Inside Money, Employment, and the Nominal Rate

Melanie Friedrichs*

March 1, 2024

UPDATES IN PROGRESS

please click here for the latest version

Abstract

Most general equilibrium models of monetary policy do not simultaneously incorporate a real role for money and match expected empirical moments. This paper develops a tractable flexible price business cycle model that can do both, and also help resolve several empirical puzzles. Deposits provided by the private financial sector are necessary for payments. Monetary policy that reduces the provision of inside money by the financial sector raises the nominal rate, which acts like a tax on consumption and employment, reducing real output. Contractionary shocks produce declines in inflation instead of "Fisherian" increases, the usual moment in monetarist models. In a special case, the solution of the model closely corresponds to the Keynesian IS-LM model, with monetary and financial shocks shifting the "LM" curve. In an extension, I show that if firms must hire workers before knowing how productive they will be — a type of risk not included in most macroeconomic models — increases in risk are contractionary and correspond to an inward shift of the "IS" curve.

Keywords: inside money, monetary policy, risk, business cycles

*New York University, Stern School of Business. Email: melanie.r.friedrichs@gmail.com. I am grateful to Stan Zin, Venky Venkateswaran, Ricardo Lagos, and Mark Gertler for their advice and support. I also wish to thank Simon Gilchrist, David Miller, Thomas Philippon, and seminar participants at NYU Stern, NYU Stern, the Council of Economic Advisers, the Joint Committee on Taxation, the Office of Management and Budget, and the Department of Treasury Offices of Economic Policy and Financial Research. All errors are my own.

1 Introduction

All models are wrong, and in a crisis usually even more so. Tractable policy frameworks built on solid economic theory are extremely important for formulating good macroeconomic policy responses and defending against bad ones; and the more of them we have, the more likely it is that in the next crisis at least one will be useful. In the past, the macroeconomic policy toolkit included both empirical relationships like the Phillips curve and ad-hoc theoretical frameworks like the Keynesian IS-LM and AD-AS models and the monetarist quantity theory of money.[1] Today, empirical relationships are still important for policy analysis, but ad-hoc theoretical frameworks are less popular, and in academia have been almost entirely replaced by microfounded models consistent with the Lucas critique (1972, 1976). The New Keynesian framework, which builds a version of the Phillips curve and the AD-AS model and from sticky-price microfoundations (Gali 2015, 2018), is regularly used by policymakers as well as academics, but few other models as successfully combine rigor and practicality. Microfounded models have made the macroeconomic policy toolkit of today more robust than it was a half century ago, but also in some ways less flexible and therefore more fragile.

Notably, there is no equally popular microfounded *monetarist* framework, despite the efforts of the New Monetarist school (Lagos, Rocheteau, & Wright 2017) and others. By expanding the role of the financial sector and the labor market relative to typical models, this paper generates several novel policy implications in a tractable monetarist setting. First, instead of focusing on outside money (i.e. cash) and abstracting from the financial sector, I focus on inside money (e.g. deposits). This choice allows me to study financial policy directly and to model monetary policy as working through financial institutions, consistent with the view of many policymakers. Second, I assume that inside money is necessary both to purchase goods *and* to pay wages. As in a typical cash-in-advance model, the nominal rate is proportional to the opportunity cost of holding money and acts like a tax on output; but because this tax applies to both consumption *and* employment, changes in the nominal rate have a larger impact on output than in a typical model. Three key results demonstrate the potential of this framework for policy analysis:

- First, I show that contractionary monetary policy shocks that raise the nominal rate lower both employment *and* inflation. Sticky price New Keynesian models can produce these moments, but contractionary monetary policy shocks in flexible price models usually lead to *higher* inflation, due to a weaker link between the nominal and real rate.

[1] The Investment Savings-Liquidity Money (IS-LM) model was proposed by Hicks (1937) to graphically summarize Keynes' 1936 General Theory of Interest, Employment & Money. The Aggregate Demand–Aggregate Supply (AD-AS) model origins are less clear; textbooks often use the IS-LM to derive the AD curve.

The ability of New Keynesian models to match monetary policy moments is an important reason why they are more widespread in central banks than monetarist models.

- Second, in a special case I get an analytical solution that, surprisingly, closely resembles the ad-hoc Keynesian IS-LM model in both form and interpretation. Contractionary monetary policy shocks shift the "LM" curve in, increasing the nominal rate and reducing employment. Shocks to the productivity of the financial sector also shift the "LM" curve, and shocks to the productivity of the goods sector shift the "IS" curve. This "Monetarist IS-LM" representation is useful both because it is tractable and intuitive, and because, like the analogue between the Keynesian and New Keynesian AD-AS models, it provides a link between microfounded models and the older ad-hoc frameworks that many policymakers still prefer.[2] In an extension, I show that if firms must hire workers before knowing how productive they will be, shocks that increase the volatility of firm productivity (entrepreneurial risk) look like demand shocks, and shift the "IS" curve in, reducing employment.[3]
- Third, I show that, unlike in the baseline New Keynesian model where the slope of the New Keynesian Phillips curve (NKPC) is a fixed constant determined by microeconomic parameters, the slope of the equivalent object in my framework varies depending on both the type and persistence of the shocks hitting the economy. This property means that my framework can be used to explain or possibly predict changes in trade-off between inflation and unemployment (controlling for inflation expectations), especially after unusual shocks like the COVID-19 pandemic.[4]

All of the results above come from the flexible price baseline model, but I also solve a version with sticky prices to study the monetarist and New Keynesian mechanisms together. Because I do not rely on sticky prices, I avoid several well-known empirical and theoretical issues with the baseline New Keynesian model. The core mechanism in this model is also consistent with the growing literature connecting monetary policy to the price of liquidity,

[2] While I do not know of a direct New Keynesian IS-LM analogue, New Keynesian papers often label the Euler equation as the "IS" or "Intertemporal IS" curve. The "IS" curve in this paper comes from the negative relationship between the nominal rate and output present in many cash-in-advance models. The relevant rate is the nominal rate. Hick's IS-LM did not clearly differentiate between the nominal and real rate; modern textbooks sometimes assume that prices are fixed, and that therefore the nominal and real rate are equal.

[3] Risk shocks in New Keynesian models with sticky prices can also be contractionary, but risk shocks in most appropriately parameterized flexible price models produce real expansions.

[4] The baseline NKPC relates the output gap to inflation and expected inflation. Controlling for expected inflation is difficult, and empirical estimates of level and variability of the slope of the NKPC or related objects depend on how expectations are measured. My goal is not to contribute to this empirical literature, but to point out that monetarist models can explain expectations-augmented Phillips curve slope shifts.

as well as with macro-financial facts relating private credit to economic activity. Although many of my results are novel, the key assumptions that underpin my model are not, and I use standard solution methods. The contribution of this paper is to bring several interesting assumptions together in a tractable framework, and study their policy relevant implications.

This paper proceeds as follows. In section 2, I discuss the related literature and put my objectives and contributions in context. In section 3, I present the model and characterize the flexible price solution. In section 4, I discuss the assumptions and interpret the solution; for example I explain why the standard Friedman rule does not apply in my framework, and that the strength of the relationship between the nominal rate and the real economy depends on the number of transactions required for each unit of final output.[5] In section 5, I present the results of a monetary policy shock. In section 6, I discuss the empirical support for my assumptions and the implications for the slope of the expectations-augmented Phillips curve. Finally, in section 7, I conclude. In the appendix, I solve the model with sticky prices and show how, depending on the persistence of the monetary shock, sticky prices either amplify or dampen the monetary policy response. I also solve a version of the model with entrepreneurial risk, and show how increases in risk are contractionary and deflationary.

2 Literature

This paper sits at the intersection of many literatures.

First, this paper relates to the literature on inside money. A classic reference is Bagehot (1873), who emphasized the relationship between the provision of inside money by London banks, especially those located on Lombard Street, and British prosperity. Fisher (1933) (who was also fond of lists) discussed the relationship between debt and business cycles, particularly inflation. More recently, Williamson (1999) and Kiyotaki et al. (2000), among others, study environments where inside (or private) money is an important medium of exchange. Brunnermeier and Sannikov (2016) study the interaction between bank net worth, the creation of inside money, and the allocation of productive capital. Lagos and Zhang (2022) focus on competition between inside money provided by private banks and outside money provided by a monetary authority. Piazzesi and Schneider (2018) and Bianchi and Bigio (2022) both include an inside money (deposits) cash in advance constraint, but focus on the details of the interbank market and the transmission of specific monetary policy instruments to the financial sector, instead of the transmission of monetary policy to aggregate employment and

[5] This is broadly consistent with the idea that networks amplify shocks, as in Acemoglu et al. (2016)

inflation. Williamson (2012) also looks and monetary policy and financial crises in a model with inside money. Lagos et al. (2017) survey New Monetarist models of money, some of which feature inside money.

Second, this paper relates to the large and diffuse literature on financial intermediation liquidity, and financial development. Kashyap et al. (2002) and Nagel (2016) discuss the liquidity creation role of financial sector. Many papers have studied the role of the financial sector over the business cycle, including, for example, King and Plosser (1982), Williamson (1987), and Gertler and Kiyotaki (2010). Ajello (2016) shows that shocks to the productivity of the financial sector can generate business cycle fluctuations in a model with sticky prices, as I do with flexible prices. Iacoviello (2015) and Jones et al. (2022) also model financial shock driven business cycles. Although the primary focus of this paper is the short term, the level of financial development in my baseline model also has aggregate implications in the long term, and is potential explanation observed differences across countries, as in Levine (1997) or Buera et al. (2011). An empirical counterpart to the cost of intermediation in my model is the measure developed by Philippon (2015), who also looks at how this cost has evolved over time in the US.

Third, this paper relates to the growing literature on alternative monetary policy transmission mechanisms. As discussed in section 4, the monetary transmission mechanism in my model can be interpreted as a cost channel, following Barth III and Ramey (2001) or Ravenna and Walsh (2006). The "cost" in this paper is the cost of inside money, and is therefore related to the "inflation tax" in Cooley and Hansen (1989) (for example) or the cost of money in any monetarist or New Monetarist model. Many more recent papers, including Gertler and Karadi (2011), Drechsler et al. (2017), as well as Afonso and Lagos (2015), Piazzesi and Schneider (2018), and Bianchi and Bigio (2022) deal with monetary policy transmission mechanisms that work through the financial sector. Goodfriend and McCallum (2007) also look at an inside money cost channel of monetary policy, but in a setting with sticky prices. As also discussed in section 4, the qualitative results of this paper do not depend on the specific way that monetary policy impacts the financial sector; these papers can be thought of as additional or alternative microfoundations for monetary policy transmission.

Fourth, this paper relates to the historical literature on the IS-LM or Investment-Savings Liquidity-Money model, which was first introduced by Hicks (1937) as an attempt to roughly mathematically summarize Keynes' General Theory (1936) and was further formalized (although not fully microfounded) by Modigliani (1944) and Samuelson (1948) among others. The IS-LM is still included in many undergraduate textbooks, for example Mankiw (2000), where it is often introduced as a foundation for the aggregate demand curve in the Keynesian Aggregate Demand and Aggregate Supply (AD-AS) mode. Bordo and Schwartz (2003) discuss the mostly unsuccessful attempts made in the 1970s to reconcile Monetarism with IS-LM, which were related to efforts to elaborate the underpinnings of the LM curve, for example by Tobin (1969) and Tobin (1972). Gali (1992) examines at the the empirical performance of the IS-LM post-WWII, and King (2000) discusses the differences between the ad-hoc Keynesian IS-LM and the three equation microfounded baseline New Keyensian model, which I also discuss briefly in section 3.

Fifth, this paper relates to the large literature on the Phillips curve (Klein and Goldberger (1955), Phillips (1958)), the expectations-augmented Phillips curve (Phelps (1967)), Friedman (1968)) and the related NKPC. Mavroeidis et al. (2014) argue that it is difficult to empirically estimate the slope of the NKPC from macroeconomic data. Others including Beraja et al. (2019), Hazell et al. (2022) and attempt to do so with microeconomic data; the latter find a relatively consistent flat slope. The 2021-2022 inflation is a new challenge to this literature; in 2021 inflation began to steeply rise without changes in most expectations measures (CEA (2023)). A sample of recent papers concerning Phillips curve slopes include Galí and Gambetti (2019), Del Negro et al. (2020), Guerrieri et al. (2021), Benigno and Eggertsson (2023).

Sixth and finally, because of the entrepreneurial risk extension this paper relates to the literature on risk and business cycles. Several papers show that risk shocks look like demand shocks (produce real downturns) in models with nominal frictions, including Christiano et al. (2010), Leduc and Liu (2016), Basu and Bundick (2017), and Bayer et al. (2019). Bloom et al. (2018) document the empirical relationship between uncertainty and aggregate outcomes, and propose a flexible price mechanism with investment frictions to explain this fact. Di Tella (2020), Szoke (2020), Brunnermeier et al. (2020) and Friedrichs (2021) look at flights to safety from risky, productive capital to safe assets in flexible price settings. Many others study the impact of risk in heterogenous agent settings. The entrepreneurial risk assumption in this paper is most similar to that in Arellano et al. (2019), where increases in risk produce real economic contractions in a heterogeneous firm setting with default. Because I additionally assume that households have Greenwood–Hercowitz–Huffman (GHH) preferences (Greenwood et al., 1988), I am able generate contractions in a representative agent setting.

3 Baseline Model

In this section I write down a model with inside money, perfect competition, and flexible prices and characterize the equilibrium. In appendix A, I extend the baseline model to include sticky prices and in appendix B, I extend the baseline model to include entrepreneurial risk.

3.1 Model

A representative household consumes, supplies labor, operates firms, and operates banks, and a central bank provides central bank reserves backed by household debt, and adjusts the size of its balance sheet to satisfy a policy rule.

Households own and operate all firms. Firm output is a linear function of labor and all firms have the same productivity, A_t^F.[6] Households consume and supply labor; they have Greenwood–Hercowitz–Huffman (GHH) preferences, which eliminate the wealth effect on labor supply.[7] Households also operate banks. Bank liabilities are deposits d_{t+1} that are used for payments.[8] Banks hold can hold two types of assets: bonds b_{t+1} that are the liabilities of households (private debt) and central bank reserves CB_{t+1} that are the liabilities of the central bank.[9]. There is no bank equity. Banks in order to order to intermediate bonds and deposits, which can be interpreted both as financial services (monitoring, screening, loan origination, etc) and payments services (transferring, accounting, market clearing, etc). The quantity of *real* intermediation services a bank must provide is proportional to the *real* amount of bonds and deposits it intermediates. Deposits backed by central bank reserves do not require intermediation services and the return on reserves is equal to the return on deposits, making banks indifferent to the quantity of reserves they hold, provided that quantity satisfies an exogenous reserve requirement. The quantity of intermediation services a bank produces is a linear function of the labor it hires, and all banks have the same productivity A_t^B. Deposits pay no net nominal return. I discuss what specific bank assumptions are necessary to obtain the key results of this paper further in section 4.

A key assumption of this paper is that deposits provided by banks are necessary for payments, both from consumers to firms in the goods market and from firms and banks to workers in the labor market. Another way to think about this is that in t, the only way to pay for real goods or services is with promises to provide future real goods or services in $t+1$ (plus interest). Debt is the only medium of exchange; there is no barter and there is no

[6] I assume that production is linear in labor to keep things simple and to get my nearly closed form solution. All results go through with capital.

[7] All results except those in section 6 also go through with standard separable preferences. In many models, GHH preferences better match the empirical response of the labor supply to a variety of business cycle shocks. In this model, they also simplify some closed form solutions.

[8] Deposits used for payments in t mature in $t+1$ and are therefore denoted by d_{t+1}. More generally, I denote individual variables with lowercase letters and aggregate variables with uppercase letters. As this is a representative agent problem, in equilibrium lowercase variables will equal uppercase variables.

[9] Most macroeconomic models assume that bonds are in zero net supply. In a representative agent model with zero-sum debt, the gross quantity of household borrowing (gross private debt) is undetermined. In this model the gross quantity of household borrowing is also undetermined. However, the aggregate quantity of deposits is, and is equal to the *net* supply of private debt.

commodity money. And not just any debt will do; only deposits, which are bank liabilities, or promises by banks to provide real goods or services in $t + 1$ (plus interest), are acceptable to counterparties. This assumption is interpretable as a commitment friction. Banks can credibly commit, but households and firms can only credibly commit to banks. In order to be able to credibly commit, however, banks must exert real effort; the intermediation services in this model can be interpreted the cost of commitment, or the cost required to turn untradable household debt into tradable bank debt, or produce liquidity.[10] Note that the *only* function of banks in this model is to produce liquidity; as this is a representative agent model banks do not, for instance, provide insurance.

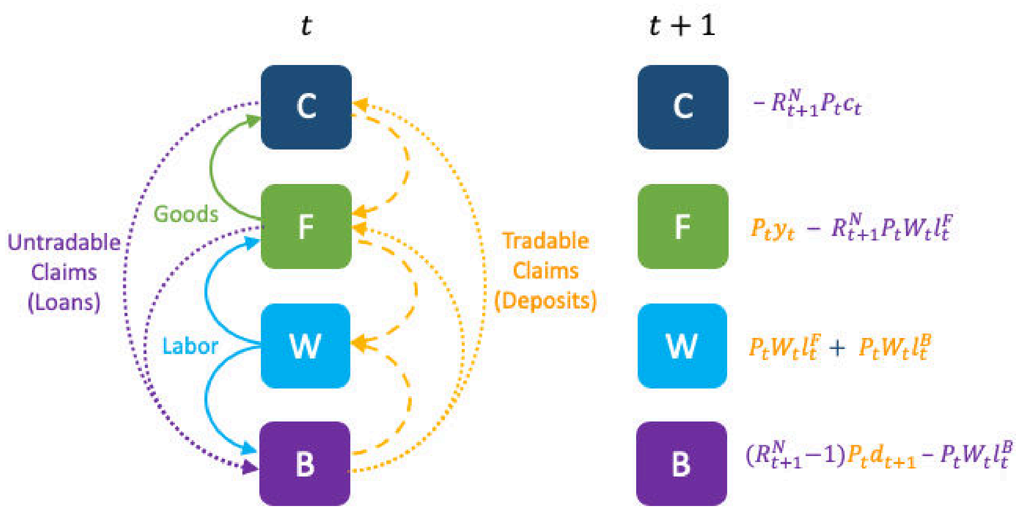


Figure 1: A model of interemediated debt payments

Figure 1 depicts how payments work in this model. In t, in order to purchase consumption from firms, consumers (C) must go to banks (B) and exchange untradable debt or bonds for tradable debt or deposits. They then use those deposits to pay firms (F). Firms also must go to banks and exchange untradable debt for tradable debt, to pay workers (W). Banks also pay workers with deposits. As is implied by the figure, there is no sub-period timing; all of the transactions described above occur simultaneously.[11] In $t + 1$, all assets mature.

[10]Debt as a medium of exchange is a common assumption in monetarist models, but normally the only type of debt acceptable in exchange is government debt, a liability either of a monetary or fiscal authority. Government debt used as a medium of exchange is called "outside money" or cash. Liabilities of the private financial sector used as a medium of exchange are called "inside money." This is a model of inside money only, although adding cash would not change key results (see discussion in section 4).

[11]In figure 1 banks (B) include both private banks and the central bank. The consolidated financial sector

Consumers hold no deposits, but they do owe the bank the amount they borrowed, which in the aggregate is equal to amount they spent, plus interest. Firms hold the deposits they received from consumers, in proportion to the amount they sold; they owe the bank the amount they borrowed, plus interest. Workers owe the bank nothing, and hold deposits they received both from firms and banks. And finally, banks earn the spread between the return on bonds and the return on deposits times the size of their balance sheet, excepting the deposits used by the bank directly to pay bank workers.

The problem of the representative household that corresponds to figure 1 is below. Households choose how much labor l_t^S to supply in their role as a worker, how much labor to demand in their role as a firm l_t^F and how much labor to demand in their role as a bank l_t^B. Households also choose the quantity of real bonds b_{t+1} they hold.[12]

Household problem:

$$\max_{\ell_t^S,\ell_t^F,\ell_t^B,b_{t+1}} \mathop{\mathbb{E}}_t \sum_{\tau=t}^{\infty} \beta^{t+\tau} \frac{x_{t+\tau}^{1-\gamma}}{1-\gamma}$$

$$\text{s.t. } P_{t\text{-}1} W_{t\text{-}1} \ell^S_{t\text{-}1} + P_{t\text{-}1} \underbrace{A^F_{t\text{-}1} \ell^F_{t\text{-}1}}_{y_{t\text{-}1}} + (R^N_t - 1) P_{t\text{-}1} \underbrace{A^B_{t\text{-}1} \ell^B_{t\text{-}1}}_{d_t - CB_t} + R^N_t P_{t\text{-}1} b_t =$$

$$P_t c_t + P_t W_t \ell^F_t + P_t W_t \ell^B_t + P_t b_{t+1}$$

$$CB_{t+1} \geq \phi^{RR} d_{t+1} \quad (d_{t+1} \equiv A^B_t \ell^B_t + CB_{t+1})$$

From left to right in the budget constraint are: deposits received for supplying labor in $t-1$ that mature in t, where W_{t-1} is the real wage in $t-1$; deposits received for selling goods $t-1$; income received from operating banks in $t-1$; maturing real bonds b_t; expenditures on goods consumed in t; expenditures on both firm and bank labor in t; and the choice of bonds. Everything on the left hand side of the budget constraint is in yesterday's prices; everything on the right hand side is in today's prices.[13]

Importantly, banks are also subject to a reserve requirement. Central bank reserves CB_{t+1} are central bank liabilities and are backed bonds. The central bank must also hire labor to intermediate bonds and reserves, and has the same productivity function as private banks.

balance sheet has private household debt (bonds) on the asset side and deposits on the liabilities side.

[12] In the aggregate, this quantity will be negative, and correspond to the borrowing necessary to back deposits used for payments to firms for consumption and to workers to hire labor for firm and bank production.

[13] The budget constraint does not include deposits directly held by households. To simplify the problem I am not allowing households to hold deposits directly, but if I did in equilibrium households would not hold deposits in excess of what is required for payments bonds are also safe and pay a higher return.

Central bank reserves also pay no net nominal return, and the central bank is a price taker in the bond market; its only policy choice is the size of the balance sheet. Any profits are rebated lump sum to households. Due to the way I model the central bank, without the reserve requirement constraint changes in the size of the central bank balance sheet are neutral and have no effect on the economy; intermediation services provided by the central bank crowd out private intermediation services but do not change prices, the overall quantity of deposits, or aggregate employment and output. In other words, the only way that monetary policy affects the provision of inside money is through the reserve requirement. My goal is to keep the mechanism clear and simple; in section 4 I discuss alternative and possibly more realistic ways to model monetary policy.

When the reserve requirement constraint binds, I assume that the central bank targets the nominal rate via a Taylor rule that responds to inflation and employment, and that central bank reserves adjust to satisfy this rule. v_t is an exogenous monetary policy innovation that follows an AR(1) process. When the reserve requirement does not bind the central bank cannot impact the economy.

Monetary policy:

$$CB_{t+1} = A_t^B L_t^B \qquad \text{(Central bank technology)}$$

$$R_{t+1}^N = R_{ss}^N \left(\frac{\pi_t}{\pi_{ss}}\right)^{\phi^\pi} \left(\frac{L_t}{L_{ss}}\right)^{\phi^L} v_t \qquad \text{(Monetary policy rule)}$$

$$\ln v_t = \rho_v \ln v_{t\text{-}1} + \epsilon_t^v \qquad \text{(Monetary policy shock)}$$

Dividing the budget constraint by P_t shows that the real return on deposits R_{t+1}^D is the inverse of the rate of inflation, $\pi_t \equiv P_t/P_{t-1}$. There are three key rates in this model:[14]

Interest rates in the model:

$$R_{t+1}^D \equiv \frac{P_t}{P_{t+1}} = \frac{1}{\pi_{t+1}} \qquad \text{(Real return on deposits)}$$

$$R_{t+1}^B \equiv R_{t+1}^N \frac{P_t}{P_{t+1}} = R_{t+1}^N \frac{1}{\pi_{t+1}} \qquad \text{(Real return on bonds)}$$

$$R_{t+1}^N = R_{t+1}^B \pi_{t+1} = \frac{R_{t+1}^B}{R_{t+1}^D} \qquad \text{(Nominal rate)}$$

The nominal rate is equal to the ratio of the real return on bonds (sometimes here referred

[14]The interest rate definitions on this page all stem from the assumption that deposits pay no net nominal return and the *gross* Fisher equation $R_t^N = R_t^B \pi_t$. The more familiar *net* Fisher equation is $r_t^N \approx r_t^B + \tilde{\pi}_t$, where $R_t^N \equiv (1 + r_t^N)$, $R_t^B \equiv (1 + r_t^B)$, and $\pi_t \equiv (1 + \tilde{\pi}_t)$

to as the real rate) to the real return on deposits, or inside money. The difference between the real return on bonds and the real return on deposits ($R^B_{t+1} - R^D_{t+1}$) is the real spread that banks earn for providing deposits for payments in t, and the spread that consumers and firms *lose* when they must borrow from the bank in order to obtain deposits for payments. The nominal rate is proportional to this spread, and in the equations that follow I will interpret it as the price of inside money.

Aggregate firm and bank productivity follow AR(1) processes. I calibrate the steady state values of firm productivity A^F_{ss} and bank productivity A^B_{ss} to roughly match the share of bank employment in total employment in the U.S., scaled by ratio of liquid liabilities to total assets (see calibration in section 5.2).

Technology:

$$\ln A^F_t = \rho_F \ln A^F_{t\text{-}1} + (1 \text{ - } \rho_F) \ln A^F_{ss} + \epsilon^F_t$$
$$\ln A^B_t = \rho_B \ln A^B_{t\text{-}1} + (1 \text{ - } \rho_B) \ln A^B_{ss} + \epsilon^B_t$$

There are four first order conditions:

First order conditions:

$$\frac{1}{R^N_{t+1}} = \beta \frac{\mathbb{E}[x_{t+1}^{-\gamma}]}{x_t^{-\gamma}} \frac{1}{\pi_{t+1}} \qquad \text{(Euler equation)}$$
$$\ell_t^{S\eta} = \beta \frac{\mathbb{E}[x_{t+1}^{-\gamma}]}{x_t^{-\gamma}} \frac{1}{\pi_{t+1}} W_t \qquad \text{(Labor supply)}$$
$$W_t = \beta \frac{\mathbb{E}[x_{t+1}^{-\gamma}]}{x_t^{-\gamma}} \frac{1}{\pi_{t+1}} A^F_t \qquad \text{(Firm labor demand)}$$
$$W_t + \frac{\lambda_t^{RR} A^B_t}{x_t^{-\gamma}} = \beta \frac{\mathbb{E}[x_{t+1}^{-\gamma}]}{x_t^{-\gamma}} \frac{1}{\pi_{t+1}} (R^N_{t+1} - 1) A^B_t \qquad \text{(Bank labor demand)}$$

The first condition above is standard. The second is standard for GHH preferences, where labor supply depends only on the wage, except for the temporality introduced by the requirement that wages in t are paid using deposits that mature in $t+1$. From the Euler equation, this temporality is equal to the nominal rate and acts a tax on wages. The third condition is also standard – the wage W_t is proportional to the marginal product of labor A^F_t, except again for the temporality introduced by payments. The last condition governs the supply of inside money. The price of bank output, which is the spread banks earn on deposits or the net nominal rate ($r^N_{t+1} \equiv R^N_{t+1} - 1$), is proportional to bank marginal cost or W_t/A^B_t plus the cost of the reserve requirement constraint represented by its Lagrange multiplier λ^{RR}_t. Because banks also have to hire labor with deposits the nominal rate appears in this relation a second time, acting as a tax on bank output.

3.2 Market clearing

Finally, there are four market clearing conditions.

Market clearing conditions:

$$C_t = Y_t \quad \text{(Goods market clearing)}$$

$$L_t^S = L_t^F + L_t^B + L_t^{CB} \quad \text{(Labor market clearing)}$$

$$B_{t+1} + B_{t+1}^B + B_{t+1}^{CB} = 0 \quad \text{(Bond market clearing)}$$

$$W_t L_t^F + W_t L_t^B + C_t = D_{t+1} \quad \text{(Money market clearing)}$$

In the first condition, C_t is the aggregate analogue of representative household consumption c_t, and Y_t of representative firm production. In the second, there are two sectors that hire labor in this economy, the goods sector and the financial sector, and in the financial sector labor is hired both by private banks (L_t^B) and the central bank (L_t^{CB}). The third equation is the bond market clearing condition; B_{t+1} is the amount of household debt held by households, B_{t+1}^B is the amount held by private banks on the asset side of their balance sheets, and B_{t+1}^{CB} the amount held by the central banks on the asset side of its balance sheet. Because central bank reserves CB_{t+1} are held by private banks as assets, in the aggregate $-B_{t+1} = D_{t+1}$ (this is the "economy balance sheet"). The last condition is the money market clearing condition; the real quantity of intermediation services provided by banks must equal the real amount of transactions deposits facilitate.[15]

3.3 Flexible price solution

The monetary rule, the first order conditions and the market clearing conditions above can be combined into the following system of four equations, where $X_t \equiv C_t - \frac{L_t^{(1+\eta)}}{1+\eta}$:

[15]The money market clearing constraint can be interpreted as an inside money cash in advance constraint. In many models of money, cash in advance is a constraint on the household; that is not the case here, because the budget constraint incorporates the assumption all payments are made with deposits. If I allowed households to hold deposits directly, this constraint would also include those deposits.

Flexible price solution:

$$L_t^\eta = (\frac{1}{R_{t+1}^N})^2 A_t^F \qquad \text{(Goods supply)}$$

$$L_t^\eta = \frac{1}{R_{t+1}^N}(\frac{1}{R_{t+1}^N}(R_{t+1}^N - 1) - \frac{\lambda_t^{RR}}{X_t^{-\gamma}})A_t^B \qquad \text{(Money supply)}$$

$$R_{t+1}^N = R_{ss}^N(\frac{\pi_t}{\pi_{ss}})^{\phi\pi}(\frac{L_t}{L_{ss}})^{\phi L}\upsilon_t \qquad \text{(Monetary policy rule)}$$

$$\frac{1}{R_{t+1}^N} = \beta\frac{\mathbb{E}[X_{t+1}^{-\gamma}]}{X_t^{-\gamma}}\frac{1}{\pi_{t+1}} \qquad \text{(Euler equation)}$$

The first equation comes from substituting the labor supply condition into the firm labor demand condition. This equation involves a square of the nominal rate because every unit of output produced involves two payments: from the firm to the worker, and from the consumer to the firm. The second equation comes from substituting the labor supply condition into the bank labor demand condition.[16] The third equation is the monetary rule and the fourth equation is the Euler equation.

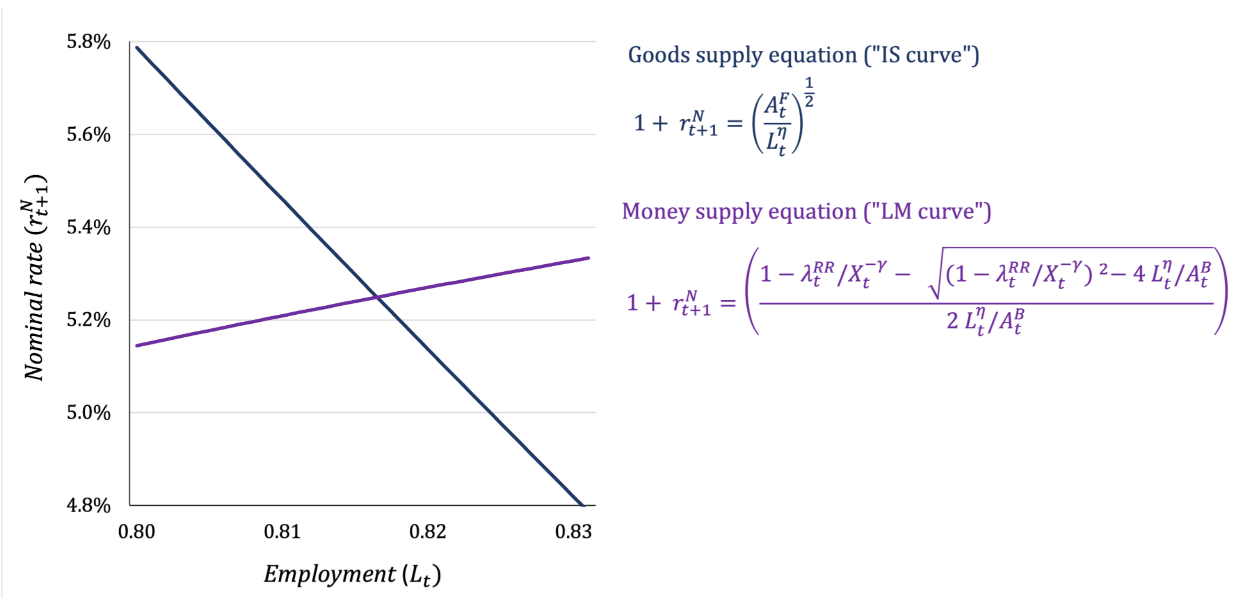


Figure 2: A Monetarist IS-LM[13]

[16]To fully solve the model the breakdown of aggregate employment into goods sector and financial sector employment must determined using the money market clearing condition. The fraction of employment in the goods sector $\frac{L_t^F}{L_t}$ is equal to $(\frac{A_t^B}{A_t^F} - \frac{1}{R_{t+1}^N})(\frac{A_t^B}{A_t^F} + 1)^{-1}$. I calibrate the ratio of financial sector to goods sector productivity $\frac{A_t^B}{A_t^F}$ to about 100. This high value means that the share of financial sector employment does not vary much over the business cycle or in response to monetary policy shocks that shift R_{t+1}^N.

In the special case where λ_t^{RR} is fixed, plotting these two equations with employment L_t on the x-axis and the net nominal rate r_{t+1}^N on the y-axis, yields figure 2. This figure summarizes the role of inside money on the economy. The goods supply curve is downward sloping because a higher nominal rate means that households and firms must pay a larger spread to banks in order to transact, which decreases firm labor demand. The money supply curve is upward sloping curve because the nominal rate is the price of inside money, the service produced by banks.[17] Although the model is dynamic, its solution is almost static. In an extra special case the reserve requirement does not bind and $\lambda_t^{RR} = 0$, the goods supply equation and the money supply equation uniquely determine L_t and R_{t+1}^N.[18] As shown in section 4, increases in firm productivity push out the goods supply curve and increases in bank productivity push out the money supply curve.

The key friction in this model is monetarist, but, surprisingly, this figure closely resembles the textbook Keynesian IS-LM model, with employment instead of output on the x-axis. The goods supply curve, which is derived from the firm labor demand condition, can be interpreted as an Investment-Savings (IS) curve because the revenue received for labor hired and paid for in t does not mature until $t + 1$; in other words, in this model employment is investment.[19][20]. The money supply curve can be interpreted as a Liquidity-Money (LM) curve, although it also differs from the classic Keynesian concept.[21] In this model the money supply curve is derived from the bank labor demand condition, which directly relates the nominal rate, the price of bank output, to the wage and therefore employment. The money supply is endogenous; for example an increase in output in the goods sector that increases the wage increases both the money supply (the quantity of deposits) and the nominal rate, the price of money (the spread earned by banks). And because inside money is provided by the private financial sector, its supply also depends on financial productivity A_t^B and potentially on other financial constraints, as discussed further in section 4. Both curves appear linear

[17] The square root in the figure above comes from the quadratic formula. The calibration of specific parameters in this figure matches the calibration in section 5.

[18] $\lambda_t^{RR} = 0$ corresponds to the "free banking" case discussed in section 4.

[19] Interpreting employment as investment becomes even more plausible with the additional assumption of entrepreneurial risk the appendix.

[20] The textbook IS curve (e.g. Mankiw (2000)) is normally derived from the Keynesian cross, where investment is directly assumed to depend negatively on the interest rate. In the New Keynesian framework the Euler equation is often interpreted as an "intertemporal IS curve," because it consumption in t is negatively related to the nominal rate (and positively related to consumption in $t + 1$)

[21] The textbook LM curve is derived from household money demand, which is assumed to be increasing in output and decreasing in the nominal rate (the opportunity cost of holding money). When real (outside) money balances are exogenously fixed, for instance by a monetary authority, this induces a positive relationship between output and the nominal rate. These relationships are often illustrated by a "money market" diagram.

in the vicinity of the solution. The flatter the IS curve, the greater the impact of a change in the money supply curve on the economy. The flatness of the IS curve depends on η, and also on the number of transactions required to produce a unit of output; in the baseline this number is 2, one in the goods market, and one in the labor market. I discuss generalizing this in section 4.

The goods supply equation and the money supply equation are the core of the flexible price model. Through the Euler equation, inflation depends on the evolution of employment and the nominal rate over time. Through the Taylor rule, the value of λ_t^{RR} varies endogenously with π_t.

4 Discussion

The point of this section is to clarify some things about how the baseline model works that may not be clear after reading the previous section, and also argue for its broad applicability. I divide the points I make into two groups. The first group applies mostly to the interpretation of the goods supply equation and the mechanisms that link changes in the nominal rate to changes in aggregate employment, output, and inflation. The second group applies mostly to the interpretation of the money supply equation and the mechanisms that link monetary policy to the provision of inside money by the private financial sector and the nominal rate. In the money supply equation section I also discuss how shocks to the private financial sector unrelated to monetary policy affect the nominal rate, and therefore aggregate employment, output, and inflation.

4.1 Goods supply equation

In the baseline New Keynesian model, the mechanism that links the nominal rate to the real economy is sticky prices. In this model the mechanism that links the two is a monetarist and is summarized by the goods supply equation or "IS" curve.

- **This equation can be interpreted as an "inside money cost channel"**

  This paper is related to the "cost channel" of monetary policy literature, which distinguishes between sticky price or New Keynesian monetary policy transmission mechanisms and mechanisms where higher rates suppress real output by increasing firm costs (Barth III and Ramey, 2001). In some models of the cost channel the relevant cost is the real rate, which, for example, might impact the real economy via heterogeneity and a working capital constraint, as in Christiano and Eichenbaum (1995). But others focus, like this model, on the nominal rate; the cost channel in this model is closely related to that in Ravenna and Walsh (2006).

- **R^N_{t+1} is a tax on employment in many cash-in-advance models**

  The flexible price baseline is classically Monetarist in the sense that the object of interest is the spread between the real return on bonds and the real return on deposits ($R^B_{t+1} - R^D_{t+1}$). The nominal rate ($R^N_{t+1} = \frac{R^B_{t+1}}{R^D_{t+1}}$) acts as a tax on output in the same way in any cash-in-advance (CIA) with a labor supply problem, although this not typically true in money-in-the-utility-function (MIU) models, and many models that feature a CIA constraint do not also feature a labor supply problem. The representative household problem in the section above is equivalent to a problem where households hold deposits directly and are subject to individual CIA constraints. However, one common criticism of CIA models is that they do not specify how exchange occurs or why money is necessary. The discussion accompanying figure 1 in the section above specifies, at a high level, a mechanism of exchange ("debt payments") and a motivation for money (a commitment problem that the financial sector solves, with effort), and the way that I have written the budget constraint emphasizes this interpretation.

- **The strength of the cost channel depends on the complexity of the economy**

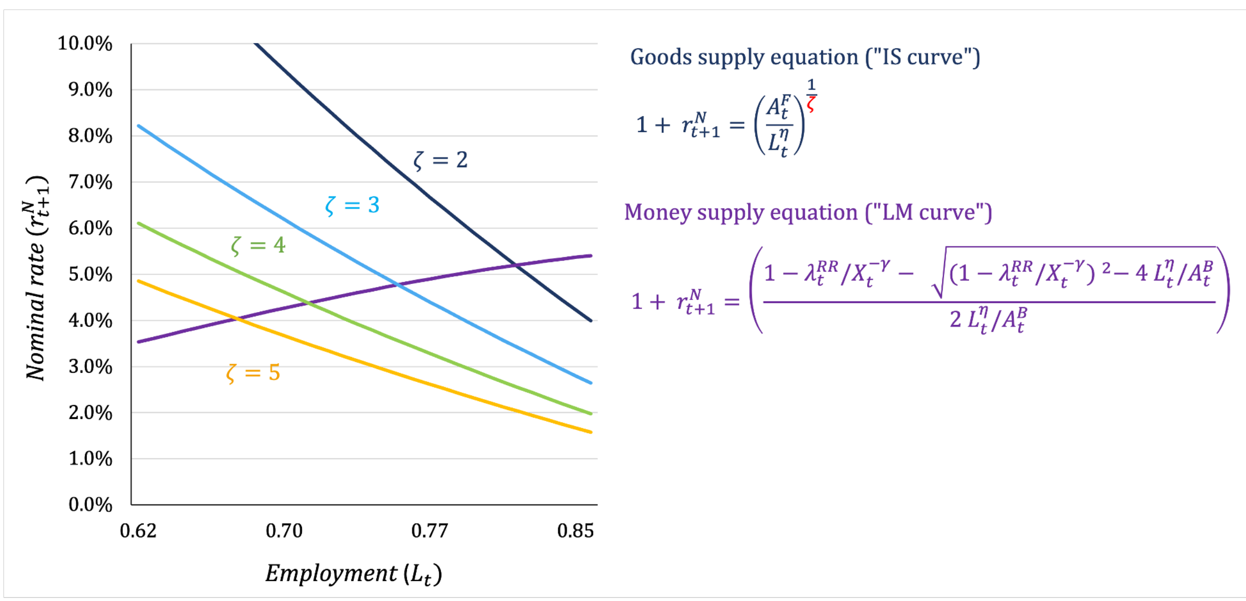


Figure 3: The Monetarist IS-LM with different degrees of economic complexity

A square appears in the goods supply equation because each unit of output requires two money transactions, one in the labor market (to hire workers) and one in the goods market (to sell to consumers). If three money transactions are required, for example if (as in some versions of the baseline New Keynesian model) there are both final goods firms and intermediary goods firms, this square would be a cube. This produces a flatter IS curve, which means that employment is more sensitive to changes in the nominal rate. Generalizing, the more the more money transactions required per unit of output, or the longer supply chains are, or the more complex the economy is, the more sensitive that economy is to changes in the cost of inside money. Figure 3 shows the goods supply curve in economies with varying degrees of complexity.

- **No intermediation cost means no cost channel ("Friedman rule")**

  The flexible price baseline has two key assumptions: first that deposits are necessary for payments, and second that in order to provide deposits the private financial sector has to pay an intermediation cost. If there is no intermediation cost, meaning that banks can costly transform bonds into deposits, then equilibrium prices and quantities coincide with those of a real business cycle model with GHH preferences and no capital, both in the steady state and in response to shocks. This case can be interpreted as a model of debt payments without a commitment problem: consumers still have to pay firms with debt, and firms still have to pay workers with debt, but bonds that pay the nominal rate are directly acceptable as a medium of exchange. The following are the first order conditions in the case with no intermediation cost:

  No intermediation cost first order conditions:

$$1 = \beta \frac{\mathbb{E}[X_{t+1}^{-\gamma}]}{X_t^{-\gamma}} \frac{P_t}{P_{t+1}} R_{t+1}^N \qquad \text{(Euler equation)}$$

$$\ell_t^S = \beta \frac{\mathbb{E}[X_{t+1}^{-\gamma}]}{X_t^{-\gamma}} \frac{P_t}{P_{t+1}} R_{t+1}^N W_t \quad \rightarrow \quad \ell_t^S = W_t \qquad \text{(Labor supply)}$$

$$W_t = \beta \frac{\mathbb{E}[X_{t+1}^{-\gamma}]}{X_t^{-\gamma}} \frac{P_t}{P_{t+1}} R_{t+1}^N A_t^F \quad \rightarrow \quad W_t = A_t^F \qquad \text{(Goods supply)}$$

  This is this model's version of a Friedman rule: when there is no intermediation cost the real return on deposits R_{t+1}^D is equal to the real return on bonds R_{t+1}^B, the "cost" of transacting is zero, the labor supply is function only of the wage (standard for GHH preferences), and the wage is equal to the marginal product of labor, A_t^F. The intuition is that if money is free, there is no distortion to the real economy.[22]

[22]When there is no intermediation cost, it is not clear how the rate of inflation should be defined. If the assumption is still that deposits are the unit of account, then the rate of inflation would be defined as the inverse of the real return on debt $1/\pi_{t+1} = R_{t+1}^D = R_{t+1}^B$. This would translate to a gross nominal return

However, optimal policy in the flexible price baseline is not literally a Friedman rule, because the central bank does not have the power to entirely eliminate intermediation cost and set $R^D_{t+1} = R^B_{t+1}$. All it can do supply reserves such that the constraint does not bind and $\lambda^{RR}_t = 0$, in which case the endogenously determined "free banking" rate of inflation (see below) is optimal. Neither the flexible nor sticky price model in this paper is intended to be a realistic model of optimal policy; but as long as the central bank is unable to entirely subsidize or replace the private financial sector, optimal policy will not be a Friedman rule, because money in this model is not free.[23][24]

- **Productivity shocks shift the goods supply curve**

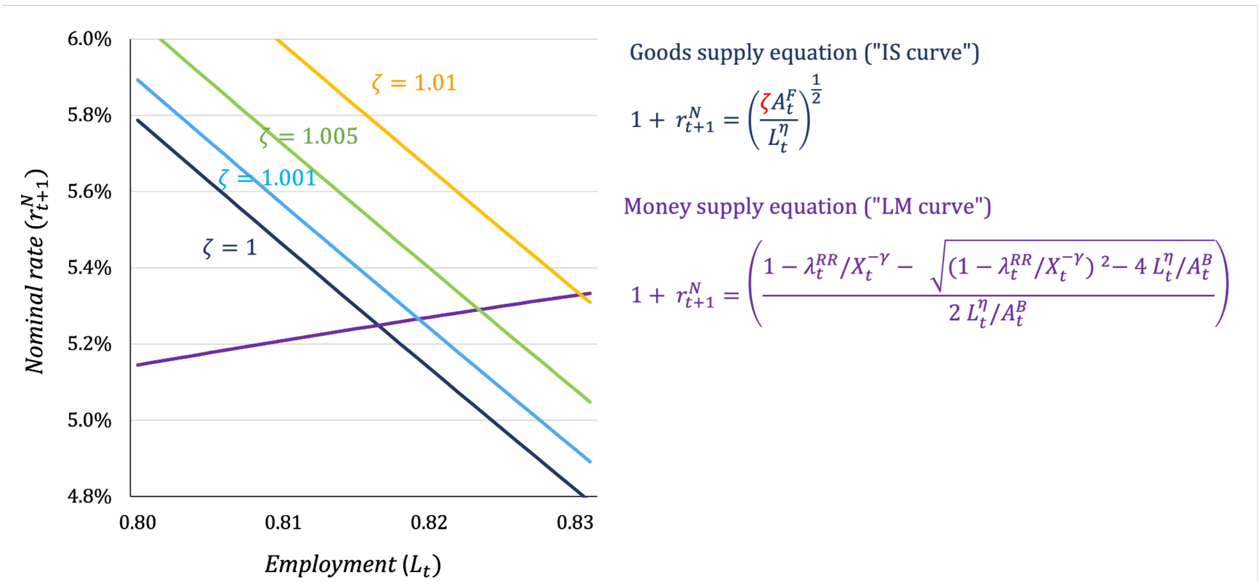


Figure 4: Increase in firm productivity A^F in the "Monetarist IS-LM"

Figure 3 shows how one parameter can shift the goods supply curve. More relevant over the business cycle are changes in firm productivity, A^F_t. Increases shift the goods

of 1 on private household debt $R^N_{t+1} = R^B_{t+1}/R^D_{t+1} = 1$, or a net nominal return of 0. The baseline model has a has a built in nominal zero lower bound, because (barring a negative intermediation cost), the return on deposits cannot be lower than the return on bonds.

[23] Money is not free because of the background assumption that a commitment problem prevents private debt from circulating without effort (financial and payments services). Models of outside money often assume that government debt can circulate without cost, which leads to a Friedman rule; but the Friedman rule does not hold in models of both inside and outside money where the provision of money has a cost, for example as in Sanches and Williamson (2010) .

[24] To be a reasonably informative model of optimal policy, this model would need a more realistic type of liquidity constraint (see discussion below), as well as additional elements such as menu/utility costs associated with higher/accelerating inflation and default risk that endogenously responds to the size and composition of bank balance sheets.

supply curve out. The response of the nominal rate R^N_{t+1} and employment L_t depends on policy – the reactionary change in λ^{RR}_t, but if λ^{RR}_t is fixed (for example if the reserve requirement is not binding) R^N_{t+1} and L_t will increase. Figure 4 shows the dynamic response of key variables to a shock to A^F_t in the case when λ^{RR}_t is fixed. The two lines show shocks with varying degrees of persistence. Less persistent shocks have a smaller impact on the real rate R^B_{t+1} and therefore a smaller impact on inflation π_{t+1}. The calibration is discussed in section 5.

4.2 Money supply equation

In the baseline model there is one mechanism that links monetary policy to the nominal rate: the reserve requirement. In this section I argue that it is possible to model a number of plausible alternative or additional monetary policy channels while leaving the form and interpretation of the money supply equation mostly unchanged. I also explain how financial shocks can, through the money supply equation, impact the provision of inside money by the private financial sector, the nominal rate, and real output. Finally, I clarify the role of several specific financial sector modeling choices.

- **Modeling monetary policy differently does not change the "LM" intuition**

  In the baseline model, the central bank impacts the provision of inside money by the private financial sector only through the reserve requirement; when the reserve requirement binds, changes in the real quantity of reserves supplied by the central bank affect the magnitude of the constraint λ^{RR}_t on private banks, and therefore change the economy-wide nominal rate R^N_{t+1}. This mechanism is illustrated in the figure below. This is a conveniently simple but unrealistic type of liquidity constraint, and limits the interpretability of the model.

  Alternative or additional monetary policy channels could be modeled as alternative or additional *liquidity constraints*. For example, a more realistic model might connect the provision of inside money to an interbank lending rate R^{FFR}_{t+1} via a mechanism involving deposit withdrawal shocks similar to those in Afonso and Lagos (2015), Piazzesi and Schneider (2018), Bianchi and Bigio (2022). This channel could also be represented in the money supply equation as a constraint (e.g. λ^{FFR}_t). If the central bank can change the magnitude of this constraint by adjusting R^{FFR}_{t+1}, then it can influence the provision of inside money, the economy-wide nominal rate, and the real economy.[25]

[25] This type of monetary policy channel could also be modeled in an ad-hoc way by assuming that the

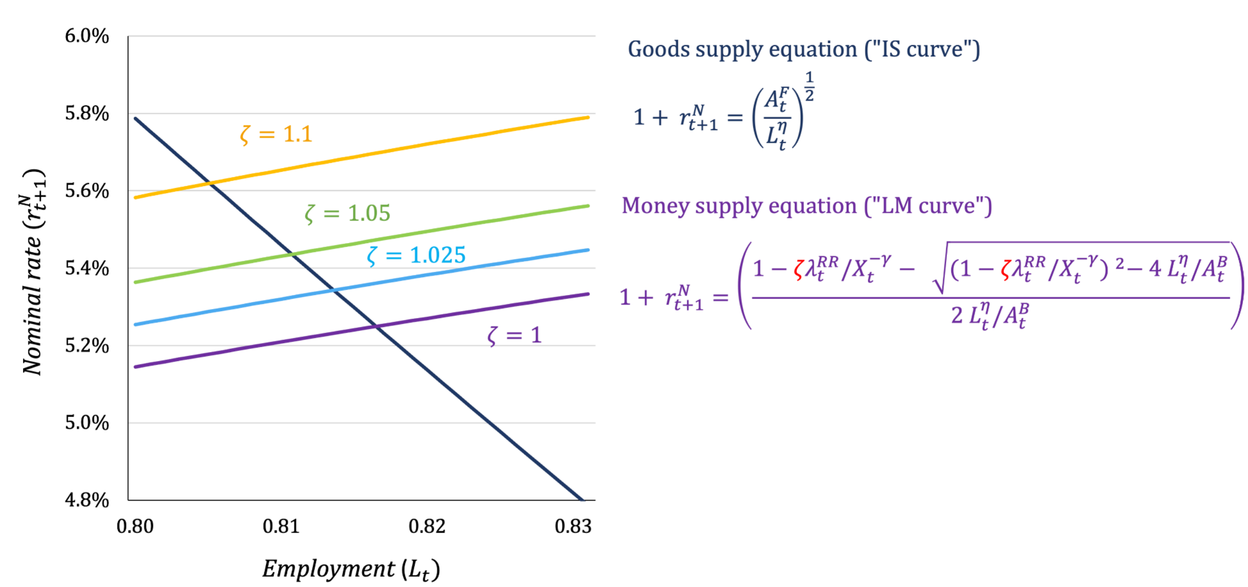


Figure 5: The Monetarist IS-LM with different targeted nominal rates

Monetary policy could also affect the provision of inside money by lowering the price of close substitutes for deposits (such as cash, see the bullet below), increasing *competitive pressure* and lowering financial sector markups, as in Drechsler et al. (2017) or Lagos and Zhang (2022). This type of channel could also be represented in the money supply equation as a constraint (e.g. λ_t^C). Additionally, if banks as well as firms were monopolistically competitive and subject to nominal pricing frictions, endogenous changes in bank markups in response to monetary policy would also impact the real economy via the inside money cost channel.

Banks in the baseline model do not have equity. If they did and were subject to *capital constraints*, monetary policy or regulatory changes that affect the magnitude of such constraints (e.g. λ_t^E) would also affect the provision of inside money, the nominal rate, and the real economy via the inside money cost channel, in addition to any impact they might have through the New Keynesian or other mechanisms, similar to Gertler and Karadi (2011).

Finally, monetary policy might also plausibly influence the provision of inside money by indirectly or directly impacting the *intermediation cost*, or the amount of real labor effort required to transform untradable household debt into tradable deposits. This can be modeled in an ad-hoc way as a direct impact on the bank productivity parameter

magnitude of the liquidity constraint depends directly on the Federal Funds Rate.

A_t^B, and could for example proxy for a technological advantage the central bank has in intermediating debt and deposits, for a bank production function with increasing returns to scale, or a change in required risk management effort due to changes in liquidity constraints or changes in the endogenous probability of default.[26][27]

The contribution of this paper is not to articulate a particular monetary policy channel, but rather to show how many mechanisms can be flexibly represented by money supply and goods supply equations, and to study their common implications.

- **Financial constraints also impact the nominal rate and the real economy**

  In the bullet above I discussed how monetary policy might influence the provision of inside money by affecting liquidity, competitive, or capital constraints on the private financial sector. Non-monetary policy shocks that affect these constraints would of course also impact the provision of inside money, the nominal rate, and therefore the real economy. Additional financial frictions could also be modeled as additional constraints. More broadly, anything that impacts the financial sector in this model also impacts the real economy; the financial sector is not neutral.

- **With no reserve requirement, this is a model of "free banking"**

  If the reserve requirement does not bind, the central bank is essentially just another private bank. All money is fiat money, but it is privately supplied and the nominal rate and the rate of inflation are endogenously determined. This can be thought of as a model of "free banking", for example of Scotland in the 18$^{\text{th}}$ and 19$^{\text{th}}$ centuries, when many private banks issued banknotes that circulated as currency.[28] The "free banking" case emphasizes that in this model the government has only partial control over the money supply, and also provides a theory for how exchange might occur without a state. However, due to the absence of default, this is an idealized representation of "free banking", not subject to the bank runs and depreciations that have historically plagued such economies.

- **If the policy rate differs from R_{t+1}^N, monetary policy pass-through is partial**

[26] If in the baseline model the central bank has a technological advantage, it is optimal for it to provide all deposits, or replace the financial sector entirely. Decreasing returns to scale in the central bank's technological advantage would rule out this unrealistic scenario.

[27] Monetary policy that works through A_t^B instead of λ_t^{RR} also makes it slightly easier to generate a decline in inflation in response to a monetary policy shock, although I do not discuss this scenario in this paper.

[28] If required reserves are gold instead of fiat money this model can be thought of as a model of commodity money with fractional reserve banking.

In the baseline model there is only one nominal rate, and so the policy rate equals the economy-wide rate. In reality policy rates differ from the spreads that private financial institutions charge on deposits. If, for instance, the policy rate is the Federal Funds Rate R_{t+1}^{FFR} and it impacts the financial sector by changing the magnitude of some liquidity constraint λ_t^{FFR}, changes in the policy rate would only partially pass through to R_{t+1}^N. This economy would be something like a half step between the baseline flexible price model and "free banking" case; monetary policy would only have a limited ability to respond to shocks that shift the goods supply and money supply curves.

- **Large negative shocks to A_t^B can be interpreted as financial crisis shocks**

  Instead of a single aggregate productivity parameter, as is the case in most representative agent business cycle models, there are two productivity parameters in the baseline model, one for the goods sector and one for the financial sector. As illustrated in figure 2, the relative steady state values of A_t^F (firm productivity) and A_t^B (bank productivity) influence the steady state nominal rate and steady state employment. Long term differences in $\frac{A_t^B}{A_t^F}$ across countries, could, for example, partly explain long term differences in domestic interest rates. Long term trends in $\frac{A_t^B}{A_t^F}$ could also partly explain secular trends in the nominal rate.[29]

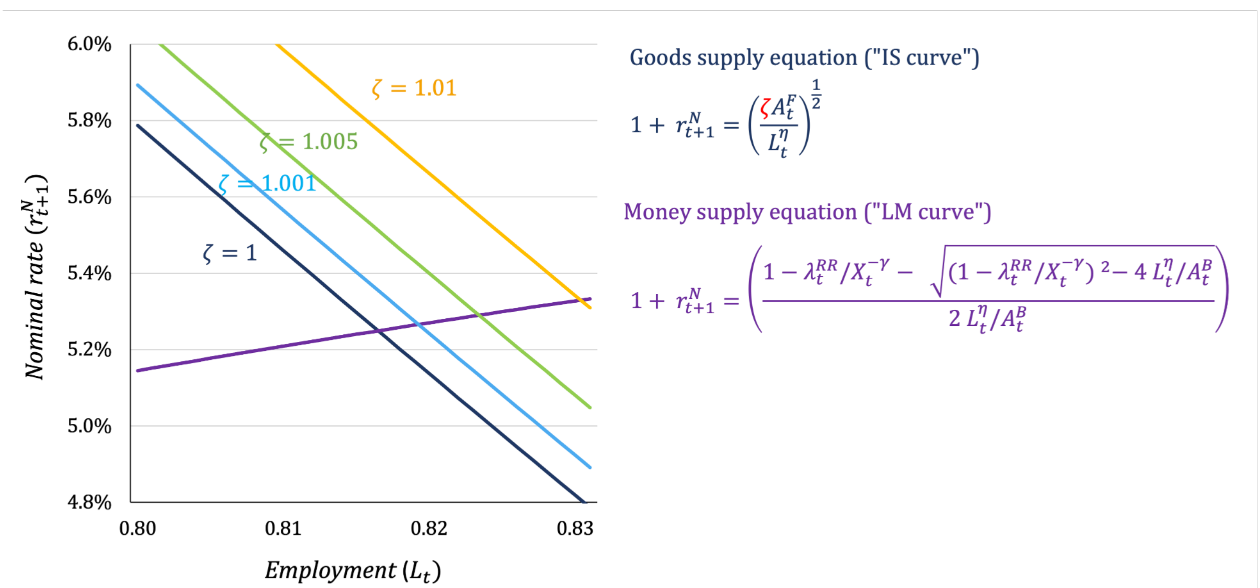


Figure 6: Decrease in bank productivity A^B ("financial crisis")

[29] In an endogenous growth setting, growth in A_t^F that increases the nominal rate should lead to increased innovation effort in the financial sector, leading to growth in A_t^B, and vice versa.

Changes in the relative values of A_t^B and A_t^F are probably more relevant over longer horizons, but negative shocks to A_t^B can also be interpreted shocks to the financial sector. Because the financial sector in my baseline calibration accounts for only a small fraction of employment, small shocks to A_t^B do not have a large impact on the economy. However, a large negative shock – which I interpret as a "financial crisis" shock – does significantly impact the real economy.[30] In figure 2, shifts in A_t^B shift the money supply curve in. Figure 6 shows the impact of a large negative shock A_t^B when λ_t^{RR} is fixed.

- **Deposits can pay a positive net nominal return and cash can coexist**

  The assumption that deposits pay no net nominal return[31] is necessary to define the nominal rate R_{t+1}^N as the ratio of the real return on bonds and the real return on deposits $\frac{R_{t+1}^B}{R_{t+1}^D}$, and therefore to derive the nice, nearly closed form solutions in the section above. This assumption is equivalent to assuming that all other quantities are measured in terms of deposits, and is consistent with the idea that that inside money is literally money – a store of value, a medium of exchange, and a unit of account.[32] However, I could add another no-net-nominal-return medium of exchange to the model, for example another type of central bank liability called cash. The main results of this paper should go through as long as cash is used only in a small percentage of transactions, cash and deposits are close substitutes, and the spread between the return on cash and return on deposits is small and does not vary significantly over the business cycle or in response to policy.

- **Banks do not need to directly hire labor**

  In this model, both firms and banks directly hire labor. This assumption is not critical for the results that follow in section 5 and section 6, but it is necessary to obtain an upward slope of the money supply curve in figure 2. This is because if the intermediation cost is denominated in goods instead of labor, changes in A_t^F that shift the goods supply curve do not affect the *relative* price of intermediation services, because financial sector inputs become cheaper at the same rate that demand for financial services (due to

[30] For example, the spread of financial innovations such as structured asset backed securities and credit default swaps contributed to both financial and real growth in the late 20th century, and the 2007-2008 financial crisis was caused, arguably, by a negative shock to the real and/or perceived usefulness of these innovations, harming the ability of the financial sector to transform risky debt into safe, tradable debt.

[31] Or equivalently, a gross nominal return on 1

[32] This assumption also means that the model object D_{t+1} does not precisely align with empirical deposits, which generally pay a positive net nominal return, and which in this model could correspond to some combination of inside money and zero sum debt.

greater output) increases, resulting in a flat money supply curve. Modeling financial sector employment makes the problem slightly harder, but it is more realistic, and more clearly conveys the idea the employment and consumption depend both on the productivity of the goods sector A_t^F and the productivity of the financial sector A_t^B.

5 Monetary policy analysis

5.1 Impulse response

The main result of this paper is that in the flexible price baseline a contractionary monetary shock that increases the target nominal rate R_{t+1}^N lowers both employment L_t and inflation π_t, provided that the shock is not too persistent.[33] This result is surprising, because in many Monetarist models contractionary monetary policy produces "Fisherian inflation": an increase in the nominal rate R_{t+1}^N is associated with an increase in inflation π_t. In this model contractionary monetary policy is still Fisherian in the long term: a persistent shock raises the rate of inflation. But it is Keynesian in the short term; a *temporary* increase in the nominal rate raises the real rate enough to lower inflation.

The intuition behind this result is as follows. The object of interest in this model and most Monetarist models is the same, the spread between the real return on safe assets (bonds) and the real return on money (deposits) $(R_{t+1}^B - R_{t+1}^D)$, which is proportional to the nominal rate R_{t+1}^N, which is the price of money. A contractionary shock widens this spread, making money more expensive acting as a tax on real output. In many Monetarist models, the monetary authority increases this spread by increasing the growth rate of the outside money supply, which increases the rate of inflation π_{t+1}, which lowers the real return on money R_{t+1}^D, which is equal to the inverse of inflation. π_{t+1} increases in response to a contractionary monetary policy because (typically) an increase in π_{t+1} *is* the experiment studied in these models.[34]

In this model, the central bank implements a contractionary shock by increasing the price the private financial sector charges for providing intermediation services, not by changing π_{t+1}. In other words, a contractionary shock increases the spread $(R_{t+1}^B - R_{t+1}^D)$ directly, leaving the real return on money undetermined. The response of π_{t+1} to a contractionary shock depends on the evolution of this spread (which is proportional to the nominal rate)

[33] The version of the model with sticky prices presented in the appendix additionally incorporates the standard New Keynesian mechanism; there I show the marginal effect of sticky prices.

[34] Many Monetarist models also either do not include a cost channel linking the price of money to the real economy, or focus on long term steady states, where, in both Monetarist and New Keynesian models as well as in this model, an increase in the nominal rate generally produces an increase in the rate of inflation.

and the evolution of the real return on safe assets R^B_{t+1} (the real rate), which through the Euler equation is determined by the path of employment and real output. Due to the inside money cost channel, output falls in response to a contractionary shock and then slowly recovers to its steady state value, pushing the real rate up. In the baseline calibration, the real rate increases by more than the nominal rate, which means the real return on money increases, and inflation falls.

Figure 7 shows the response of key variables to a contractionary monetary shock (an increase in v_t) in the flexible price baseline model presented in section 2. This shock corresponds to a temporary inward shift of the money supply curve in figure 2. The impulse responses plotted below vary only in the persistence of the monetary shock (ρ_v). The shock is to the monetary policy rule, which directly increases the target nominal rate, but as discussed in section 2 the central bank targets the nominal rate by changing the level of central bank reserves CB_{t+1}, which change the magnitude of the constraint on the financial sector λ^{RR}_t. The change in the quantity of central bank reserves is shown in the first panel of figure 7.

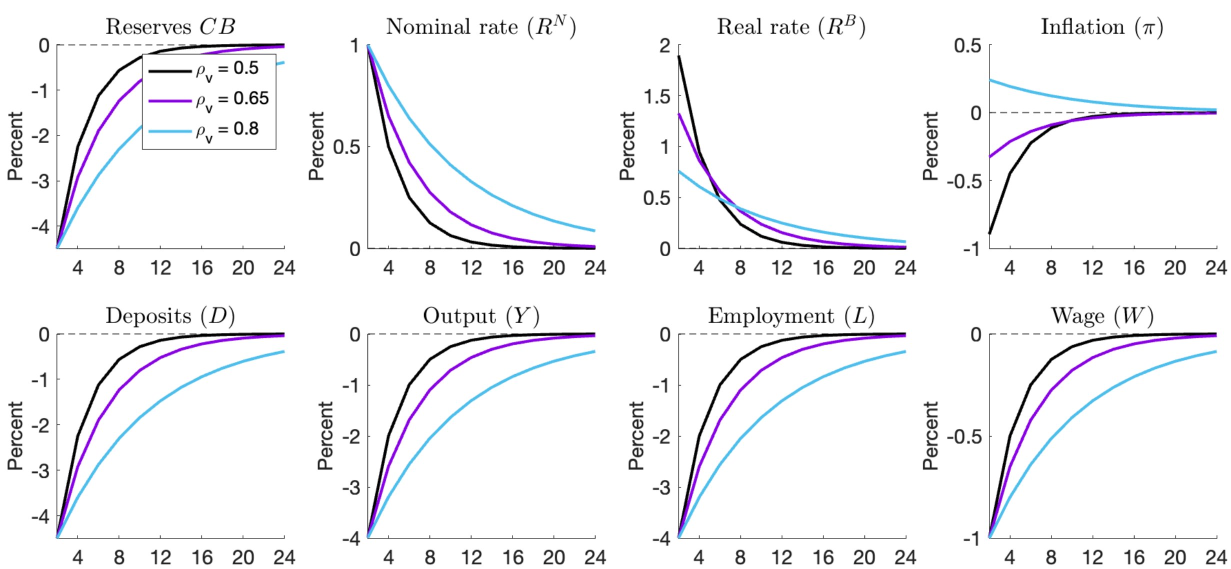


Figure 7: Baseline flexible price monetary shock, with three different persistence levels

The calibration is discussed below. The x-axis shows the number of quarters from the initial monetary shock. Responses are shown in percent deviations from the steady state. Interest rates are gross interest rates, meaning that a 1% increase in the nominal rate R^N_{t+1} relative to its steady state value, 1.05, corresponds to approximately an 105 basis point increase in the nominal rate. Likewise, a 1% decrease in inflation relative to its steady state value corresponds to about a 100 basis point decrease in inflation. For this experiment I assume that the central bank targets a fixed nominal rate R^N_{ss} and does adjust this target in response to inflation or employment ($\phi^\pi = 0$ and $\phi^L = 0$).[35]

The least persistent of the three shocks plotted above produces the sharpest decline and recovery in employment, output, and the wage. Through the Euler equation, this translates into the largest increase in the real rate. Inflation is then determined by the difference between the nominal rate and the real rate. Because in the least persistent case the real rate rises by almost twice as much as the nominal rate, inflation falls by about 1%. Inflation also falls in response to the second least persistent monetary policy shock, although because the decline in output is not as sharp and the real rate therefore does not increase by as much, inflation does not fall by as much.

In response to the most persistent of the three shocks, inflation increases. This is the "Fisherian" inflation that is common in monetarist models. If the shock is permanent, the resulting permanent increase in the nominal rate will correspond to a permanent increase in inflation, because long run steady state real rate is determined only by time preference β. A permanent increase in the nominal rate will also lead to a permanent decline in employment and output, as illustrated in figure 5 in section 4.

5.2 Calibration

This section discusses the calibration of the baseline model, and the importance of each choice for the key results of the paper. The baseline model is highly stylized, with very few free parameters, and neither the steady state solution nor the impulse responses presented above are intended to fully match reality. The goal of this section is to convince readers that the mechanisms described above *could* be quantitatively relevant in an extended model with a more serious calibration. Table 1 summarizes. Parameters are the same in the flexible price and the sticky price model presented in the appendix, except for θ and ϕ^π, as noted.

First, it is necessary to define the length of time that corresponds to one model period. The baseline model is (a version of) a cash in advance model with unit velocity, and one period corresponds to the length of time it takes for the stock of inside money to circulate once. Empirically, the stock of inside money in the U.S. can be approximated by M2, which measures the quantity of money deposited in checking accounts, savings accounts, and other short-term saving vehicles.[36] Comparing nominal M2 to nominal transactions, an appropriate

[35] See appendix for the response of the flexible price model with a full Taylor rule.

[36] As discussed in section 4, the model object D_{t+1} does not correspond exactly to empirical deposits. M2 is still, however, the most obvious empirical analogue.

Name	Parameter	Value	Target	Notes
Preferences				
Time preference	β	.961	R^B_{ss}	Di Tella et al, 2023
Frisch Elasticity	η	2	$\sim L_t$ dynamics	Standard: $\approx$ .5
CRRA	γ	5	$\sim \pi_{t+1}$ dynamics	Standard: at least 2
Technology				
Relative fin. productivity	A^B_{SS}/A^F_{SS}	100	L^F_t/L_t	NIPA: $\approx$ 5%
Nominal frictions	θ	0 / 0.9	PC slope	Hazell et al (2022)
Policy				
Steady state nominal rate	R^N_{ss}	1.052	π_{ss}	NIPA: $\approx$ 2.3%
Response to inflation	ϕ^π	0 / 1.01		Depends on experiment
Response to employment	ϕ^L	0 / 0		Depends on experiment
Reserve requirement	ϕ^{RR}	0.25	D_t/CB_t	M2/M0 $\approx$ 5

length for one period about half a year.[37] To keep with convention, I have relabeled the x-axis of the impulses responses plotted above such that one period is one quarter, but in this calibration one period is two quarters.

The second challenge is identifying the right measure for the steady state nominal rate. In the baseline model the steady state nominal rate is a *policy* variable; as long as the reserve requirement binds, the central bank can determine its value. I calibrate the steady state nominal rate to match the "zero beta rate" in Di Tella et al. (2023).[38] They find a annualized real safe rate equal to about 8.3%; plus long-term inflation ($\sim$ 2.3%) this translates to a two quarter steady state nominal return of about 5.2%.

The intertemporal elasticity of substitution (IES), which with CRRA preferences is equal to $1/\gamma$, is important for generating a decline in inflation in response to a contractionary monetary policy shock. The lower the IES, the larger the response of the real rate to changes in output and employment. I set the IES to 0.2 ($\gamma = 5$), which is on the lower (but not lowest) end of IES estimates consistent with the zero beta rate. A lower IES also helps with the entrepreneurial risk results in the next section.

For inflation to fall in response to a contractionary monetary policy shock, the elasticity of employment to the nominal rate must be high enough to generate an increase in the real rate larger than the increase in the nominal rate. As illustrated in figure 2, the response of employment to shocks that shift the money supply curve depends on the flatness of the goods supply curve. To generate a sufficiently flat goods supply curve, I assume that the

[37] The velocity of money measure calculated by the Federal Reserve Bank of St. Louis and is generally between 1 and 2, but compares M2 to *annualized* quarterly GDP.

[38] Another possible approach to claibrating the nominal rate is to use the cash in advance market clearing condition and the ratio of the spending on financial services to total GDP in the national accounts to approximate the spread the financial sector earns, similar to the approach in Philippon (2015). However, this approach conflates the role the financial sector as a provider of liquidity and as a provider of insurance.

Frisch elasticity is 2; most micro estimates are closer to 0.5. However, I think it is reasonable to assume that an extended model with a more serious calibration could generate a sufficiently flat goods supply curve with a Frisch elasticity more in line with micro estimates. For example, I discuss in section 4 how longer supply chains flatten the goods supply curve; if I assume that each unit of output requires four money transactions, I can generate similar impulse responses to those in figure 7 with a a Frisch elasticity of 1.[39] I can do the same with a lower IES (~ 0.1).

Finally, I calibrate the ratio of the steady state values of financial sector and goods sector productivities to roughly match the fraction of employment in the financial sector,[40] and the reserve requirement to match the ratio of central bank reserves to transactions.

6 Empirical support

This section discusses empirical support for my assumptions and for my framework more generally. There are are least three ways I can approach empirically validating my framework:

1. **Comparison of model predictions**

   First, I can compare the empirical predictions of my framework to the predictions of other business cycle frameworks, or more specifically, the New Keynesian framework. This is a bit of a challenge, partially because my primary result is to show that I can do something the baseline New Keynesian model can also do (standard monetary policy), but without sticky prices, and partially because the New Keynesian literature is so large, I cannot say for sure that my model can do anything that a creatively extended sticky price model cannot. However, there are some implications of my model that differ significantly from the implications of the baseline New Keynesian model.

   Most importantly, because the key relationship in my model is between employment and the nominal rate and there is no New Keynesian Phillips curve (NKPC), the relationship between employment, inflation, and expected inflation varies depending on the type and persistence of shocks hitting the economy. Figure 8 plots the impulse responses to identical monetary policy shocks in the baseline New Keynesian model and the flexible price baseline model on axes that roughly correspond to expectations-augmented Phillips curve (Phelps (1967)), Friedman (1968)). As there is technically no

[39] A unit of consumption would require four money transactions if, for example, the good was produced with labor by an intermediary firm, and then sold to a retailer who also hires labor, before being sold to a final consumer. Most goods require far more than four money transactions to reach the end consumer.

[40] This ratio does not move significantly over the business cycle, either in the data or in this model.

unemployment in either the baseline New Keynesian model or the flexible price baseline in this paper, the x-axis plots the inverse of in employment relative to the steady state, and the y-axis plots inflation minus expected inflation. The shocks are the same as in figure 7; the only difference between the colored dots is the persistence of the monetary policy shock generating the impulse responses. Because the NKPC has a fixed slope determined by exogenous parameters, the slope in the left panel below does not vary in response to changes in persistence. In contrast the slope in the right varies significantly with changes in persistence. The light blue dots in the right panel of figure 8 correspond to the light blue lines in figure 7, the "Fisherian inflation" case, which produces an upward sloping Phillips curve.[41]

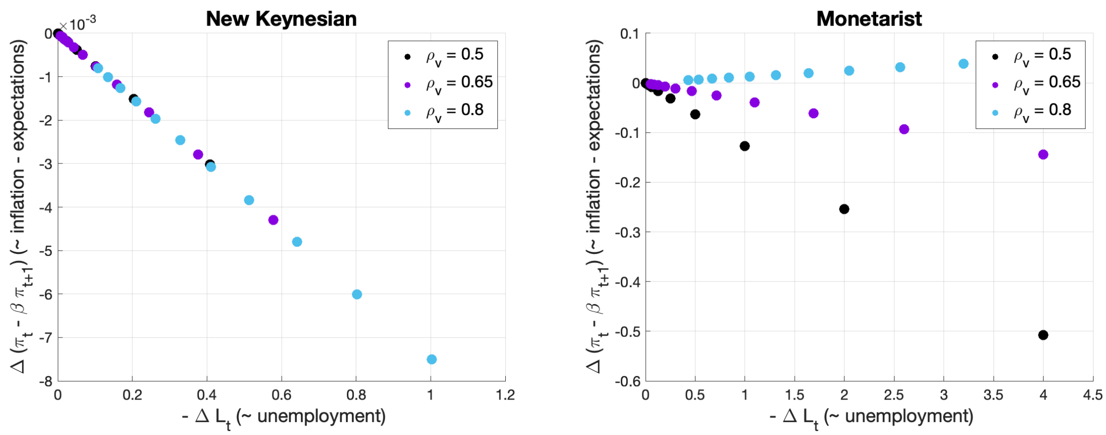
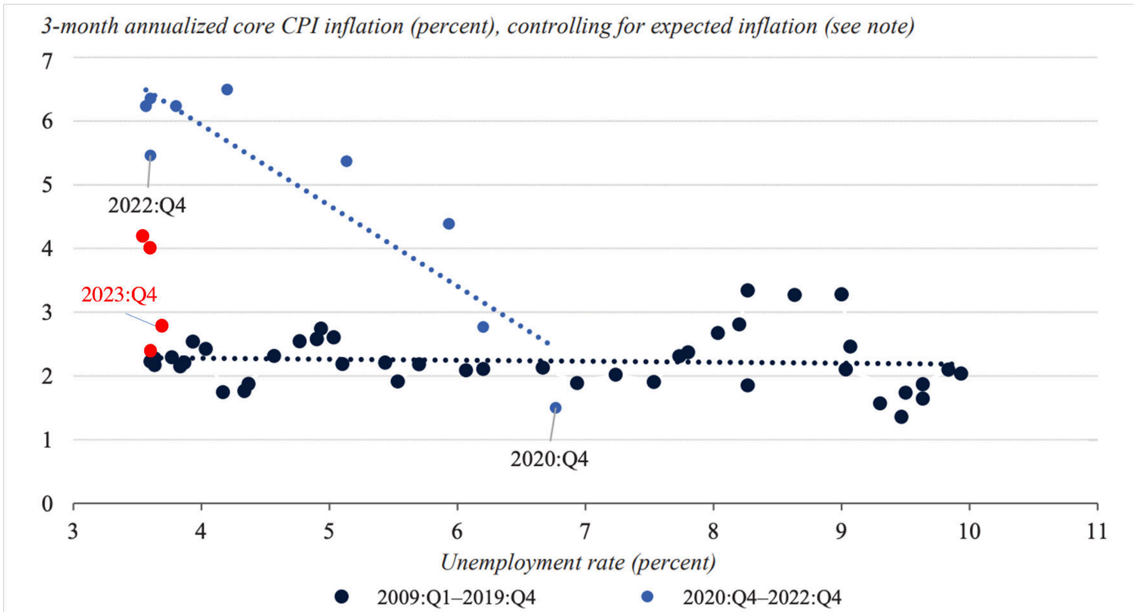


Figure 8: Impulse response generated Phillips curve in two models

There is widespread agreement that the slope of the naive (not expectations-augmented) Phillips curve shifts over time; this was one of the reasons why economists started looking at expectations-augmented Phillips curve in the first place. The literature on the variability of the expectations-augmented Phillips curve is more divided. The difficulty is that expectations are hard to measure. The easiest way to measure inflation expectations is to conduct surveys. Many survey measures of inflation expectations, especially long-term inflation expectations, are slow-moving lag actual inflation, meaning that estimates of the slope of the expectations-augmented Phillips curve calculated using survey measures often resemble estimates of the slope of the naive Phillips curve. For example, Figure 9, reproduced from the 2023 Economic Report of the President, shows empirical expectations-augmented Phillips curve over two intervals. The red dots represent the four two quarters of 2024 (not included in the original figure). A more formal

[41] In the appendix, I show these plots for productivity shocks.

cross-country exploration of Phillips curve slopes by Hobijn et al. (2023) confirms that Phillips curve slopes seem to have changed recently, even controlling for expectations. However, other measures, notably Hazell et al. (2022) estimate a relatively fixed slope over time.



Sources: Bureau of Labor Statistics; Federal Reserve Bank of Philidelphia.
Note: CPI = Consumer Price Index. The y axis shows a measure of the actual rate of inflation minus the difference betwen the expected rate of inflation and the long-term rate of inflation, or π - (E[π] - π*), where π = core CPI inflation, E[π] = 1-year lagged median 1-year ahead core CPI inflation expectations from the Federal Reserve Bank of Philidelphia's Survey of Professional Forecasters, and π* = the long-term (post-2000) average of core CPI inflation, 2.3 percent. Actual CPI inflation seasonally adjusted.

Figure 9: The expectations-augmented Phillips curve over two intervals

Both the baseline New Keyensian model and the flexible price baseline model produce "Fisherian inflation" in response to persistent contractionary shocks, but it is substantially *easier* to produce it here than in the New Keynesian model, consistent with this paper's monetarist roots. Previous papers have noted that, depending on the on the use case, this can be seen as an advantage. Specifically, Barth III and Ramey (2001) argue that a cost channel can help resolve the empirical "price puzzle", where inflation first rises and then falls in response to a monetary shock. While the existence of the price puzzle is a subject to debate (Rusnák et al., 2013), it is possible to replicate it in this framework, with a a slow-moving monetary shock (see appendix).

2. **Validation of the "inside money cost channel"**

   Another way to validate my framework is to look for empirical support for my assumptions and their microeconomic implications. The primary difficulty of this approach is finding appropriate empirical analogues for model objects. I give two examples.

First, the money market clearing condition implies that there is a correlation between real economic activity, i.e. employment and output, with the supply of money, and because money is inside money, with gross private household debt.[42] This turns out to be true in the data, as shown in the figure 10, which plots the demeaned growth rates of the Bank for International Settlements measure of total credit to the private nonfinancial sector and the sum of GDP and Personal Income.[43] Expansions in gross private debt are associated with economic expansions; when debt is money, the economy must go into debt to grow.

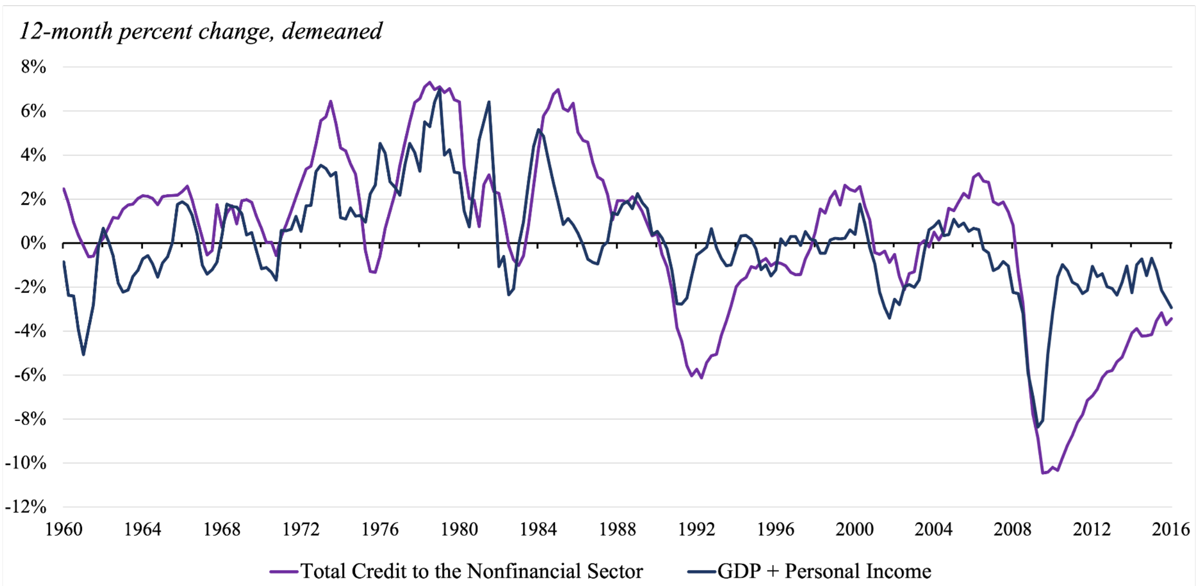


Figure 10: Correlation between growth of gross private debt and transactions

Second, regardless of the particular way I model monetary policy, a key idea is that monetary policy affects the quantity and therefore the price of inside money provided by the private financial sector, or in other words, the price of liquidity. Money is a services flow; the financial sector creates *liquidity*, the ultimate measure of which is the nominal rate. The baseline model does not model financial sector in detail and includes

[42] I compare real economic activity to gross debt instead of a more obvious measure of the money supply like M2 because "deposits" in this framework does not exactly correspond to empirical deposits. Most importantly, the *only* role of banks in this model is to provide liquidity; they do not perform another key financial sector function, providing insurance. Deposits are also an important safe asset used for insurance purposes, and as such their quantity may vary over the business cycle for other reasons.

[43] In a heterogeneous agent version of the model, the quantity gross debt may differ from transactions due to the fluctuations in the quantity of of zero-sum debt. In figure 11, demeaning controls for trends in zero-sum gross debt.

only one nominal rate, but in reality there are a wide range of nominal rates. Assets that are more liquid, either because they are easier to trade and use for payments, or more useful for interbank clearing, generally pay lower nominal rates. If monetary policy works by changing the price of liquidity, contractionary shocks should increase the spreads between less liquid and more liquidity assets. Figure 11 shows the response of the Federal Funds Rate, employment (total non-farm payroll), and a measure of liquidity, the spread between the 3-month Treasury bill and the Federal Funds Rate, to a Romer & Romer monetary policy shock.[44] The relationship between liquidity spreads and monetary policy is also discussed in Kashyap et al. (2002), Nagel (2016), and Drechsler et al. (2018).

Figure 11: Response of liquidity spreads to a monetary policy shock

3. **Avoidance of several known empirically sticky issues**

   There is a large literature that documents and proposes resolutions for empirical "puzzles" associated with the baseline New Keynesian model. A third, lazy way to empirically validate my framework is simply to note that by avoiding sticky prices I avoid these issues. For example, as previously discussed, the standard New Keynesian determinancy constraint does not apply in the flexible price baseline model, making it possible to study a variety of monetary policy rules. This is empirically relevant because historically (and recently) monetary policy has sometimes deviated from the set of Taylor rules consistent with a determinant New Keyensian solution (Orphanides, 2003). Also, in a New Keynesian models expansionary demand shocks (monetary or otherwise) raise output by lowering firm markups. Demand-driven business cycles therefore generate countercyclical markups. The empirical evidence on the cyclicality of markups

[44]Impulse responses are calculated using the Jorda local projection method. Controls for this specification are industrial production, VIX, & the S&P 500.

is mixed, with many studies finding acyclicality and some finding procyclicality (e.g. Nekarda and Ramey (2013)). Adjusting for time preference, there are no profits in the the flexible price baseline model of this paper and the core mechanism does not depend on fluctuations in profits or markups. Further, the flexible price model also avoids the forward guidance puzzle, for example as documented by Del Negro et al. (2023).[45] Fourth and finally, the flexible price mechanism does not, by definition, depend on sticky prices, the empirical relevance of which has occasionally been challenged. (e.g. Bils and Klenow (2004)).[46].

7 Conclusion

In this paper I have presented a tractable flexible price business cycle model where the key friction is that inside money produced by the private financial sector is necessary for payments. The nominal rate is the cost of inside money, and increases in the nominal rate driven either by monetary policy or by other shocks to the financial sector generate a declines in aggregate employment and output. If the decline output is large enough, contractionary shocks also lower inflation, a moment that can be hard to achieve in flexible price models. The equilibrium of the model can be summarized by the intersection of two curves, the goods supply curve and the money supply curve. Monetary policy shocks, financial shocks, productivity shocks, and risk shocks (see appendix B) can be interpreted as temporary shifts in these curves.

[45] In fact, there is no role for policy or inflation expectations at all in baseline flexible price model, which is a weakness. However a role for expectations could be adding by introducing sub-period timing frictions, for example.

[46] Another commonly cited issue with the New Keynesian framework is its implications for optimal policy. In the baseline New Keynesian model welfare is maximized when net inflation and the output gap are both 0, and the monetary authority can achieve this "divine coincidence" with a very aggressive Taylor rule. This means, from an optimal policy point of view, there is no trade-off between output and inflation. This is not true with a cost channel, as noted by Ravenna and Walsh (2006). As previously discussed in section 4, optimal policy in this model is also not a Friedman rule.

References

Acemoglu, D., Akcigit, U., and Kerr, W. (2016). Networks and the macroeconomy: An empirical exploration. *Nber macroeconomics annual*, 30(1):273–335.

Afonso, G. and Lagos, R. (2015). Trade dynamics in the market for federal funds. *Econometrica*, 83(1):263–313.

Aiyagari, S. R. (1994). Uninsured idiosyncratic risk and aggregate saving. *The Quarterly Journal of Economics*, 109(3):659–684.

Ajello, A. (2016). Financial intermediation, investment dynamics, and business cycle fluctuations. *American Economic Review*, 106(8):2256–2303.

Arellano, C., Bai, Y., and Kehoe, P. J. (2019). Financial frictions and fluctuations in volatility. *Journal of Political Economy*, 127(5):2049–2103.

Bagehot, W. (1873). *Lombard Street: A description of the money market.* HS King&Company.

Barth III, M. J. and Ramey, V. A. (2001). The cost channel of monetary transmission. *NBER macroeconomics annual*, 16:199–240.

Basu, S. and Bundick, B. (2017). Uncertainty shocks in a model of effective demand. *Econometrica*, 85(3):937–958.

Bayer, C., Lütticke, R., Pham-Dao, L., and Tjaden, V. (2019). Precautionary savings, illiquid assets, and the aggregate consequences of shocks to household income risk. *Econometrica*, 87(1):255–290.

Benigno, P. and Eggertsson, G. B. (2023). It's baaack: The surge in inflation in the 2020s and the return of the non-linear phillips curve. Technical report, National Bureau of Economic Research.

Beraja, M., Hurst, E., and Ospina, J. (2019). The aggregate implications of regional business cycles. *Econometrica*, 87(6):1789–1833.

Bianchi, J. and Bigio, S. (2022). Banks, liquidity management, and monetary policy. *Econometrica*, 90(1):391–454.

Bils, M. and Klenow, P. J. (2004). Some evidence on the importance of sticky prices. *Journal of political economy*, 112(5):947–985.

Bloom, N., Floetotto, M., Jaimovich, N., Saporta-Eksten, I., and Terry, S. J. (2018). Really uncertain business cycles. *Econometrica*, 86(3):1031–1065.

Bordo, M. D. and Schwartz, A. J. (2003). Is-lm and monetarism.

Brunnermeier, M. K., Merkel, S. A., and Sannikov, Y. (2020). The fiscal theory of price level with a bubble. Technical report, National Bureau of Economic Research.

Brunnermeier, M. K. and Sannikov, Y. (2016). The i theory of money. Technical report, National Bureau of Economic Research.

Buera, F. J., Kaboski, J. P., and Shin, Y. (2011). Finance and development: A tale of two sectors. *American economic review*, 101(5):1964–2002.

CEA (2023). *Economic Report of the President.* White House.

Christiano, L. J. and Eichenbaum, M. (1995). Liquidity effects, monetary policy, and the business cycle. *Journal of Money, Credit and Banking*, 27(4):1113–1136.

Christiano, L. J., Motto, R., and Rostagno, M. (2010). Financial factors in economic fluctuations.

Cooley, T. F. and Hansen, G. D. (1989). The inflation tax in a real business cycle model. *The American Economic Review*, pages 733–748.

Del Negro, M., Giannoni, M. P., and Patterson, C. (2023). The forward guidance puzzle. *Journal of Political Economy Macroeconomics*, 1(1):43–79.

Del Negro, M., Lenza, M., Primiceri, G. E., and Tambalotti, A. (2020). What's up with the phillips curve? Technical report, National Bureau of Economic Research.

Di Tella, S. (2020). Risk premia and the real effects of money. *American Economic Review*, 110(7):1995–2040.

Di Tella, S. and Hall, R. (2022). Risk premium shocks can create inefficient recessions. *The Review of Economic Studies*, 89(3):1335–1369.

Di Tella, S., Hébert, B. M., Kurlat, P., and Wang, Q. (2023). The zero-beta interest rate. Technical report, National Bureau of Economic Research.

Drechsler, I., Savov, A., and Schnabl, P. (2017). The deposits channel of monetary policy. *The Quarterly Journal of Economics*, 132(4):1819–1876.

Drechsler, I., Savov, A., and Schnabl, P. (2018). Liquidity, risk premia, and the financial transmission of monetary policy. *Annual Review of Financial Economics*, 10:309–328.

Fisher, I. (1933). The debt-deflation theory of great depressions. *Econometrica: Journal of the Econometric Society*, pages 337–357.

Friedman, M. (1968). *The role of monetary policy*. Springer.

Gali, J. (1992). How well does the is-lm model fit postwar us data? *The Quarterly Journal of Economics*, 107(2):709–738.

Galí, J. and Gambetti, L. (2019). Has the us wage phillips curve flattened? a semi-structural exploration. Technical report, National Bureau of Economic Research.

Gertler, M. and Karadi, P. (2011). A model of unconventional monetary policy. *Journal of monetary Economics*, 58(1):17–34.

Gertler, M. and Kiyotaki, N. (2010). Financial intermediation and credit policy in business cycle analysis. In *Handbook of monetary economics*, volume 3, pages 547–599. Elsevier.

Goodfriend, M. and McCallum, B. T. (2007). Banking and interest rates in monetary policy analysis: A quantitative exploration. *Journal of Monetary Economics*, 54(5):1480–1507.

Greenwood, J., Hercowitz, Z., and Huffman, G. W. (1988). Investment, capacity utilization, and the real business cycle. *The American Economic Review*, pages 402–417.

Guerrieri, V., Lorenzoni, G., Straub, L., and Werning, I. (2021). Monetary policy in times of structural reallocation. *University of Chicago, Becker Friedman Institute for Economics Working Paper*, (2021-111).

Hazell, J., Herreno, J., Nakamura, E., and Steinsson, J. (2022). The slope of the phillips curve: evidence from us states. *The Quarterly Journal of Economics*, 137(3):1299–1344.

Hicks, J. R. (1937). Mr. keynes and the" classics"; a suggested interpretation. *Econometrica: journal of the Econometric Society*, pages 147–159.

Hobijn, B., Miles, R., Royal, J., and Zhang, J. (2023). The recent steepening of phillips curves. *Chicago Fed Letter*, (475).

Iacoviello, M. (2015). Financial business cycles. *Review of Economic Dynamics*, 18(1):140–163.

Jones, C., Midrigan, V., and Philippon, T. (2022). Household leverage and the recession. *Econometrica*, 90(5):2471–2505.

Kashyap, A. K., Rajan, R., and Stein, J. C. (2002). Banks as liquidity providers: An explanation for the coexistence of lending and deposit-taking. *The Journal of finance*, 57(1):33–73.

King, R. G. (2000). The new is-lm model: language, logic, and limits. *FRB Richmond Economic Quarterly*, 86(3):45–104.

King, R. G. and Plosser, C. I. (1982). The behavior of money, credit, and prices in a real business cycle. Technical report, National Bureau of Economic Research.

Kiyotaki, N., Moore, J., et al. (2000). Inside money and liquidity. *Unpublished manuscript, University of Edinburgh*.

Klein, L. R. and Goldberger, A. S. (1955). An econometric model of the united states, 1929-1952. *(No Title)*.

Lagos, R., Rocheteau, G., and Wright, R. (2017). Liquidity: A new monetarist perspective. *Journal of Economic Literature*, 55(2):371–440.

Lagos, R. and Zhang, S. (2022). The limits of onetary economics: On money as a constraint on market power. *Econometrica*, 90(3):1177–1204.

Leduc, S. and Liu, Z. (2016). Uncertainty shocks are aggregate demand shocks. *Journal of Monetary Economics*, 82:20–35.

Levine, R. (1997). Financial development and economic growth: views and agenda. *Journal of economic literature*, 35(2):688–726.

Mankiw, N. G. (2000). *Macroeconomics*. WH Freeman.

Mavroeidis, S., Plagborg-Møller, M., and Stock, J. H. (2014). Empirical evidence on inflation expectations in the new keynesian phillips curve. *American Economic Journal: Journal of Economic Literature*, 52(1):124–188.

Modigliani, F. (1944). Liquidity preference and the theory of interest and money. *Econometrica, journal of the econometric society*, pages 45–88.

Nagel, S. (2016). The liquidity premium of near-money assets. *The Quarterly Journal of Economics*, 131(4):1927–1971.

Nekarda, C. J. and Ramey, V. A. (2013). The cyclical behavior of the price-cost markup. Technical report, National Bureau of Economic Research.

Orphanides, A. (2003). Historical monetary policy analysis and the taylor rule. *Journal of monetary economics*, 50(5):983–1022.

Phelps, E. S. (1967). Phillips curves, expectations of inflation and optimal unemployment over time. *Economica*, pages 254–281.

Philippon, T. (2015). Has the us finance industry become less efficient? on the theory and measurement of financial intermediation. *American Economic Review*, 105(4):1408–1438.

Phillips, A. W. (1958). The relation between unemployment and the rate of change of money wage rates in the united kingdom, 1861-1957. *economica*, 25(100):283–299.

Piazzesi, M. and Schneider, M. (2018). Payments, credit and asset prices.

Ravenna, F. and Walsh, C. E. (2006). Optimal monetary policy with the cost channel. *Journal of Monetary Economics*, 53(2):199–216.

Rusnák, M., Havranek, T., and Horváth, R. (2013). How to solve the price puzzle? a meta-analysis. *Journal of Money, Credit and Banking*, 45(1):37–70.

Samuelson, P. (1948). *Economics*. McGraw Hill.

Sanches, D. and Williamson, S. (2010). Money and credit with limited commitment and theft. *Journal of Economic theory*, 145(4):1525–1549.

Tobin, J. (1969). A general equilibrium approach to monetary theory. *Journal of money, credit and banking*, 1(1):15–29.

Tobin, J. (1972). Friedman's theoretical framework. *Journal of Political Economy*, 80(5):852–863.

Williamson, S. D. (1987). Financial intermediation, business failures, and real business cycles. *Journal of Political Economy*, 95(6):1196–1216.

Williamson, S. D. (1999). Private money. *Journal of Money, Credit and Banking*, pages 469–491.

Williamson, S. D. (2012). Liquidity, monetary policy, and the financial crisis: A new monetarist approach. *American Economic Review*, 102(6):2570–2605.

A Adding Sticky Prices

A.1 Model with sticky prices

The model is the same as in section 3, except that there is a continuum of consumption goods indexed by $i \in [0,1]$, and a continuum of firms that each produce one type of consumption good. Firms take consumer demand as a given, and optimally set prices (and markups) to maximize profits. Prices are sticky; firms can reset prices in t with probability $(1-\theta)$. Households have a love of variety, with a constant elasticity of substitution ε between different consumption goods.

The problem of the representative household is below. Households choose how much of each type of consumption good $c_t(i)$ to demand, how much labor l_t^S to supply, what optimal prices $p_t^o(i)$ to set for individual goods $y_t(i)$ they produce, and the quantity of real intermediation services d_{t+1} to provide, decisions that correspond to their roles as consumer, worker, firm, and bank, respectively. Households also choose the quantity of real bonds b_{t+1} they hold; in the aggregate, this quantity will be negative, and correspond to the borrowing necessary to back deposits used for payments to firms for consumption and to workers to hire labor for firm and bank production. Each household is small and takes prices as a given (except for firm prices $p_t(i)$, where demand is taken as a given and appears below as a constraint), but because all households are identical in equilibrium individual quantities will correspond to aggregate quantities. P_t is defined such that $\int_i p_t(i)c_t(i)di = P_tC_t$ and is equal to $\left(\int_i p_t(i)^{1-\varepsilon}di\right)^{\frac{1}{(1-\varepsilon)}}$.

Household problem:

$$\max_{b_{t+1},c_t(i),\ell_t^S,p_t^o(i),d_{t+1}} \mathbb{E}_t \sum_{\tau=0}^{\infty} \beta^{t+\tau} \frac{x_{t+\tau}^{1-\gamma}}{1-\gamma} \qquad x_t \equiv c_t - \frac{\ell_t^{S\,1+\eta}}{1+\eta} \qquad c_t \equiv \left(\int_i c_t(i)^{\frac{(\varepsilon-1)}{\varepsilon}}di\right)^{\frac{\varepsilon}{(\varepsilon-1)}}$$

$$\text{s.t. } P_{t-1}W_{t\text{-}1}\ell_{t\text{-}1}^S + \int_i p_{t\text{-}1}(i)y_{t\text{-}1}(i)di + (R_t^N - 1)P_{t-1}d_t + R_t^N P_{t-1}b_t =$$
$$\int_i p_t(i)c_t(i)di + P_tW_t\int_i \ell_t^F(i)di + P_tW_t\ell_t^B + P_tb_{t+1}$$

$$y_t(i) = A_t^F\ell_t^F(i)$$
$$y_t(i) = \left(\tfrac{p_t(i)}{P_t}\right)^{-\varepsilon}Y_t$$
$$p_{t+1}(i) = \theta p_t(i) + (1-\theta)p_{t+1}^o(i)$$
$$d_{t+1} = A_t^B\ell_t^B + CB_{t+1}$$
$$d_{t+1} \le \frac{1}{\phi^{RR}}CB_{t+1}$$

There are five first order conditions:

First order conditions:

$\frac{1}{R^N_{t+1}} = \beta \frac{\mathbb{E}[x_{t+1}^{-\gamma}]}{x_t^{-\gamma}} \frac{1}{\pi_{t+1}}$ (Euler equation)

$c_t(i) = \left(\frac{p_t(i)}{P_t}\right)^{-\varepsilon} c_t$ (Consumption good demand)

$\ell_t^{S\eta} = \beta \frac{\mathbb{E}[x_{t+1}^{-\gamma}]}{x_t^{-\gamma}} \frac{1}{\pi_{t+1}} W_t = \frac{1}{R^N_{t+1}} W_t$ (Labor supply)

$\mathop{\mathbb{E}}_t \sum_{\tau=t}^{\infty} \beta\theta^{t+\tau} \Big[x_{t+\tau}^{-\gamma} \big(\frac{1}{R^N_{t+\tau+1}} \frac{p_t^o(i)}{P_{t+\tau}} - \frac{\varepsilon}{\varepsilon-1} \frac{W_{t+\tau}}{A^F_{t+\tau}} \big) y_{t+\tau}(i) \Big]$ (Firm optimal price setting)

$\frac{1}{R^n_{t+1}}(R^n_{t+1} - 1) - \big(\frac{W_t}{A_t^B} + \frac{\lambda_t^{RR}}{x_t^{-\gamma}}\big) = 0$ (Bank labor demand)

The fourth condition is standard for sticky price models – firms aim to minimize the weighted deviations of their reset price from their marginal cost, plus a markup – except, again, for the appearance of the nominal rate. Here the nominal rate acts as a tax on output, raising prices further.

Market clearing is the same, where C_t is the aggregate analogue of representative household consumption c_t, and Y_t is defined as $\left(\int_i y_t(i)^{\frac{(\varepsilon-1)}{\varepsilon}} di \right)^{\frac{(\varepsilon)}{\varepsilon-1}}$.

A.2 Solution with sticky prices

When prices are sticky and competition is imperfect, the solution to the model is almost the same except for goods supply curve, which due to sticky prices additionally relates firm marginal cost to current and future inflation. This equation can be interpreted as a New Keynesian Phillips curve with a cost channel. In log-linearized form:[1]

$$\hat{\pi}_t = \frac{(1-\beta\theta)(1-\theta)}{\theta}(\eta\hat{l}_t + 2\hat{r}^N_{t+1} - \hat{a}^F_t) + \beta\mathbb{E}[\hat{\pi}_{t+1}] \qquad \text{(Sticky price goods supply equation)}$$

The term $\eta\hat{l}_t + 2\hat{r}^N_{t+1} - \hat{a}^F_t$ captures deviations from steady state marginal cost, and includes the nominal rate because deposits are necessary for payments. Again, the square (here a 2) is because two payments are necessary for each unit of consumption produced, from the consumer to the firm and from the firm to the worker. This equation can be broken into two separate equations, one equal to the flexible price goods supply curve, and the other a Phillips curve relating inflation to the output gap.[2] In the system below, values with a star (e.g. $\hat{l}_t^*$) are deviations from aggregate steady state values in the flexible price model, and

[1]Note that in New Keynesian models the nominal return on bonds that mature in $t+1$ is sometimes referred to as R^N_t; here I am using the notation established earlier, where the nominal return on bonds that mature in $t+1$ (b_{t+1}) is R^N_{t+1}. Also note that, as with the flexible price system above, a full solution involves solving for the share of goods sector employment in total employment L^F_t/L_t and $X_t = C_t - L_t^{1+\eta}/1+\eta$.

[2]Ravenna and Walsh (2006) include a nominal interest rate gap term in their Phillips curve in order to analyze optimal policy. However, in my analysis I assume that the monetary authority always sets $\hat{r}^N_{t+1} = \hat{r}^{N*}_{t+1}$.

values without a star (e.g. $\hat{l}_t$)) are deviations from steady state values in the sticky price model.

Sticky price, imperfect competition solution:

$$\hat{a}_t^F - \eta \hat{l}_t^* - 2\hat{r}_{t+1}^N = 0 \quad \text{(Flexible price goods supply equation)}$$

$$\hat{a}_t^B - \eta \hat{l}_t + (\tfrac{A_{ss}^B}{L_{ss}^\eta} - 1)\hat{r}_{t+1}^N - (\tfrac{A_{ss}^B \lambda_{ss}^{RR}}{L_{ss}^\eta R_{ss}^N X_{ss}^{-\gamma}})\hat{\lambda}_t^N = 0 \quad \text{(Money supply equation)}$$

$$\hat{r}_{t+1}^N = \phi^\pi \hat{\pi}_t + \phi^L \hat{l}_t + v_t \quad \text{(Monetary policy rule)}$$

$$\hat{\pi}_t = \tfrac{(1-\beta\theta)(1-\theta)}{\theta}\eta(\hat{y}_t - \hat{y}_t^*) + \beta \mathbb{E}[\hat{\pi}_{t+1}] \quad \text{(New Keynesian Phillips curve)}$$

$$\hat{x}_t = \tfrac{-1}{\gamma}(\hat{r}_{t+1}^N - \hat{\pi}_{t+1}) + \mathbb{E}[\hat{x}_{t+1}] \quad \text{(Euler equation)}$$

This model differs from the baseline New Keynesian model in two ways. First, there is an inside money cost channel. The baseline New Keynesian model always includes the last three equations in the system above, which are essential for studying the response of $\hat{y}_t$, $\hat{\pi_{t+1}}$, and $\hat{R}_{t+1}^N$ to monetary policy and other "demand" shocks. The "flexible price goods supply equation" is often not included because in New Keynesian models deviations of the flexible price level of output from the steady state $\hat{y}_t^*$ typically depend only on deviations of productivity from the steady state ($\hat{a}_t^F$). If productivity is fixed so is $\hat{y}_t^*$. Here, however, $\hat{l}_t^*$ and therefore also $\hat{y}_t^*$ also depend critically on $\hat{R}_{t+1}^N$.

Second, there is a money supply equation. New Keynesian models sometimes include a money demand equation that looks similar to the money supply equation but that relates an exogenous supply of outside money to the nominal rate, like the textbook Keynesian LM curve. The money supply curve instead relates $\hat{\lambda}_t^{RR}$ to the nominal rate. Like New Keynesian money demand equations, the money supply equation in this model is not essential for studying the response of $\hat{y}_t$, $\hat{\pi}_{t+1}$, and $\hat{R}_{t+1}^N$ in response to monetary policy shocks; $\hat{\lambda}_t^{RR}$ adjusts so that the monetary policy rule is met. However, the difference in motivation widens the scope for future analysis. For instance, as discussed in section 4, a more realistic model might assume that the monetary authority has only partial control over the economy-wide nominal rate $\hat{R}_{t+1}^N$ but full control over the Federal Funds Rate $\hat{R}_{t+1}^{FFR}$, which impacts the financial sector by changing the magnitude of some financial sector liquidity constraint $\hat{\lambda}_t^{FFR}$. When monetary policy only has limited control over the inside money supply, changes in A_t^B and other financial shocks also impact the economy-wide nominal rate, and therefore employment and output.

The difference between this sticky price model and the flexible price model is of course the New Keynesian Phillips curve. In the flexible price model, the rate of inflation has no direct impact on output (or utility), and is essentially just a residual determined by the nominal rate, the real rate, and the Fisher equation. In the sticky price model, inflation is related to the output gap via the Phillips curve. This also introduces indeterminancy. In the flexible price model, as is standard in monetarist models, π_{t+1} is determined in t, the solution is determinate for a variety of monetary policy rules. The standard New Keynesian issues apply in the sticky price model; $\phi_\pi \geq 1$ is a sufficient condition for determinism.

A.3 Monetary policy analysis with sticky prices

The figures below compares the response of key variables to a contractionary monetary shock in the sticky price and the flexible price baseline model. In figure 8, the persistence of the monetary shock ρ_v is 0.65 and the flexible price impulse responses correspond to the the medium persistence level in figure 7. In figure 9, the persistence of the monetary shock ρ_v is 0.8 and the flexible price impulse responses correspond to the the highest level of persistence level in figure 7.

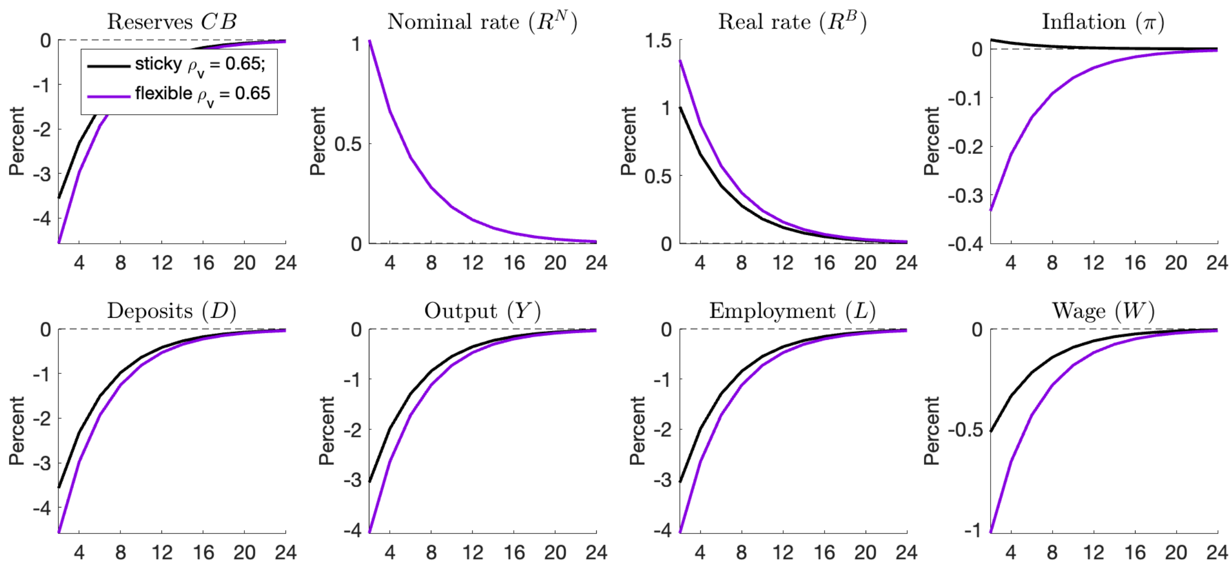


Figure A.1: Sticky vs flexible price responses, less persistent monetary shock

In the first scenario, when the monetary shock is less persistent, sticky prices actually attenuate the impact of the monetary shock. This is because in this case the cost channel causes the real rate to rise by more than the nominal rate, and so firms find it optimal to increase prices. This is similar to what happens in a New Keynesian model in response to a negative productivity shock, which also reduces flexible price output and therefore raises the flexible price real rate compared to the nominal rate. In the baseline calibration, this attenuation affect is modest; aggregate employment and output, and therefore the real rate, fall by slightly less than in the flexible case price initially, which, through the Fisher equation, leads to slightly positive inflation.[3]

[3]Note that with this calibration the sticky price model achieves something that a monetary shock in a model where sticky prices are the only friction generally cannot: the nominal rate, the real rate, and inflation all move in the same direction.

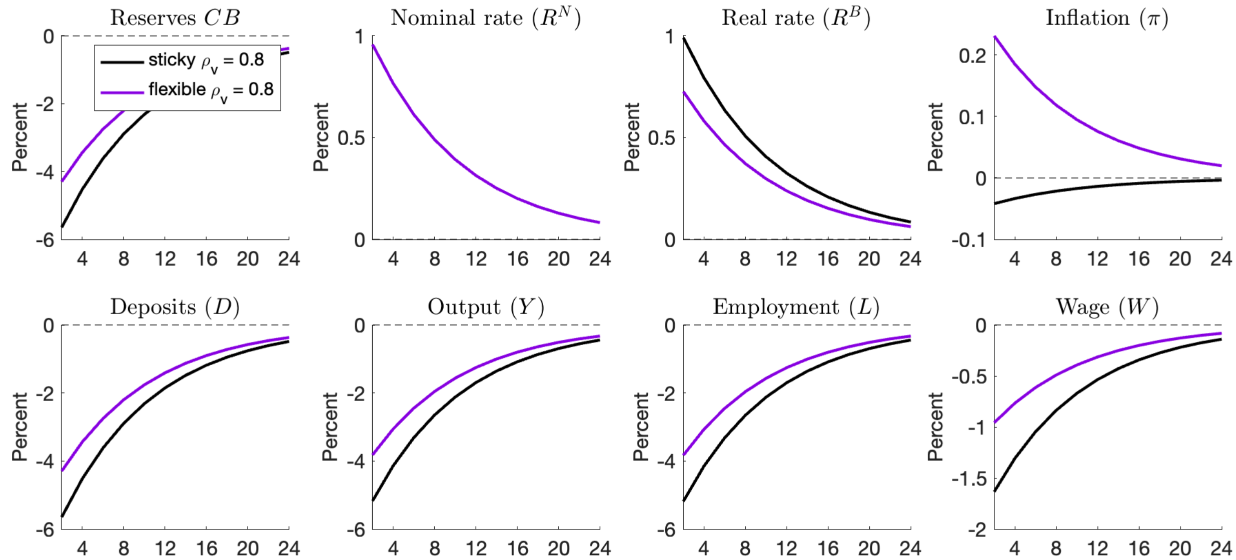


Figure A.2: Sticky vs flexible price responses, more persistent monetary shock

In the second scenario, when the monetary shock is more persistent, sticky prices slightly amplify the impact of the monetary shock. This is because in this case the cost channel causes the flexible price real rate to rise, but by less than the nominal rate, and so firms find it optimal to lower prices. However, this amplification is relatively modest, at least compared to the impact of monetary policy on real variables in a model with only sticky prices (i.e. the baseline New Keynesian model). This is because the increase in the flexible price real rate due to the inside money cost channel lowers the difference between it and the nominal rate, weakening the New Keynesian channel.

Together, the two figures above suggest that the flexible price inside money cost channel and the New Keynesian sticky price mechanism are more substitutes than complements, when it comes to jointly explaining the response of the nominal rate, inflation, and employment to short term monetary policy shocks. If the response of employment to the nominal rate is large enough to raise the flexible price real rate above the nominal rate and generate a decline in inflation in the flexible price model, sticky prices reverse the decline in inflation. If the response of employment to the nominal rate is not large enough to generate a decline in inflation in the flexible price model (Fisherian inflation), sticky prices will reverse the increase inflation, creating the expected negative correlation between the nominal rate and inflation, but the overall impact on inflation will be small.

B Adding Entrepreneurial Risk

In the New Keynesian framework, monetary policy shocks change the real rate, which via sticky prices and imperfect competition changes aggregate output. Monetary policy shocks are interpreted as "demand shocks", and so are a wide variety of non-productivity shocks that impact the economy in the same way, including, for example, risk shocks and fiscal policy shocks. In the sections above I have proposed a way to model monetary policy without sticky prices, and I have also argued that a wide variety of flexible price financial shocks impact the economy in the same way. I have not, however, proposed an alternative way to model non-monetary and non-financial "demand" shocks. To do this I am going to introduce a new element, "entrepreneurial risk" and argue that shocks that either directly or indirectly impact "entrepreneurial risk" correspond to shifts in the goods supply curve, and can be interpreted as demand shocks.

B.1 Entrepreneurial risk simple example

Many papers have documented an inverse relationship between measures of risk and uncertainty and measures of aggregate output, including Basu and Bundick (2017), Bloom et al. (2018), and Di Tella and Hall (2022). However, in most flexible price macroeconomic models increases in risk are expansionary. In this subsection I define "entrepreneurial risk", contrasting it with two types of risk more commonly found in macroeconomic models, "capital risk" and "labor risk", and explain why increases in entrepreneurial risk can generate flexible price contractions where increases in capital and labor risk do not. I then characterize the impact of entrepreneurial risk in a simple model without inside money.

In a standard representative agent real business cycle model, the only type of risk that matters for aggregate output is "capital risk". Increases in the volatility of firm productivity affect aggregate output by increasing the volatility of the return on capital. The impact of higher capital return volatility on aggregate capital investment and therefore output depends on the household intertemporal elasticity of substitution (IES). If the IES is greater than one, risk is contractionary. If the IES is less than one, the case consistent with most microeconomic estimates, the precautionary motive dominates and risk is expansionary. Because an increase in firm productivity volatility means that future consumption is more volatile, households want to save more to insure themselves, and because in a representative agent real business cycle model the only aggregate savings vehicle is capital, this precautionary motive leads to an expansion in investment. Heterogeneous agent models commonly introduce another type of risk, "labor risk", which is often modeled as an idiosyncratic labor productivity process. In a model with capital, an increase in the variance of idiosyncratic labor prodcutivity increases the volatility of marginal utility and therefore impacts aggregate capital investment and output through the same channel as capital risk Aiyagari (1994).

I define "entrepreneurial risk" as the risk incurred by firms who must hire productive inputs (labor and capital) before they knowing how productive those inputs will be. Many macroeconomic models assume that to produce output in t firms hire the labor and capital in t, after productivity for t is realized, meaning that there is no entrepreneurial risk.[4] Entrepreneurial risk lowers demand for both labor and capital; the net impact on the economy depends on the response of labor and capital supply. In a representative agent model where labor that is hired in advance is the only production input, an increase in the volatility of

[4]Many macroeconomics models also *do* include entrepreneurial risk. For example, firm dynamics models that assume that firms with idiosyncratic productivity must produce with privately owned capital instead of rented capital include *capital* entrepreneurial risk. Labor market search models that assume labor must be hired before productivity is realized include *labor* entrepreneurial risk.

firm productivity is typically expansionary, because households respond to an increase in the volatility of consumption by supplying more labor. But when households have GHH preferences, there is no income effect and therefore no offsetting increase in labor supply, and so an increase in entrepreneurial risk lowers employment.[5] In a representative agent model with only capital, the impact of entrepreneurial risk on investment is similar to the impact of capital risk on investment. However, both capital and labor are productive inputs and entrepreneurial risk lowers employment, the expected marginal product of capital can fall by enough to also lower investment.

Below I write a simple representative agent problem where the only production input is labor and the only friction is that labor must be hired in advance, i.e. households who operate firms must choose the amount of labor they hire in $t+1$ in t, before productivity in $t+1$ is realized. As in the baseline model in section 2, output is a linear function of firm labor, ℓ_t^F. In the aggregate, labor demand L_t^F equals labor supply L_t^S. Both firm productivity A_t^F and the volatility of firm productivity σ_t^F follow AR(1) processes.[6][7]

Household problem:

$$\max_{\{\ell^S_{t+1},\ell^F_{t+1}\}} \quad \mathop{\mathbb{E}}_{t=0} \sum_{\tau=t}^{\infty} \beta^{t+\tau} \frac{x_{t+\tau}^{1-\gamma}}{1-\gamma}; \quad x_t \equiv c_t - \frac{{\ell_t^S}^{1+\eta}}{1+\eta}$$

$$\begin{aligned} \text{s.t. } W_{t+1}\ell^S_{t+1} + A_t^F \ell_t^F &= c_t + W_{t+1}\ell^F_{t+1} \\ \ln A_t^F &= \rho_F \ln A^F_{t\text{-}1} + (1 \text{ - } \rho_F) \ln A^F_{ss} + \sigma^F_{t-1}\epsilon_t^F \\ \ln \sigma_t^F &= \rho_{\sigma^F} \ln \sigma^F_{t-1} + \sigma_{\sigma^F}\epsilon_t^{\sigma^F} \end{aligned}$$

First order conditions:

$$x_t^{-\gamma} W_{t+1} = \beta \mathbb{E}[x_{t+1}^{-\gamma}] {\ell^S_{t+1}}^{\eta} \qquad \text{(Labor supply)}$$

$$x_t^{-\gamma} W_{t+1} = \beta \mathbb{E}[x_{t+1}^{-\gamma} A^F_{t+1}] \qquad \text{(Labor demand)}$$

$$\rightarrow \quad L^{\eta}_{t+1} = \frac{\mathbb{E}[X_{t+1}^{-\gamma} A^F_{t+1}]}{\mathbb{E}[X_{t+1}^{-\gamma}]}$$

There are two first order conditions that after market clearing can be combined into one expression for aggregate employment. The term on the right hand side of the last expression above is decreasing in the volatility of firm productivity. In response to an increase in this

[5] More generally, an increase entrepreneurial risk is only contractionary in this model if the income effect is weaker than the substitution effect. In the long term, empirical evidence suggests that the income effect is slightly stronger than substitution effect, meaning that this mechanism is mostly relevant only in the short-term mechanism.

[6] To keep things as simple as possible I assume there are no assets, but adding a zero-sum bond would not change the problem.

[7] Wages are paid in advance, and the background assumption is that workers who are paid in t can costlessly commit to working the agreed upon amount of labor ℓ_{t+1} in $t+1$. If alternatively I wrote the problem such wages were agreed upon in advance but not paid until $t+1$, the main insights would be the same.

risk, employment and therefore aggregate output falls.

B.2 Model with entrepreneurial risk

The simple example in the subsection above is an entirely real model; there is no money and the price level is not defined. To study the impact of risk on inflation, I now add labor in advance to the baseline model presented in section 3. Timing gets somewhat complicated: due to the combination of labor in advance and debt payments, firms that hire labor in t to produce output in $t+1$ do not get the revenue from that output in $t+2$. The flexible price household problem is written below. I assume that only firm labor must be chosen in advance; banks chose the amount of labor they hire to produce intermediation services knowing period productivity A_t^B. The household chooses the amount of labor it supplies to firms in $t+1$, $\ell_{t+1}^{S,F}$, and the amount of labor it supplies to banks in t, $\ell_t^{S,B}$, separately.

Household problem:

$$\max_{b_{t+1},\ell_{t+1}^{S,F},\ell_t^{S,B},y_{t+1},d_{t+1}} \mathbb{E}_t \sum_{\tau=0}^{\infty} \beta^{t+\tau} \frac{x_{t+\tau}^{1-\gamma}}{1-\gamma} \qquad x_t \equiv c_t - \frac{\ell_t^{S\,1+\eta}}{1+\eta}$$

$$\text{s.t. } P_{t-1}W_t^F \ell_t^{S,F} + P_{t-1}W_{t-1}^B \ell_{t-1}^{S,B} + P_{t-1}y_{t\text{-}1} + (R_t^N - 1)P_{t-1}d_t + R_t^N P_{t-1}b_t = P_t c_t + P_t W_{t+1}^F \ell_{t+1}^F + P_t W_t^B \ell_t^B + P_t b_{t+1}$$

$$y_t = A_t^F \ell_t^F$$

$$\ell_t^S = \ell_t^{S,F} + \ell_t^{S,B}$$

$$d_{t+1} = A_t^B \ell_t^B$$

$$d_{t+1} \le \frac{1}{\phi^{RR}} CB_{t+1}$$

The simple closed form solutions from the baseline model are not obtainable due to the addition of entrepreneurial risk and the two-period delay between the labor market and the maturation of firm and bank revenue. However, the intuition from the simple example above and the intuition from the baseline model developed in sections 3, 4, and 5 do not change. Figure 14 shows the response of key variables to a shock that doubles the volatility of firm productivity, when monetary policy targets a fixed nominal interest rate.[8]

To generate a deflation in response to a contractionary risk shock, it is important that the shock be not very persistent. Increases in risk put downward pressure on the real rate, and the fall in output must be large and rapid enough to outweigh this downward pressure and increase in the real rate. This shock can be thought of as a sudden spike in uncertainty, for instance in response to a financial crisis or other world event, both severe and short lived. I discuss the calibration further in subsection 6.4.

[8]When monetary policy does not target a fixed nominal rate the equilibrium nominal rate declines slightly, consistent with an inward shift in the goods supply curve.

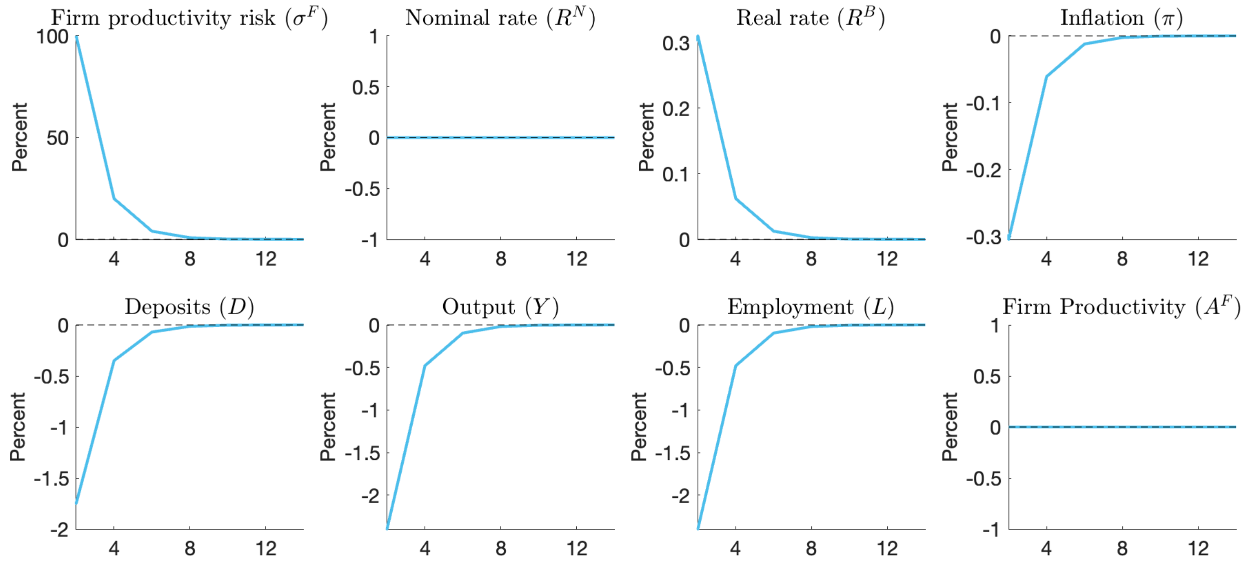


Figure B.3: Risk shock

B.3 Entrepreneurial risk model discussion

The bullets below clarify how the entrepreneurial risk mechanism outlined above works and how it should be interpreted, and briefly discuss applications relating to finance and fiscal policy.

- **Insurance increases output (finance & fiscal policy matter)**

  As can be seen in the expression in section 6.1, both increases in the volatility of firm productivity and increases in volatility of household consumption can lead to declines in employment and output. This means that increases in other types of risk, for example idiosyncratic labor productivity risk, can also generate contractions. Similarly, shocks or policy responses that increase insurance and lower the volatility of household consumption can be expansionary. For example, in a heterogeneous agent model with entrepreneurial risk temporary increases in unemployment insurance or in redistributionary transfers, both of which were U.S. fiscal policy responses to the 2020 COVID recession, could be expansionary. Further, in a heterogeneous agent model with entrepreneurial risk shocks that impact the financial sector would affect aggregate employment and output not only through the inside money cost channel, but also by affecting the provision of private insurance.

- **This mechanism can be interpreted as a flight to safety**

  Labor hired in t does not produce revenue until $t+2$, and firms (entrepreneurs) do not know the productivity of labor when they hire it. Wages can therefore be interpreted as risky "equity". Specifically, $P_t W_{t+1} \ell^F_{t+1}$ can be relabeled as firm equity e^F_{t+2} and $P_{t+1} y_{t+1}$ can be relabeled as the return on equity $R^E_{t+2} e^F_{t+2}$, where $R^E_{t+2} \equiv \frac{A_{t+1}}{W_{t+1}} \frac{P_{t+1}}{P_t}$. Both risk and inside money act like taxes on output, pushing the wage below the productivity of labor. When risk, perceived risk, or risk aversion increases, households lower amount of equity they hold. The safe asset in this scenario is leisure.

- **"Equity" can be either investment OR consumption**

  I have defined entrepreneurial risk as the risk incurred because the productivities of productive inputs are unknown prior to production. Firms (or banks) can be the parties exposed to this risk, as in the problem above, but consumers can also be exposed to this risk. For example, a consumer who purchases a car does not know how much utility that car will ultimately provide at the time they purchase it. The conversion from the productive inputs that went into the making of the car (labor and capital) to final consumption units is unknown, and the consumer is the one exposed to this entrepreneurial risk. Empirically, therefore, a flight to safety caused by an increase in risk can be interpreted either as a decline in demand for investment, or a decline in demand for consumption. This flexibility of interpretation widens the scope for possible applications.

B.4 Entrepreneurial risk model Calibration

The calibration of the parameters in the extended model including entrepreneurial risk is the same as for the baseline model presented in section 5.4. Here I briefly discuss the role of γ and η. As noted in subsection 6.1, risk is typically expansionary in models with only "capital risk", because the precautionary motive dominates when the IES is less than 1. An increase in capital risk in a model with an IES less than 1 can be contractionary in sticky price models, but usually only with an IES that is *close* to 1. Higher risk aversion generally increases the likelihood that a risk shock will be contractionary, but with standard CRRA preferences risk aversion is the inverse of the IES; if the IES is high, risk aversion is low. Basu and Bundick (2017) use Epstein-Zin preferences to show that in a model with sticky prices, high risk aversion, and an IES slightly below 1 risk shocks are contractionary. However, in this paper, the combination of entrepreneurial risk and GHH preferences means that a lower IES does not make an expansion in response to risk more likely. Higher values of γ produces larger contractions. Generating a decline in risk that is also deflationary is slightly difficult, because through the Euler equation risk pushes down the real rate at the same time that the decline and recovery in output pushes it up. Generating a large output response to a decline is risk is therefore important, and the low η from the calibration in 5.4 helps achieve this.

C Additional discussion & figures

Building on section 4, the point of this appendix is to clarify some things about how the baseline flexible price model works that may not be clear after reading the main body of the paper.

- **Quantity equation**

  A version of the familiar quantity equation is implicit in this model. Starting from the cash-in-advance market clearing condition and multiplying by some price level implies:

$$D_{t+1} = C_t + W_t L_t$$

$$P_t D_{t+1} = P_t(C_t + W_t L_t)$$

$$\widetilde{D}_{t+1} V_t = P_t T_t$$

Where $\widetilde{D}_{t+1}$ is the nominal quantity of inside money, V_t is velocity, P_t is the price level and T_t is the quantity of real transactions $C_t + W_t L_t$. As in most cash in advance models, V_t is fixed at 1; the modeling assumption is that D_{t+1} is the quantity of real intermediation services needed for T_t to circulate once. Note that because I assume both transactions in the goods market and transactions in the labor market require money, $T_t \neq Y_t$ and the commonly written but less precise version of the quantity equation $M_t V_t = P_t Y_t$ does not hold.

The quantity equation is an identity and not controversial. The "quantity theory of money" usually refers to the idea that the nominal quantity of money (here $\widetilde{D}_{t+1}$) is set by some monetary or fiscal authority and velocity V_t is fixed, and that therefore the price level P_t is determined by the ratio of the exogenous nominal quantity of money to the quantity of real output (or more precisely transactions). In this model, the *real* quantity of money D_{t+1} is determined by profit-maximizing private financial institutions. The rate of inflation π_t is determined by market clearing in period $t-1$; in other words, given some P_{t-1}, P_t is determined in $t-1$. Real outcomes do not depend on P_{t-1}, which is a free variable.[9]

Of course, when money is measured as either the nominal quantity of central bank reserves or more commonly as the nominal quantity of deposits (M2), empirically observed velocity is not constant. Volatile empirical velocity is consistent with this model only if the model object D_{t+1} is not literally equal to empirical deposits. The model object D_{t+1} is defined precisely as the quantity of real debt that is used for transactions. Empirical deposits are best thought of as some combination of D_{t+1} and safe interpersonal (zero-sum) debt, the gross quantity of which is undefined in this representative agent model. Observed declines in empirical velocity (the ratio of M2 to nominal GDP) during recessions could be explained by an increased demand for safe deposits relative to other forms of interpersonal debt.

- **Expectations**

  In the flexible price baseline there is no role for expectations except through the Euler equation.[10] R_{t+1}, π_{t+1} and P_{t+1} are all determined in t. One way to introduce expec-

[9] It is therefore technically accurate to say that in the baseline flexible price model money is neutral: a one time *unanticipated* increase in the price level will not change anything about the real economy. But money is not superneutral, and real money is necessary for exchange.

[10] If monetary policy is expected to contract in $t+1$ (an increase in R^N_{t+2}) this will translate to a decline in expected output and employment in $t+1$ and a decline in R^B_{t+1}. In the "free banking" case this would have

tations or uncertainty about the price level would be to assume sub-period timing, or specifically to assume that consumers and employers must obtain deposits for transactions in t before they know what the price level in t will be.

- **Profits**

  In the baseline "free banking" flexible price model, both firms and banks are competitive and there are no real economic profits after adjusting for time preference (discounting). This is shown for both the firm and bank problems below.

Firm	Bank
Firm labor demand FOC:	Bank labor demand FOC:
$W_t = \frac{1}{R^N_{t+1}} A^F_t$	$W_t = (1 - \frac{1}{R^N_{t+1}}) A^B_t$
Firm revenue - costs:	Bank revenue - costs:
$\underbrace{\frac{1}{\pi_{t+1}} A^F_t \ell^F_t}_{t+1} \underbrace{- W_t \ell^F_t}_{t}$	$\underbrace{(R^B_{t+1} - \frac{1}{\pi_{t+1}}) A^B_t \ell^B_t}_{t+1} \underbrace{- W_t \ell^B_t}_{t}$
$\frac{1}{R^B_{t+1}} \frac{1}{\pi_{t+1}} A^F_t \ell^F_t - W_t \ell^F_t$	$\frac{1}{R^B_{t+1}} (R^B_{t+1} - \frac{1}{\pi_{t+1}}) A^B_t \ell^B_t - W_t \ell^B_t$
$\frac{1}{R^N_{t+1}} A^F_t L^F_t - W_t \ell^F_t$	$(1 - \frac{1}{R^N_{t+1}}) A^B_t \ell^B_t - W_t \ell^B_t$
$W_t \ell^F_t - W_t \ell^F_t$	$W_t \ell^B_t - W_t \ell^B_t$

  Note that real economic profits and nominal period cash flow are not the same. For firms, for example, per period cash flow in t is $P_{t-1} A^F_{t-1} \ell^F_{t-1} - P_t W_t \ell^F_t$ in nominal terms and $\frac{1}{\pi_t} A^F_{t-1} \ell^F_{t-1} - W_t \ell^F_t$ in real terms. In the steady state this is also zero, but may can vary out of the steady state.

  In the flexible price model where the reserve requirement restricts the quantity of inside money produced, profits are positive and increasing in λ^{RR}_t. However this may not be the case in a more complex model featuring, for instance, maturity transformation. In the flexible price model with entrepreneurial risk presented in section 6, increases in risk push the wage below marginal product and, assuming firms and banks are the ones who are compensated for that risk, increase aggregate profits. In this way the model behaves similarly to the New Keynesian aggregate demand mechanism. However, as discussed in 6.3, if consumers bear the entrepreneurial risk, the correlation between profit rates and output is not necessarily countercyclical.

- **Free banking Monetarist IS-LM**

  The figure below shows the solution of the model in the baseline calibration when the reserve requirement is not binding ($\lambda^{RR}_t = 0$)

no impact on real variables in t, and in the baseline case with only labor this would only impact t if the monetary policy rule responds to inflation; however in models with capital this would impact investment.

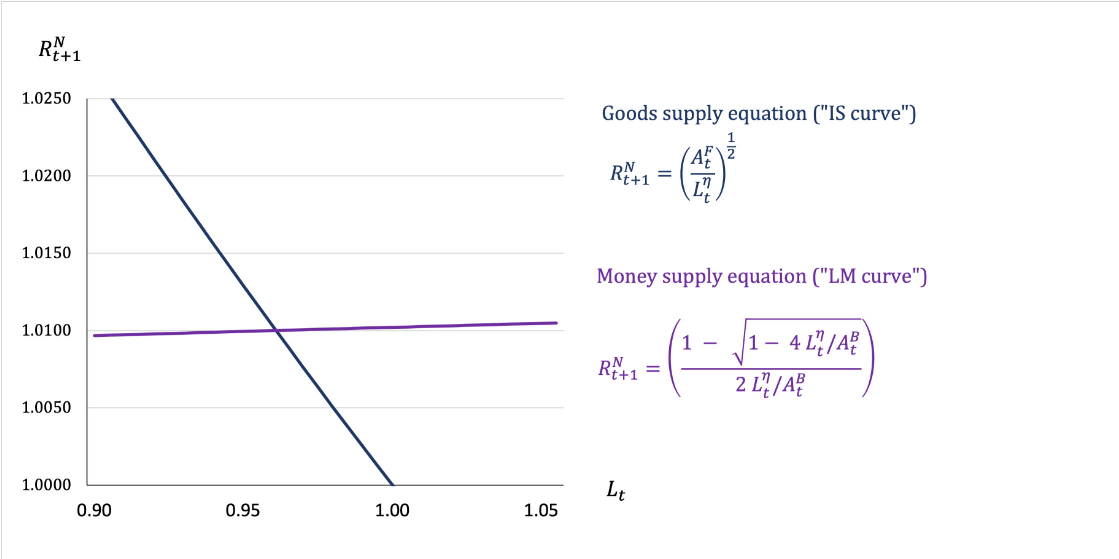


Figure C.4: Free banking Monetarist IS-LM

- **Separable preferences Monetarist IS-LM**

  The main results of sections 1-5 go through with separable preferences. The equations below characterize the solution of the flexible price baseline in this case.

Flexible price, perfect competition solution with seperable preferences:

$$L^\eta_t = (\tfrac{1}{R^N_{t+1}})^2 \tfrac{A^F_t}{C^\gamma_t} \qquad \text{(Goods supply)}$$

$$L^\eta_t = \tfrac{1}{R^N_{t+1}}(\tfrac{1}{R^N_{t+1}}(R^N_{t+1} - 1) - \tfrac{\lambda^{RR}_t}{C^{-\gamma}_t})\tfrac{A^B_t}{C^\gamma_t} \qquad \text{(Money supply)}$$

$$R^N_{t+1} = R^N_{ss}(\frac{\pi_t}{\pi_{ss}})^{\phi\pi}(\frac{L_t}{L_{ss}})^{\phi L} v_t \qquad \text{(Monetary policy rule)}$$

$$\tfrac{1}{R^N_{t+1}} = \beta \tfrac{\mathbb{E}[C^{-\gamma}_{t+1}]}{C^{-\gamma}_t} \tfrac{1}{\pi_{t+1}} \qquad \text{(Euler equation)}$$

The separable version of figure 2 is below. The main difference between the models is that the "IS" curve is steeper, indicating that money has less of an impact on the economy.

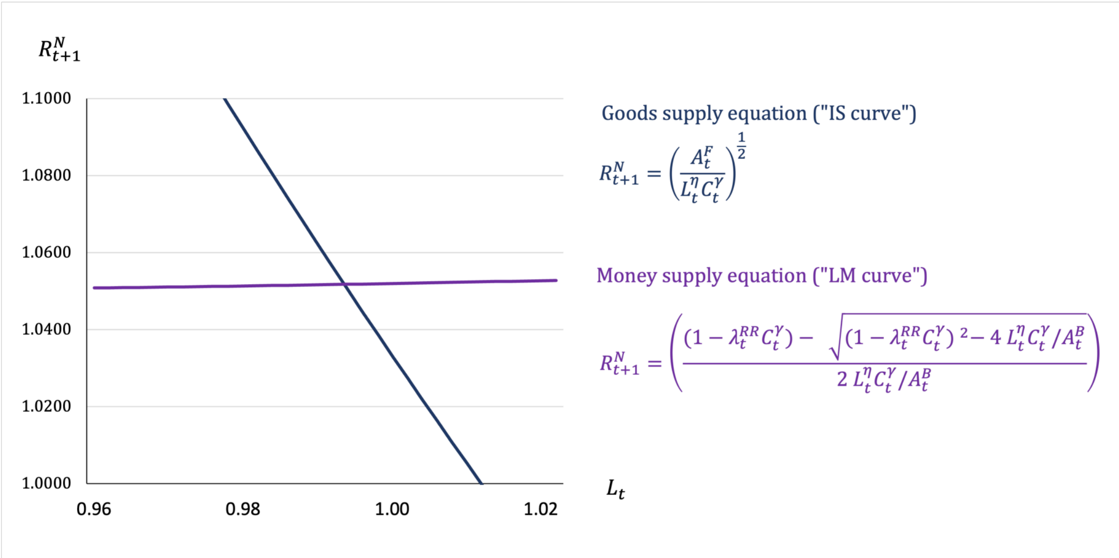


Figure C.5: Monetarist IS-LM with Separable Preferences

- **Reactive Taylor rules**

  In the flexible price baseline calibration for figure 7 I assumed that the monetary authority targeted a steady state nominal rate, and that this target was only changed due to exogenous monetary policy shocks: $R^N_{t+1} = R^N_{ss} v_t$. This simple rule allows for possibly the cleanest monetary policy experiment. In the sticky price model, the model is not deterministic without a reactive monetary policy rule ($\phi^\pi > 1$). When $\phi^\pi = 1.01$ in the sticky price model, dynamics change, as shown in figure B.2.

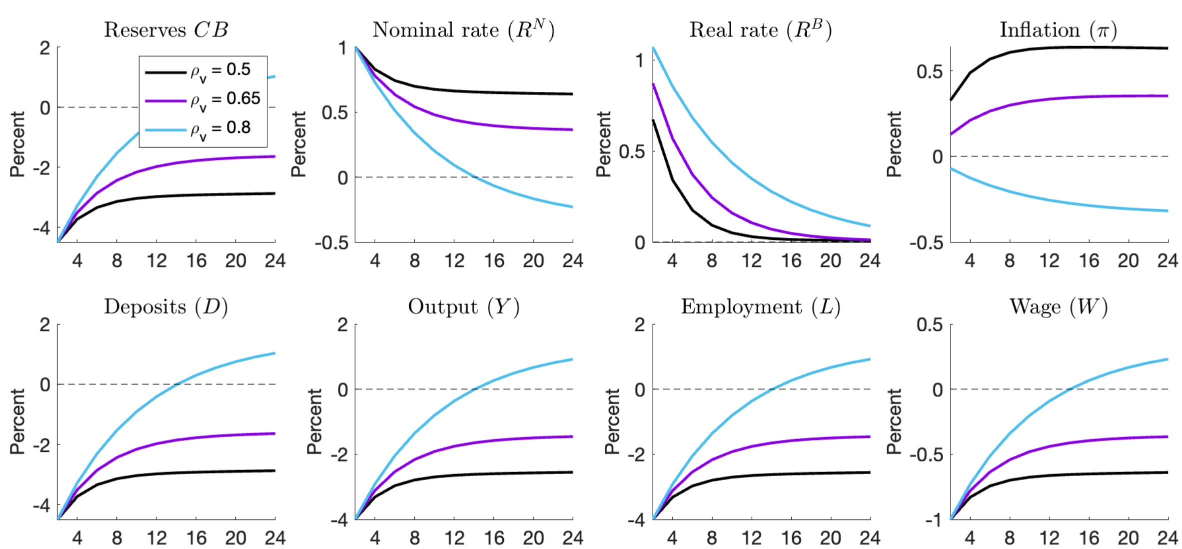


Figure C.6: Flexible price monetary shock with Taylor Rule

The core dynamics are the same; the nominal rate determines the path of employment and output, which determines the path of the real rate, which determines inflation (through the Euler equation). A more persistent increase in the nominal rate (which, interestingly, corresponds to a less persistent initial shock) means that the real rate grows by less; in the case above this results in an increase in inflation. The major difference is that when the monetary rule induces a positive relationship between inflation and the nominal rate, this can lead to very persistent deviations in those values, and subsequently also employment and output, from the steady state.[11]

- **Price puzzle**

  Below is a simple example showing how the model can produce, to a first order, the "price puzzle", where prices first rise in response and then fall in response to a contractionary monetary policy shock. The figure was produced by manipulating the shape of the monetary shock such that the path of the nominal rate becomes more convex over time, which in turn creates a path of output and a path of the real rate such that inflation first increases and then decreases relative to the steady state.

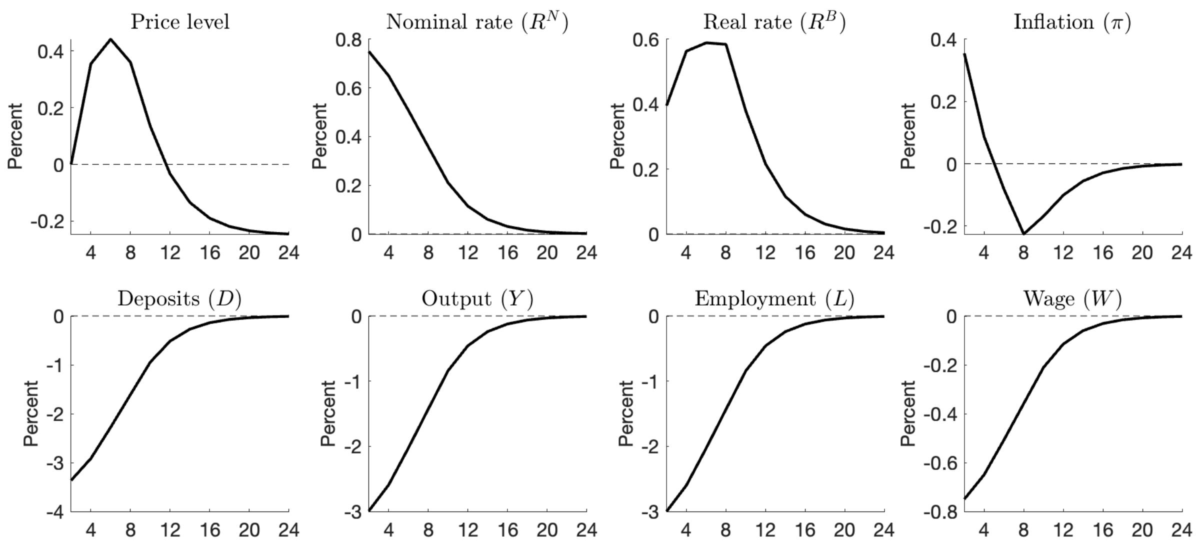


Figure C.7: Price puzzle example

- **Monetary shock with entrepreneurial risk**

  The figure below shows the response of the model to a monetary shock in the entrepreneurial risk model. The persistence and size of the shock is the same as in the "middle" case of figure 7. The response of employment, output, the real rate, and inflation is greater than in the baseline flexible price model, suggesting that entrepreneurial risk amplifies the inside money cost channel.

[11]When $\phi^{\phi} = 1$, a shock can result in a permanent change.

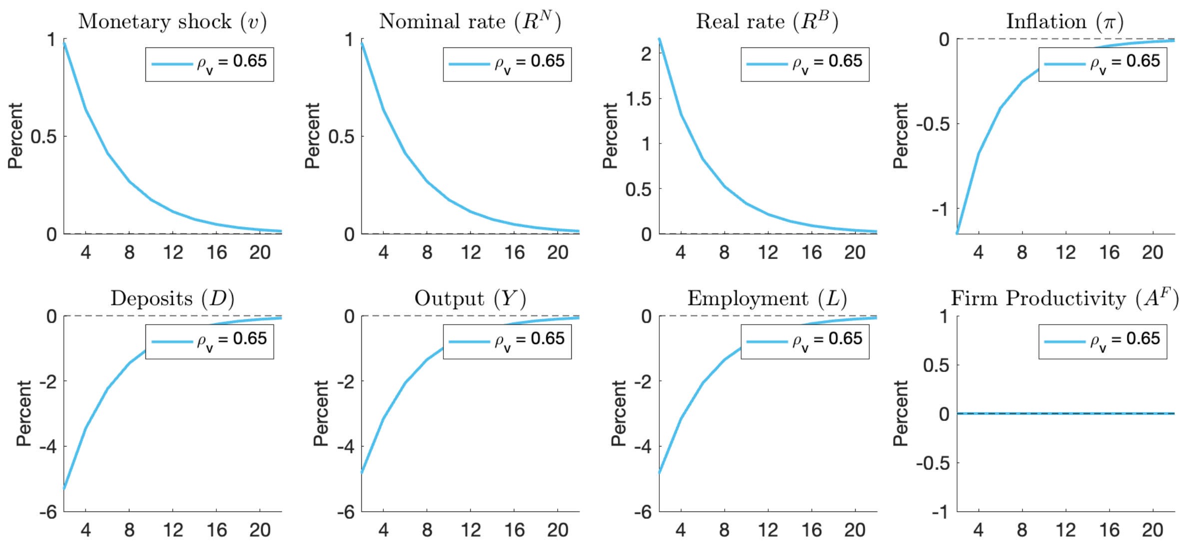


Figure C.8: Flexible price monetary shock with entrepreneurial risk

- Impulse response to a positive firm productivity A^F shock

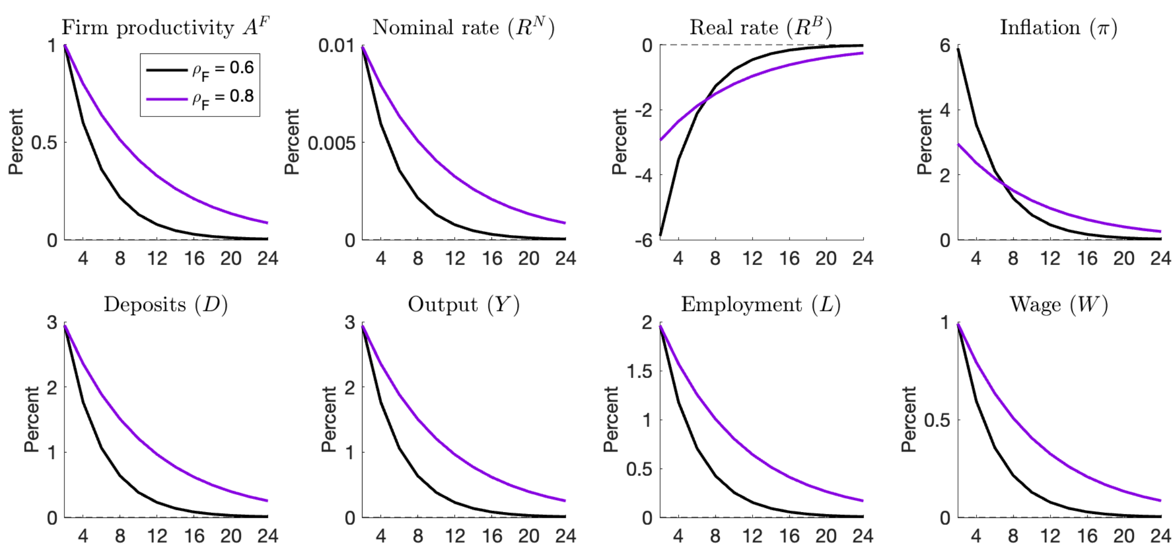


Figure C.9: Firm productivity shock

- Impulse response to a large decrease in bank productivity A^B (a "financial crisis" shock)

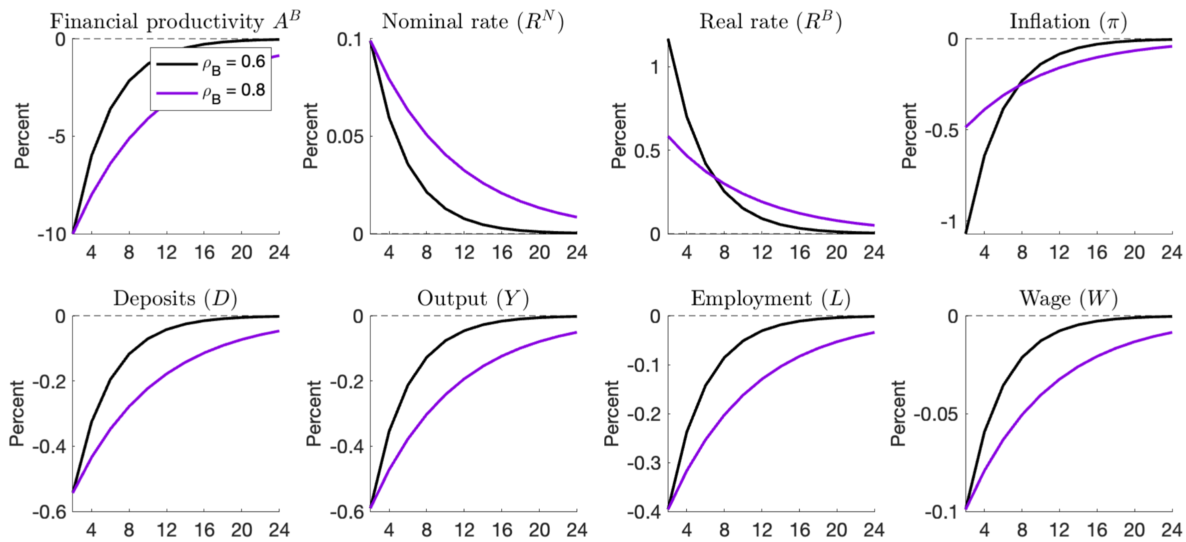


Figure C.10: "Financial crisis" shock

- Response of the expectations-augmented Phillips curve to identical *productivity* shocks in flexible price vs sticky price model. Note that in the flexible price model slope also depends on the monetary rule and the response of the nominal rate to the productivity shock.

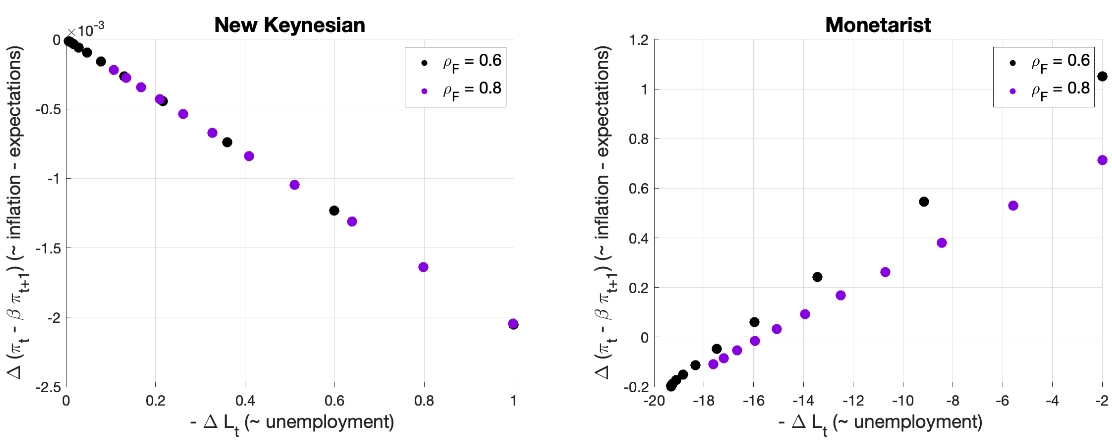


Figure C.11: Productivity shocks & Phillips curves

- Entrepreneurial risk in the free banking case (∼ inward "IS" curve shift)

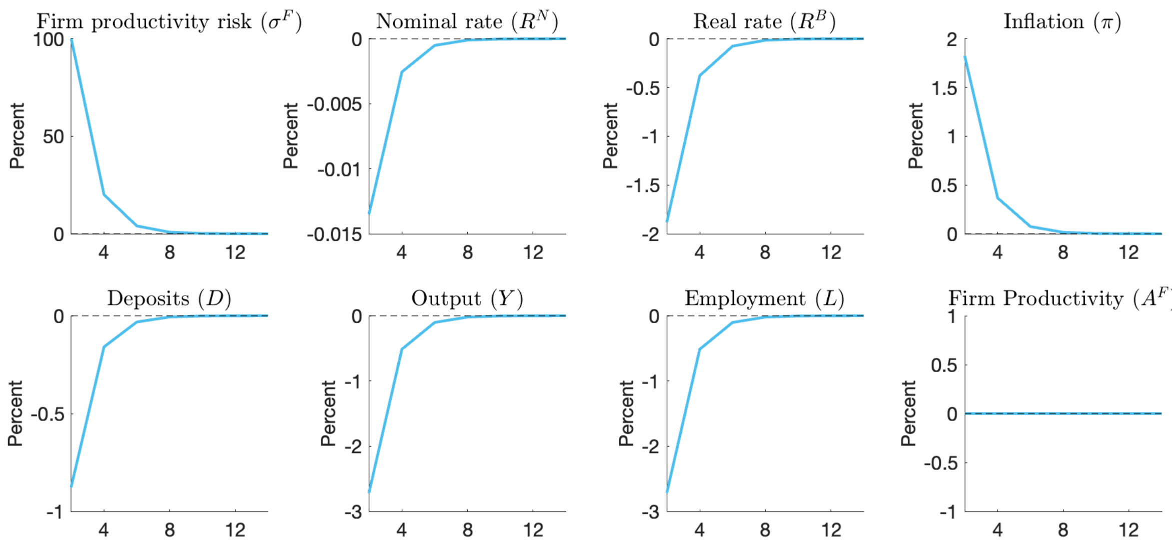


Figure C.12: Entrepreneurial risk in the free banking case