the posterior estimates of the model.

**Posterior estimates of the parameters.** A number of observations are worth making regarding the estimated processes for the exogenous shock variables. Overall, the estimation results seem to be consistent with JPT (2012) for non-financial parameters and with CMR (2013) for the financial parameters. The data appear to be very informative for the stochastic processes of the exogenous disturbances. In our model, presence of financial frictions decreases the importance of the investment shock, labor supply shock and monetary policy reaction to the output growth and inflation, compared to the economy of JPT (2012), without financial frictions. By comparing the posterior means across two models we can observe that the variance of marginal efficiency of investment shock drops to 4.89 compared to 7.56 in JPT (2012). Further, the mean of autocorrelation parameters of this shock drops to 0.2 compared to 0.69 in JPT. The variance of labor supply shock drops to 2.76 from 4.73 in JPT. The price stickiness is also estimated to be smaller (0.67 comparing to 0.84 in JPT). Investment adjustment cost is lower (2.43 compared to 3.93 in JPT). Control parameters of monetary policy feedback rule also drop from 2.32 and 0.85 in JPT to 1.43 and 0.09, for inflation reaction parameter and output growth reaction parameter respectively. The posterior mode of the steady state probability of default is 0.004 and this value is close to its prior mean. The mode of monitoring cost is 0.43, which is not very close to the prior mean. The distance of prior mean from the posterior mode indicates informativeness of data about the parameter. It seems that data are very informative about monitoring cost but not as much about steady state probability of default, $F(\bar{\omega})$. In next section I will investigate the variance decompositions of the model.
<table>
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<tr>
<th>Name</th>
<th>Description</th>
<th>Distribution</th>
<th>Mean</th>
<th>S.DV</th>
<th>Mean</th>
<th>Mode</th>
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<th>95%</th>
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<td>0.03</td>
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**Stochastic**

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</table>
3.1.1 Variance Decomposition

The variance decompositions for variables in the model are computed at the business cycle frequency. Table X in the appendix, reports the contributions of the 11 most important shocks in the model to the variance of macroeconomic variables. The first result to stress is that with presence of financial shock, marginal efficiency of investment shock is less important than in the model without financial frictions. The explanatory power of spread shocks for output, investment, hours of work, spread and the rental rate of capital is very high. Technology shock is the most important shock for most of the macroeconomic variables. Price markup shocks are the main driver of inflation volatility. Most of the variations in the consumption are explained by the preference shocks and technology shocks. And finally, the measurement errors seem to have no explanatory power for the variables listed; therefore we don’t show them in the table.

In the New Keynesian DSGE model of Justiniano, Primiceri, and Tambalotti (2012), without financial frictions, almost half of output variation is explained by the marginal efficiency of investment shocks, while TFP shock are the second most significant shock. In an economy with information asymmetry, where the spread between borrowing and lending is nonzero, costly state verification puts in place a mechanism to monitor the risk in entrepreneurship activities. Uncertainty in an entrepreneurial project imposes a risk that affects borrowers’ financial position and hence the cost of funding that they face. A rise in the cost of funding, limits the demand for productive capital, and as a result the production and the output of the economy. Spread shock is a demand shock and implies a procyclical price of capital. One the other hand, marginal efficiency of investment is a supply shock and implies the value of the stock market- equity or net-worth- is countercyclical. By including financial observables in our estimation procedure, we can decompose the uncertainty-related part of investment shock. This is the main reason that in the presence of the financial frictions block, the data favors spread shock over the investment shock. Net worth shocks, or the so-called equity shocks, are also a demand shock, but since they produce countercyclical movements in borrowings (or credit), our VDC analysis doesn’t give much importance to them in explaining the business cycle. The normalized impulse response functions (IRF) presented in figure XX make this point more clear. We finally note that, our IRF and VDC results are largely consistent with CMR (2013).
4 Frictions and Output Gap

In this section we study the impact of financial frictions on the efficient frontier of the economy and the output gap. Financial frictions act through two channels in affecting output: the accelerator and financial shocks. Exogenous disturbances to the external finance premium and equity would lead output to depart from its efficient frontier. These financial shocks are inefficient shocks and explain 21.56% of the volatilities in output (VDC table). Presence of the BGG accelerator implies a wedge between the expected return on capital and the risk-free rate; this wedge further distorts the households’ intertemporal decision-making behavior and hence the economy on aggregate. Moreover, the financial accelerator is a function of the aggregate financial conditions in the economy; the health of the credit market and the banking sector determine the ease in borrowing-lending activities and the availability of finance for investment projects. This ultimately determines the level of economic activity that can be sustained and the efficient frontier of the economy overall. We contribute to the literature by disentangling the impact of these two channels using a quantitative model-base framework. The evidence presented here highlights the importance of the financial accelerator mechanism in understanding the historical path of output. In what follows we discuss the path of potential output, output and the output gap of the economy.
Table 3: Variance Decompositions at Business Cycle Frequency

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<td>4.71</td>
<td>8.39</td>
<td>1.48</td>
<td>11.03</td>
<td>15.7</td>
<td>0.46</td>
<td>4.82</td>
<td>14.43</td>
<td>7.13</td>
</tr>
<tr>
<td>Consumption</td>
<td>0.93</td>
<td>31.21</td>
<td>1.61</td>
<td>0.24</td>
<td>0.08</td>
<td>7.23</td>
<td>56.09</td>
<td>0.06</td>
<td>0.7</td>
<td>0.22</td>
<td>1.63</td>
</tr>
<tr>
<td>Investment</td>
<td>10.85</td>
<td>21.02</td>
<td>0.04</td>
<td>12.71</td>
<td>1.66</td>
<td>4.38</td>
<td>4.56</td>
<td>0.44</td>
<td>4.71</td>
<td>21.67</td>
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<td>Hours</td>
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<td>20.89</td>
<td>4.89</td>
<td>7.94</td>
<td>1.56</td>
<td>11.24</td>
<td>15.02</td>
<td>0.48</td>
<td>4.96</td>
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<td>0.06</td>
<td>0.38</td>
<td>10.5</td>
<td>0.63</td>
<td>0.42</td>
<td>1.65</td>
<td>1.66</td>
<td>0.43</td>
<td>0.55</td>
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<tr>
<td>Inflation</td>
<td>0.62</td>
<td>17.28</td>
<td>0.21</td>
<td>0.28</td>
<td>42.36</td>
<td>0.09</td>
<td>2.75</td>
<td>0.42</td>
<td>25.04</td>
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<td>0.19</td>
<td>4.79</td>
<td>0.23</td>
<td>1.19</td>
<td>0.21</td>
<td>6.2</td>
<td>0.25</td>
<td>3.68</td>
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<td>0</td>
<td>0.09</td>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
<td>0</td>
<td>0.02</td>
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<td>Net-worth</td>
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<td>0.41</td>
<td>0.57</td>
<td>1.62</td>
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<td>0.01</td>
<td>0.84</td>
<td>6.71</td>
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<td>Real Rate</td>
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<td>9.94</td>
<td>0.25</td>
<td>0.03</td>
<td>7.22</td>
<td>0.08</td>
<td>2.12</td>
<td>0.2</td>
<td>14.65</td>
<td>0.72</td>
<td>4.56</td>
</tr>
<tr>
<td>Rental Rate</td>
<td>16.8</td>
<td>19.82</td>
<td>3.41</td>
<td>1.46</td>
<td>1.94</td>
<td>5.79</td>
<td>2.78</td>
<td>0.03</td>
<td>3.55</td>
<td>27.98</td>
<td>16.45</td>
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<td>Capital</td>
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<td>0.25</td>
<td>9.52</td>
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<td>2.63</td>
<td>4.21</td>
<td>0.23</td>
<td>1.57</td>
<td>9.03</td>
<td>9.46</td>
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</table>
4.1 Potential Output and Output

Potential output in our economy is unobserved and it is the counterfactual level of output that emerges if prices and wages have been flexible and there are no financial shocks, but firms maintain constant monopoly power in the goods and labor markets. Therefore, the markups are constant at their steady state level. Moreover, the financial wedge is in place and absent financial shocks, it depends on the leverage ratio. Such notion of the potential output is what we call the third best equilibrium.

First best equilibrium, or efficient allocation, is the equilibrium prevailing under perfect competition in goods and labor markets, with no nominal rigidities and no financial frictions - an absence of financial wedge and financial shocks. The second best equilibrium is when we relax the condition on markups and assume they are constant but non-zero. Thus it is the allocation under perfect financial markets (no financial frictions), no nominal rigidities, but where firms maintain constant monopoly power in the goods and labor markets, implying the markups are constant at their steady state level. While first- and second-best outputs vary over time, the gap between these two remains constant. However, the gap between first- and third-best equilibrium depends on the time varying leverage ratio. Comparing the potential outputs across the models with and without frictions, helps understanding the accelerator channel. While comparing the associated outputs highlights the joint impact of financial shocks and the accelerator.

Figure XX plots the logarithm of US GDP and the posterior median of potential outputs inferred from the model with and without financial frictions (JPTBGG and JPT respectively). The shaded area corresponds to the National Bureau of Economic Research (NBER) recessions. As it is clear from the graph, all three outputs fluctuate around almost the same balance growth path. With the accelerator mechanism explicitly embedded in the model, potential output is higher than the counterpart in the economy without financial frictions, during the 80s; but more importantly, it falls below the potential output driven from the model without financial frictions over last 20 years. The other interesting observation is that the output gap is positive and increasing since the start of the Clinton administration in 1993 up to the onset of the recent mortgage crisis. This could be due to easy and loose financial condition and availability of the credit in the market during this period. Easy money helped boost the economy and as a result the realized output exceeded its potential. The output gap seems to free-fall to a negative value by the start of the financial turmoil. This drop in the output gap is related to the increase in the cost of funding due to the financial distress. This evidence underlines the important role of financial frictions in improving the
ability of the model to track fine historical events.

In the JPT economy without financial friction, the Euler equation implies rental rate of capital to be equal to the risk free interest rate:

$$\frac{\partial U(t)}{\partial C(t)} = \beta E_t R_{t+1}^{k} \frac{\partial U(t + 1)}{\partial C(t + 1)}$$

Presence of financial frictions imposes a new inefficient wedge, so called the ’financial wedge’. The financial wedge between the expected return to capital and the risk free rate distorts households’ intertemporal decision-making. This wedge depends on the leverage ratio and the contractual share of returns going to the lender. In the equilibrium, absent financial shocks, the contractual share of returns going to lenders is 1, so the financial wedge depends solely on the leverage ratio:

$$\frac{R_t^k}{R_{t+1}} = \frac{Q_t K_{t+1}}{\bar{N}_{t+1}^{wedge}}$$
From the above discussion we conclude that fluctuation in the potential output is driven by two sources: (1) the steady state of wage and price markups and (2) the time-varying leverage ratio. Next, we focus more closely on cyclical behavior of the economy. Figure XX depicts the potential and actual outputs inferred from the JPT model (second best allocation) and the JPTBGG model (third best allocation). In the left panel, the red dotted curve shows the JPTBGG potential output and the solid blue line represent the JPT potential output. Several observations are worth making. First, the 3rd best allocation (JPTBGG potential) is less volatile than the 2nd best allocation (JPT potential). Second, during the great moderation, the JPTBGG potential output is lower than the JPT potential. This would imply a higher leverage ratio, availability of easy credit, and an enhanced financial condition during this period. The right panel compares the output between the two models. The output implied by the model with financial frictions is smaller than the counterpart inferred from the model without financial frictions, before the great moderation and vice versa for the period after. During the 2000s, both measures track each other relatively well. Finally, the drop in the output during the recent recession is sharper in the model without financial frictions.
To understand better the dynamic interaction of financial frictions with the frontier of the economy, we start with underpinning some of the properties of the financial wedge. We construct a time varying measure of financial frictions in US postwar data. This measure is based on our structural model. At any point in time, this measure is the difference between the output gaps across the two economies, JPT and JPTBGG. Figure XX illustrate our measure of financial wedge. Both channels of financial frictions, shocks and the accelerator, are present in this measure. The blue line is our normalized, time varying BGG measure. The grey bars are the NBER recession lines. The red dashed line is normalized, default risk spread, constructed as the distance between BAA and AAA corporate bond yields. The measure of financial frictions is highly correlated with the default risk; Taheri Sanjani (2013) provides a comprehensive discussion of default risk spread and its relationship with financial frictions. The shaded areas correspond to the NBER recessions. They highlight the pronounced countercyclical behavior of the DSGE-based financial frictions, which peaks during the recessions. The highest peak occurred during the early 80s recession. The peak of this recession was in the last quarter of 1982, when the USA nationwide unemployment rate reached 10.8%, highest since the Great Depression. Another interesting observation is that both default risk spread and frictions in the financial market have been very high during the early 80s crisis; this is while, in the recent crisis, financial frictions didn’t increased as much as the default risk spread. Starting from the onset of the recent financial turmoil in 2007Q4, the default risk spread increased by more than four fold by 2008Q4. During this period, BGG frictions increased 1.5 times.

Figure YY in the appendix plots time varying financial frictions with 2 measures of financial condition: (1) the Chicago Fed National Financial Conditions Credit Subindex (NFCICREDIT) in solid black, (2) the Chicago Fed National Financial Conditions Risk Subindex (NFCIRISK) in dashed red. One can observe that financial condition indices are highly correlated with the BGG frictions. The correlation with the credit subindex is 0.62 and with the risk subindex is 0.53, for the period between 1973Q1 till 2009Q4. Appendix XX provides more information about these two series.

4.2 Output Gap

Potential output and output gap are not observable economic variables. Yet they are crucial variables for policy makers in helping them to gauge the stance of policy,

\footnote{The start of quantitative easing 1 (QE1) and the forward guidance in Nov 2008 seems to lowered default risk spread substantially and financial frictions moderately.}
be it in setting interest rates or the size of fiscal balance. Yet, the recent financial crisis has been a sobering experience for economic analysts and policy makers as it has put in serious doubt previous estimates of potential output and output gap. Crucially, most estimates of potential output simply focus on the role of labour, capital, technology and sometimes trade variables, and ignore the role of financial variables. A key motivation behind this section is to discuss the missing link of financial variables to models used to analyze the implications for optimal policy making.

Figure XX presents DSGE-based output gap inferred from the NK models with and without financial frictions and unemployment wedge. The top panel demonstrates the output gap constructed from DSGE with financial frictions (JPTBGG) in solid blue line, and the gap from the NK-DSGE model of JPT, without financial frictions, in dash red line. The presence of financial frictions allowed by our reformulation has a substantial impact on the estimated output gap, which now looks considerably more plausible. It can capture the negative output gap during the early 1980s recessions. Additionally, it plunges during the recessions. The bottom panel is from Gali, Smets and Wouters (2011). It illustrates two versions of the output gap, as implied by the estimated NK-DSGE models with and without unemployment, respectively. The solid line is the output gap drawn from the model with unemployment, and the dashed line is inferred from the model without unemployment. This panel shows that the separate identification of labor supply exogenous process and addition of the unemployment wedge, in Gali,
Figure 6: Output gap implied by the estimated models with and without financial frictions

Figure 7: Output gap implied by the estimated models with and without unemployment
Smets and Wouters (2011), has a significant effect on the estimated output gap. By comparing these two panels, we can observe that our JPTBGG version of output gap has a similar pattern to the one from Gali, Smets and Wouters (2011). From the above discussions we can conclude that, financial frictions improves the performance of the DSGE models by providing a more realistic picture of the economy. The output gap implied by our model has been positive during the great moderation, up to the onset of the financial crisis. This indicates that policy was loose during this time. Starting from the onset of the crisis, it sharply declined and reached its lowest level, -5.6, in 2009Q2 and bounced back after that.

4.2.1 Monetary Policy Trade-offs

How successful optimal policy has been in stabilizing the economy? In an environment where financial frictions are relevant source of inefficiencies, can stabilization policy counteract the inefficient fluctuations in output and inflation? What would be its impact on financial variables? In what follows, we try to answer these questions. To do so, we first compute the model’s optimal equilibrium path. This is the welfare maximizing equilibrium, chosen by the central planner [under commitment], subject to the economy’s constraints. We then compute the counterfactual evolution of the economy using the approach proposed by JPT (2012). Specifically, we use the solution of the model under the Ramsey problem to compute the historical path of output and other endogenous variables that would have emerged if policy had always been optimal and the economy had been perturbed by the same series of estimated shocks in the baseline specification in which the Taylor interest rate rule had been in place as the central bank monetary policy instrument.

In our economy monetary authority faces a trade-off in stabilizing output around its potential, stabilizing price and wage inflation. The trade-off stems from different frictions and wedges in our economy: price and wage rigidities, habit persistence, capital accumulations, financial frictions and cost push shocks. Therefore, at the equilibrium output gap, spread, desired price and wage are not

\[ QLF = W_y(Y_t - Y_t^*)^2 + W_\pi(\pi_t - \pi_t^*)^2 \]

We compute the Ramsey policy directly as we have financial variables in our model; hence the choice of an appropriate LQ objective function is not immediate.
constant. In order to study these trade-offs more comprehensively, we compute
the optimal equilibrium path of the model.

4.3 Optimal Monetary Policy

Optimal monetary policy from a timeless perspective (Woodford (2003)) follows by:

\[
\max_{\Theta} \quad E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t) \quad \text{Ramsey}
\]
\[s.t. \quad F.O.C.s\]

We characterize this optimal equilibrium following the Ramsey policy by computing the first order approximation of the policy that maximizes the policymaker’s objective function under the constraints provided by the equilibrium path of the economy. Note that the optimal equilibrium is not affected by the inflation target shock, \(\pi_t^*,\) and the monetary policy shock, \(\varepsilon_{R,t},\) since we replaced the interest rate by the optimal rule. \(^{13}\) Next, we compute the counterfactual path of output and of the other endogenous variables that would have been observed if the followings would hold: 1) the policy had always been optimal; this would allow us to use transition functions obtained from the equilibrium solution under the Ramsey problem. 2) The endogenous variables start from the same initial points as in the baseline economy. 3) The economy had been perturbed by the same sequence of shocks estimated in the baseline specification under the historical interest rate rule. The state space evolution of the model under the counterfactual equilibrium is as follow:

\[
y(t) = y_{estim}^{ss} + A_{opt}(y(t - 1) - y_{estim}^{ss}) + B_{opt}u_{estim}(t)
\] (31)

\(^{12}\)In reality the USA congress established the legislative objectives for monetary policy in the Federal Reserve Act; this includes maximum employment, stable prices, and moderate long-term interest rates.

\(^{13}\)Literature on optimal monetary policy has been fruitful: JPT (2012), Fendolu(2011), Levin, Onatski, Williams, and Williams (2005), Schmitt-Grohe and Uribe (2007) and Christiano, Iltut, Motto, and Rostagno (2010) compute optimal, or Ramsey, monetary policy in medium-scale DSGE models. Debortoli, Maih, and Nunes(2011) also considers loose commitment problem where policymaker’s degree of commitment is not constant.
Where $y_{estim}^*$ is the steady state value of the variables under the estimated model with a Taylor rule policy instrument. $u_{estim}(t)$ is the historical path of shocks under the Taylor rule interest rate policy. $A_{opt}$ and $B_{opt}$ are the transition matrices of the model under the optimal policy solution.

Figure XX and YY present the path of actual and optimal macroeconomic variables implied by model with and without financial frictions. We focus on the macro objectives, namely output gap, price inflation and wage inflation. In the top panel we present the variables implied by our model, JPTBGG. In the bottom panel, we present our replication of the JPT (2012) trinity result. The blue lines are the variables under Taylor rule monetary policy while the red dotted lines are computed under Ramsey optimal monetary policy rule. Optimal and actual outputs are both presented in deviation from potential output inferred from baseline specification. Output gap under optimal policy is significantly more stationary, and the amplitude of the fluctuations is smaller, nonetheless the optimal output gap is not negligible unlike the counterpart in model without financial frictions (JPT (2012)). The model without financial frictions implies that output stabilization policy under optimal rule is successful. But when we take into account the effect of financial frictions, we observe that price and wage inflation are significantly less volatile under the optimal policy, but stabilization policy fails to counteract the fluctuation in output gap; that is to say, in our economy, output-inflation stabilization trade-off is substantial. Therefore a policymaker cannot achieve all its stabilization objectives at the same time and it has to prioritize stabilizing price and wage inflation even if it involves undermining output gap stabilization. This trade-off is mainly due to the presence of financial frictions and nominal rigidities. Interestingly plot (b) and plot (c), which demonstrate price and wage inflations respectively, are very similar to the ones in JPT (2012). Therefore we conclude that monetary policy cannot achieve the Pareto-optimal equilibrium that would occur under no financial frictions, flexible wages and prices; that is, the model exhibits a tradeoff in stabilizing the output gap, price inflation, and wage inflation, all at the same time.

The discrepancy between the economy’s path that prevails under the historical interest rate rule and under the optimal path is striking. This observation is also present in JPT (2012). Some of our conjectures about the reasons behind this discrepancy are: first, it might be because of the underlying differences between the statutory or real objectives of the Fed and the one that is adopted by our model. The monetary policy rule in our model is simplified and is not flexible enough to be fine-tuned or re-adjusted to capture the historical event. The other reason can

\[14\] the Taylor Rule is a rule-of-thumb, whose claims of empirical validity are based on its ability
Figure 8: (Lack of) Trinity In model with Financial Friction

Figure 9: Trinity in model without Financial Friction (JPT2012)

to track policy during periods of relatively modest volatility. Therefor it is bounded to be overly naive in tracking the policy during the periods of crisis when there is substantial economic and financial volatilities.
be that policy might have been less effective ex-post than it was thought ex-ante due to unobserved economic and financial uncertainty. Uncertainty can distort FOMC’s communications with households and businesses. This ultimately results in suboptimal decision making behavior and non-Pareto optimal equilibrium outcome. Finally, as it is proposed in the literature (Clarida, Gali, and Gertler (2000), Cogley and Sargent (2005) and Primiceri (2006)) policy could have been misguided during some periods.

**What is the effect of optimal monetary policy on financial market?**

Figure XX present the path of spread and asset prices under optimal policy, and historical interest rate rule. The blue lines are the variables under Taylor rule monetary policy while the red dotted lines are computed under Ramsey optimal monetary policy rule. The paths of financial variables under the optimal and historical rule somewhat track each other. However they have been slightly more stationary under the historical interest rate rule. Particularly actual spread exhibits smaller fluctuations than optimal one during the great moderation.

![Figure 10: Optimal Monetary Policy and the Financial Market](image_url)
5 Conclusion

Financial cycles, the booms and busts in credit and asset prices, have a significant impact on business cycle. This paper studies channels through which financial frictions affect the frontier of the US economy. Potential output and output gap are not observable economic variables. Yet they are crucial variables for policy makers in helping them to gauge the stance of policy, be it in setting interest rates or the size of fiscal balance. Yet, the recent financial crisis has been a sobering experience for economic analysts and policy makers as it has put in serious doubt previous estimates of potential output and output gap. Crucially, most estimates of potential output simply focus on the role of labour, capital, technology and sometimes trade variables, and ignore the role of financial variables. In this paper we introduce the missing link of financial variables to standard DSGE models used to analyze the implications for optimal policy making.

In this paper we analyze business cycle fluctuations in an environment where financial frictions are a relevant source of inefficiencies. We build our work based on JPT (2012) by extending their NK-DSGE model with financial accelerator block. We estimate the model using the US post war macroeconomic and financial data. Inefficiencies stem from different wedges in our economy; more precisely price and wage rigidities, habit persistence, capital accumulation, financial frictions and cost push shocks. According to our estimated model the fluctuations in the potential output of the economy are mainly driven by the steady state of the wage and price markups together with the prevailed leverage ratio, which is a function of economy's financial condition. We construct a time varying measure of financial frictions. Both channels of financial frictions, shocks and the accelerator, are present in this measure. We further show that this measure is countercyclical and highly correlated with the default risk spread and proxies of financial condition. Financial frictions enhance the model fit, and consequently, the plausibility of potential output and output gap implied from the model. The evidence provided in this paper shows that output gap has been positive during the great moderation, up to the onset of the financial crisis. This indicates that policy was loose during this time. Starting from the onset of the crisis, it sharply declined and reached its lowest level, -5.6, in 2009Q2 and bounced back after that. We find that price and wage inflation are significantly less volatile under the optimal policy, but stabilization policy fails to counteract the fluctuation in output gap, that is to say, in our economy, output-inflation stabilization trade-off is substantial. Therefore a policymaker cannot achieve all its stabilization objectives at the same time and it has to prioritize stabilizing price and wage inflation even if it involves undermining output gap stabilization. This trade-off is mainly due to the presence of financial frictions and nominal rigidities. The paths of financial variables under the opti-
mal and historical rule somewhat track each other. However, spread and asset price inflation have been slightly more stationary under the historical interest rate rule. In particular, actual spread exhibits smaller fluctuations than the optimal one during the great moderation.

The discrepancy between the economy’s path that prevails under the historical interest rate rule and under the optimal path is striking. This might be because of the underlying differences between the statutory or real objectives of the Fed and the one that is adopted by our model. The monetary policy rule in our model is simplified and is not flexible enough to be fine-tuned or re-adjusted to capture the historical event. The other reason can be that policy might have been less effective ex-post than it was thought ex-ante due to unobserved economic and financial uncertainty. Uncertainty can distort FOMC’s communications with households and businesses. This ultimately results in suboptimal decision making behavior and non-Pareto optimal equilibrium outcome. Finally, as it is proposed in the literature (Clarida, Gali, and Gertler (2000), Cogley and Sargent (2005) and Primiceri (2006)) policy could have been misguided during some periods.
References


37


38


39


A Data

Definition of data variables

Source of the original data

GDPC96 : Real Gross Domestic Product - Billions of Chained 1996 Dollars, Seasonally Adjusted Annual Rate
Source: U.S. Department of Commerce, Bureau of Economic Analysis

GDPDEF : Gross Domestic Product - Implicit Price Deflator - 1996=100, Seasonally Adjusted
Source: U.S. Department of Commerce, Bureau of Economic Analysis

PCEC : Personal Consumption Expenditures - Billions of Dollars, Seasonally Adjusted Annual Rate
Source: U.S. Department of Commerce, Bureau of Economic Analysis

FPI : Fixed Private Investment - Billions of Dollars, Seasonally Adjusted Annual Rate
Source: U.S. Department of Commerce, Bureau of Economic Analysis

CE16OV : Civilian Employment: Sixteen Years and Over, Thousands, Seasonally Adjusted

CE16OV index : CE16OV (1992 : 3) = 1

Federal Funds Rate : Averages of Daily Figures - Percent
Source: Board of Governors of the Federal Reserve System
(Before 1954 : 3-Month Treasury Bill Rate, Secondary Market Averages of Business Days, Discount Basis)

LFU800000000 : Population level - 16 Years and Older - Not Seasonally Adjusted
Source: U.S. Bureau of Labor Statistics

LNS100000000 : Labor Force Status : Civilian noninstitutional population - Age : 16 years and over- Seasonally Adjusted - Number in thousands
Source: U.S. Bureau of Labor Statistics
(Before 1976 : LFU800000000 : Population level - 16 Years and Older)
B Financial Condition

Figure 11: Time varying Financial Frictions and Financial Condition

Table 4: Correlation between BGG Frictions and Financial Condition

<table>
<thead>
<tr>
<th>Variable</th>
<th>NFCICREDIT</th>
<th>NFCIRISK</th>
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<tbody>
<tr>
<td>Correlation</td>
<td>0.62</td>
<td>0.53</td>
</tr>
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</table>

**NFCIRISK**: Chicago Fed National Financial Conditions Risk Subindex

**NFCICREDIT**: Chicago Fed National Financial Conditions Credit Subindex


Source: http://www.chicagofed.org/webpages/publications/nfci/index.cfm. “Positive values of the NFCI indicate financial conditions that are tighter than average, while negative values indicate financial conditions that are looser than average.” “The three subindexes of the NFCI (risk, credit and leverage) allow for a more detailed examination of the movements in the NFCI. Like the NFCI, each is constructed to have an average value of zero and a standard deviation of one over a sample period extending back to 1973. The risk subindex captures volatility and funding risk in the financial sector; the credit subindex is composed of measures of credit conditions; and the leverage subindex consists of debt and equity measures. Increasing risk, tighter credit conditions and declining leverage are consistent with tightening financial conditions. Thus, a positive value for an individual subindex indicates that the corresponding aspect of financial conditions is tighter than on average, while negative values indicate the opposite.” Source: http://www.chicagofed.org/webpages/research/data/nfci/background.cfm. “Source: "http://research.stlouisfed.org/fred2/series/NFCIRISK"
C Summary of Results