U.S. Business Cycles, Monetary Policy and the External Finance Premium[*]

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Enrique Martínez-García[†]
Federal Reserve Bank of Dallas

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Abstract

I investigate a model of the U.S. economy with sticky prices and a financial accelerator mechanism à la Bernanke, Gertler and Gilchrist (1999). I calculate total factor productivity (TFP) and monetary policy deviations for the U.S. and quantitatively explore the ability of this financial accelerator model and the standard Real Business Cycles (RBC) model to account for the cyclical patterns of U.S. real private GDP (excluding government), hours worked, and (year-over-year) inflation over the Great Moderation period. I show that while neither model seems to match the data over the past 2 years without assuming financial frictions implying a really high sensitivity of the interest rate spreads to the leverage of borrowers, the fact is that the plain vanilla RBC model often tracks better the endogenous variables of interest up to 2007.

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[†] Enrique Martinez-Garcia, Federal Reserve Bank of Dallas. Correspondence: 2200 N. Pearl Street, Dallas, TX 75201. Phone: +1 (214) 922-5262. Fax: +1 (214) 922-5194. E-mail: enrique.martinez-garcia@dal.frb.org. Webpage: http://dallasfed.org/research/bios/martinez-garcia.html.

1 Introduction

The 2007 recession has led to renewed concern about the role of the financial system over the business cycle among researchers and policy-makers alike. The 'credit crunch' in the United States has focused attention on the determinants of lending and the impact of credit flows on the transmission mechanism for monetary policy. In this context, the role of monetary policy is once again being hotly contested. Why does this matter? Indeed, within the standard variants of the New Keynesian framework now common for the analysis of monetary policy, one typically rules out real effects of the financial sector and abstracts altogether from financial frictions.

Evidence from past banking crisis and the current crisis suggests—or, at least, has re-invigorated the view—that the role of the financial channel may be important in the propagation and amplification of shocks. Simultaneously, the role of monetary policy rules and their interaction with financial frictions has become an issue of first-order importance in academic and policy circles. Indeed, the monetary authorities reaction—both in the U.S. and other major industrialized countries—has been unusual during the current episode and very aggressive relative to the prior experience over the past 25 years of the so-called Great Moderation. A heated debate on the role of deviations from well-established policy rules (e.g., Taylor, 1993) has ensued, and it is likely to continue for a long time.

To provide a quantitative analysis of the issues raised by the on-going policy debates, I focus my attention on the nexus between monetary policy and financial frictions. In particular, I ask how one can evaluate the macroeconomic performance of monetary policy in an environment where policy-makers realize that the interest rates they control are not equal to the marginal lending rates that determine the cost of borrowing for economic agents—in other words, if there is a non-trivial spread between the cost of borrowing and the policy rate. In a conventional New Keynesian model of the economy with no financial frictions, the transmission mechanism for monetary policy is rather stylized. Borrowing and lending has no impact on this mechanism and, consequently, no real effects.

In a world with financial frictions, the Modigliani-Miller theorem no longer holds and interest rate spreads arise. In that context, real shocks and monetary policy shocks are potentially amplified by the financial sector channel. To investigate this issue further, I draw on the financial accelerator model of Bernanke *et al.* (1999) where interest rate spreads are tied to the leverage of borrowers. I find that the economy has a stronger transmission mechanism whenever the spreads are more sensitive to the leverage of the borrowers. I also illustrate that the financial accelerator model can have a significant amplification effect when it interacts with monetary policy deviations. However, these results are very sensitive to: (a) the specification of the systematic part of the monetary policy rule, and (b) the interpretation assigned to what is the exogenous and purely discretionary component of monetary policy and what is not.

Furthermore, I also indicate that stronger propagation does not necessarily mean that the model is better suited to explain the path of endogenous variables like real private output, hours worked, or year-over-year inflation. In fact, a plain vanilla Real Business Cycle (RBC) model parameterized in a way consistent with that of the financial accelerator model will often produce a closer fit to the data. I also emphasize that the financial accelerator by itself has only mild effects unless it interacts with other frictions like nominal rigidities or the spread becomes very sensitive to the leverage of the borrowers.

I have two main additions to the literature. One, I consistently and thoroughly examine the U.S. data and provide a sensible mapping between the data and the financial accelerator model. The consistency between the way in which the model is laid down to account for the observed cyclical fluctuations and what the data itself tells us is crucial in helping evaluate the strengths and weaknesses of one of the most popular models of financial frictions available.

Two, I quantitatively investigate the ability of the financial accelerator model of Bernanke *et al.* (1999) to explain the cyclical fluctuations of real private output, hours worked and year-over-year inflation. Although this is not the first paper to investigate the model's performance (see, e.g., the estimates in Meier and Müller, 2006), it is the first paper to my knowledge that does it by the simulation method taking as given the realizations of the Solow residual and the monetary policy deviations straight from the data—rather than estimating them based on imposing the structure of the model on the observable variables. While both approaches are complementary, I would argue that the exercise I conduct in this paper is useful for the purpose of evaluating the model and accounting for the cyclical features without having to worry (among other things) that misspecification may be biasing our estimates. Moreover, it is also quite useful as a tool to inspect the financial accelerator mechanism and how it operates.

My paper proceeds as follows: Section 2 outlines the Bernanke *et al.* (1999) financial accelerator and a nested variant of the (plain vanilla) RBC model used in the simulations. I continue in section 3 with a discussion of the parameterization of the model and the derivation of the shock realizations, and then I present the quantitative findings in section 4. Section 5 provides some discussion and concludes.

2 The Financial Accelerator Model

Although there are different ways to rationalize a financial accelerator theoretically, one framework that has been extensively used in the literature is the 'costly state verification' model of credit market imperfections (see, e.g., Bernanke *et al.*, 1999). This model postulates that endogenous changes in the costs of auditing and monitoring the defaulting borrower's realized return on capital over the business cycle add an 'external finance premium' to the cost of the loans for all borrowers. This premium or spread over the risk-free rate, in turn, makes investment costlier and results in an amplification effect that intensifies the impact of a given shock and potentially alters its propagation.

I build on the financial accelerator model of Bernanke *et al.* (1999) under 'costly state verification', monopolistic competition and nominal price rigidities. Financial intermediation plays a role in funding investment, but access to external borrowing is costlier as noted before.[1] The model shares an important characteristic with the framework of Kiyotaki and Moore (1997) in that asset price movements serve to reinforce credit market imperfections (since asset price fluctuations contribute to volatility in the leverage of the borrowers), a missing feature in the Carlstrom and Fuerst (1997) framework which has been noted by Gomes *et al.* (2003).[2]

The model is populated by households and entrepreneurs, capital producers, wholesale producers, retailers, commercial banks, and a central bank. Households own all the firms, except the wholesale producers.

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[1] The literature has also investigated the role of financial intermediation to finance the wage bill instead of the capital bill (see, e.g., Carlstrom and Fuerst, 2001). In part I look at the Bernanke *et al.* (1999) model because investment -unlike labor- is an intertemporal decision. Therefore, the financial accelerator model not only has the potential to amplify the effects of a shock, but by constraining capital accumulation, it can also alter the propagation of the shock over time.

[2] Faia and Monacelli (2007) and Walentin (2005) provide an insightful theoretical comparative analysis of the Bernanke *et al.* (1999) and Carlstrom and Fuerst (1997) frameworks.

Capital producers determine a relative price for investment goods, and are subject to technological constraints in their ability to transform output into installed capital. Retailers are separated from wholesale producers in order to introduce nominal rigidities in a tractable manner. Wholesale producers themselves are owned and operated by risk-neutral entrepreneurs, and the capital returns they retain are subject to idiosyncratic shocks. Therefore, entrepreneurs are exposed to the risk of bankruptcy on all those wholesalers for which capital returns fall short of the required loan repayment.

The banking system intermediates between the households and the entrepreneurs, bank-lenders are risk-neutral and provide the entrepreneur-borrowers with loans to partly fund the capital stock allocated to the wholesale producer firms. Capital returns—determined by the profits and the collateral value of the assets (capital)—on defaulting wholesale firms are not observable by the banks, only by the wholesale firms and the entrepreneurs themselves. Hence, loan contracts are designed to reduce the agency costs associated with the asymmetry of information between the entrepreneur-borrowers and the bank-lenders. As in Bernanke *et al.* (1999), financial intermediaries take one-period deposits from households to make one-period loans and supply whatever loan amount is desired by the borrowers under the terms of the loan.

Finally, a central bank is added with powers to set monetary policy in terms of a nominal short-term interest rate. I expand the model to include a monetary policy rule à la Taylor (1993) as a characterization of the perceived monetary policy regime over most of the sample period that I investigate in this paper. The model is, otherwise, essentially the same one derived in Bernanke *et al.* (1999) with the exclusion of the fiscal side.

The contribution of this paper is not a theoretical improvement upon what is already a well-established model in the literature, but a careful quantitative evaluation of the ability of this class of models to answer questions on the role of monetary policy over the U.S. business cycle, the cyclical factors behind the Great Moderation period, and the reasons behind a financial crisis like the current one. The main contribution, therefore, is in the mapping between the model and the data and in the quantitative evaluation that is performed with this exercise.

Log-linearized Equilibrium Conditions of the Financial Accelerator Model. Since the model of Bernanke *et al.* (1999) is quite well-known in the literature, I refrain from a detailed discussion of its first principles. This section describes the log-linearized version of the equilibrium conditions of the model and its frictionless variant (the RBC model) to make the presentation more compact. As a notational convention, all variables identified with lower-case letters and a caret on top are expressed in logs and as deviations relative to their steady state values. Since the model abstracts from population growth and accounts only for the cyclical component, the endogenous variables are appropriately interpreted in per capita terms and linearly-detrended. Further discussion on the transformation of the data to express the relevant variables in per capita terms and to detrend them can be found in the Appendix.

On the demand-side, households are infinitely-lived and maximize their lifetime discounted utility, which is additively separable in consumption and labor in each period. Aggregate consumption evolves according to a standard Euler equation,

$$\widehat{c}_t \approx \mathbb{E}_t \left[\widehat{c}_{t+1}\right] - \sigma \widehat{r}_{t+1}, \tag{1}$$

where $\widehat{c}_t$ denotes real aggregate consumption, and $\widehat{r}_{t+1}$ is the Fisherian real interest rate. The Fisherian real rate is defined as the one-period nominal interest rate minus the expected inflation over the next quarter, i.e.

$$\widehat{r}_{t+1} \equiv \widehat{i}_{t+1} - \mathbb{E}_t\left[\widehat{\pi}_{t+1}\right], \tag{2}$$

where $\widehat{\pi}_t \equiv \widehat{p}_t - \widehat{p}_{t-1}$ is the inflation rate, and $\widehat{p}_t$ is the consumption price index (CPI). Nominal (uncontingent) one-period bonds are traded in zero net supply. These bonds guarantee a nominal interest rate of $\widehat{i}_{t+1}$ at time $t+1$ which is set at time t, and it is the same rate paid on household's nominal deposits by the financial intermediaries. Moreover, $\mathbb{E}_t[\cdot]$ denotes the expectations operator conditional on information available up to time t. The intertemporal elasticity of substitution, $\sigma > 0$, regulates the sensitivity of the consumption-savings decision of the households to the Fisherian real interest rate.

The first-order condition on labor from the household's problem can be expressed as follows,

$$\widehat{w}_t - \widehat{p}_t \approx \frac{1}{\sigma}\widehat{c}_t + \frac{1}{\varphi}\widehat{h}_t, \tag{3}$$

where $\widehat{h}_t$ represents aggregate household labor, and $\widehat{w}_t$ is the competitive nominal wage. The Frisch elasticity of labor supply, $\varphi \equiv \eta\left(\frac{1-H}{H}\right) > 0$, indicates the sensitivity of the supply of labor to changes in real wages *ceteris paribus*. The parameter η characterizes the inverse of the coefficient of relative risk aversion on leisure,[3] and H defines the share of hours worked in steady state.

On the supply-side, there are retailers, capital producers, wholesale producers (operated by entrepreneurs), and commercial banks. I implicitly assume that the only input required in the production of retail varieties is the wholesale good. Retailers acquire wholesale output, costlessly differentiate the goods into firm-specific varieties, and sell them. Households have well-defined tastes over all the retail varieties, but not over wholesale goods. Each retailer has monopolistic power in its own variety[4] and chooses its price to maximize the expected discounted value of its current and future profits, subject to a downward-sloping demand constraint. Due to price stickiness à la Calvo (1983), in each period only a fraction $0 < 1 - \alpha < 1$ of the retailers gets to re-optimize prices.

The CPI inflation dynamics resulting from the aggregation over all retail prices are captured by the following forward-looking Phillips curve,

$$\widehat{\pi}_t \approx \beta\mathbb{E}_t\left[\widehat{\pi}_{t+1}\right] + \left(\frac{(1-\alpha\beta)(1-\alpha)}{\alpha}\right)\widehat{mc}_t, \tag{4}$$

where I define the real marginal cost as $\widehat{mc}_t \equiv \left(\widehat{p}^w_t - \widehat{p}_t\right)$ and denote the wholesale output price as $\widehat{p}^w_t$. The intertemporal discount factor of the households is given by $0 < \beta < 1$. In turn, with perfect competition and flexible prices, the retailers intermediate the exchanges in the market for wholesale goods but will have no discernible impact on relative prices (i.e. $\widehat{p}_t = \widehat{p}^w_t$ or $\widehat{mc}_t = 0$) and on the equilibrium allocations.

The capital goods producers use the same aggregate of retail varieties that households consume as the only input to manufacture investment goods. To be consistent with Bernanke *et al.* (1999), I also assume that entrepreneurs sell their capital stock (after being used in production by the wholesale firms) to the capital

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[3] Total hours worked H_t and hours spent in leisurely activities L_t are normalized to add up to one (i.e., $H_t + L_t = 1$). If consumption and leisure are additively separable as assumed by Bernanke *et al.* (1999), and I define the per-period preferences over leisure generically as $V(L_t)$, then $\eta^{-1} \equiv -\frac{LV''(L)}{V'(L)}$ evaluated in steady state.

[4] The retailers can be thought as adding a 'brand' name to the wholesale good to introduce differentiation and, consequently, to gain monopolistic power to charge a retail mark-up.

goods producers. Capital goods producers face increasing marginal adjustment costs in the production of capital, modelled in the form of an increasing and concave adjustment cost that is a function of the investment-to-capital ratio.[5]

Capital accumulation evolves according to a conventional law of motion,

$$\widehat{k}_{t+1} \approx (1-\delta)\,\widehat{k}_t + \delta \widehat{x}_t, \tag{5}$$

where $\widehat{k}_t$ denotes the stock of capital available at time t and $\widehat{x}_t$ stands for real investment. The depreciation rate for physical capital is given by $0 < \delta < 1$. The technological constraint on capital goods producers implies that the investment-to-capital ratio is governed by the following relationship,

$$\widehat{x}_t - \widehat{k}_t \approx \left(\frac{1}{\chi\delta}\right)\widehat{q}_t, \tag{6}$$

where $\widehat{q}_t$ is the shadow value of an additional unit of installed capital (or Tobin's q) in units of consumption. The degree of concavity of the cost function around its steady state, $\chi \geq 0$, regulates the sensitivity of the investment-to-capital ratio to fluctuations in Tobin's q. Without adjustment costs (i.e. if $\chi = 0$), Tobin's q becomes time-invariant,

$$\widehat{q}_t \approx 0, \tag{7}$$

and the investment-to-capital ratio is unconstrained. However, the mechanism in Bernanke *et al.* (1999) would lose the characteristic that asset price movements serve to reinforce credit market imperfections.

The wholesale firms are responsible for manufacturing wholesale output and are owned and operated by risk-neutral entrepreneurs. The wholesale firms employ homogenous labor supplied by both the households and the entrepreneurs and capital to produce wholesale output. All factor markets are perfectly competitive, and each producer relies on the same Cobb-Douglas technology in capital, household's labor and entrepreneur's labor. Aggregate wholesale output can be expressed as follows,

$$\widehat{y}_t \approx \widehat{s}_t + (1-\psi-\varrho)\,\widehat{k}_t + \psi\widehat{h}_t, \tag{8}$$

where $\widehat{y}_t$ denotes the wholesale output, and $\widehat{s}_t$ is an aggregate productivity (TFP) shock. The household's labor share in the production function is $0 < \psi < 1$, while the entrepreneur's labor share is $0 \leq \varrho < 1$.[6] Entrepreneur's labor is assumed to be inelastically supplied and time-invariant, and hence drops out of the log-linearized expression in (8). The TFP shock follows an $AR(1)$ process of the following form,

$$\widehat{s}_t = \rho_s \widehat{s}_{t-1} + \varepsilon_t^s, \tag{9}$$

where ε_t^s is a zero mean, uncorrelated and normally-distributed innovation. The parameter $-1 < \rho_s < 1$ determines the persistence of the TFP shock.

The competitive real wages paid to households are equal to the marginal product of the household's

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[5] As in Bernanke *et al.* (1999), profits of the capital goods producers are of second-order importance and, therefore, omitted. For more details, see footnote 13 in page 1357.

[6] The entrepreneur's labor share is chosen to be small enough that this modification of the standard production function does not have a significant direct effect on the aggregate dynamics of the model.

labor, i.e.

$$\widehat{w}_t - \widehat{p}_t \approx \widehat{mc}_t + \left(\widehat{y}_t - \widehat{h}_t\right). \tag{10}$$

Real wages that compensate entrepreneurs for their labor must equal their marginal product as well (which may differ from that of the household), but real wages are not stated explicitly because they are not required to characterize the dynamics of the model. Combining equations (3) and (10), I derive a household labor market equilibrium condition in the following terms,

$$\widehat{mc}_t + \left(\widehat{y}_t - \widehat{h}_t\right) - \frac{1}{\sigma}\widehat{c}_t \approx \frac{1}{\varphi}\widehat{h}_t. \tag{11}$$

This condition suffices to describe the real marginal costs faced by the retailers, without having to keep track of real wages.

Entrepreneurs operating the wholesale firms buy the capital stock every period from the capital goods producers at a price determined by Tobin's q, using both internal funds (their own net worth) and external loans from the financial intermediaries (bank-lenders). After production takes place, the depreciated stock of capital is sold back to the capital goods producers. Accordingly, the aggregate returns to capital must be given by,

$$\widehat{r}^k_t \approx (1-\epsilon)\left(\widehat{mc}_t + \left(\widehat{y}^w_t - \widehat{k}_t\right)\right) + \epsilon\widehat{q}_t - \widehat{q}_{t-1}, \tag{12}$$

where the composite coefficient is characterized as $\epsilon \equiv \left(\frac{1-\delta}{\left(\frac{1-\psi}{1-\psi-\varrho}\right)\upsilon\left(\gamma_n^{-1}\right)\beta^{-1}+(1-\delta)}\right)$.

I denote the gross steady state ratio between the cost of external funding for entrepreneurs and the risk-free rate as $\upsilon\left(\gamma_n^{-1}\right) \equiv \frac{R^k}{R} \geq 1$. This steady state ratio is a function of the steady state gearing or leverage ratio of the entrepreneurs, $\gamma_n^{-1} \equiv \frac{K}{N}$, that is the ratio of total assets—the stock of capital, K—over the real net worth—equity, N—of the entrepreneurs.[7] The aggregate real return on capital, $\widehat{r}^k_t$, is equal to a weighted combination of the marginal product of capital, $\widehat{mc}_t + \left(\widehat{y}^w_t - \widehat{k}_t\right)$, and the re-sale value of the depreciated capital stock (as captured by Tobin's q), $\widehat{q}_t$, minus the cost of acquiring the stock of capital from the capital goods producers in the previous period, $\widehat{q}_{t-1}$.

Following the logic of the 'costly state verification' framework embedded in Bernanke *et al.* (1999), the returns to capital of each wholesale producer are subject to idiosyncratic (independent and identically-distributed) shocks that are observable to the entrepreneurs, but unobservable to the financial intermediaries. Those idiosyncratic shocks are realized after wholesale production has taken place. Therefore, such idiosyncratic shocks have a direct impact on the capital returns that entrepreneurs obtain from each individual wholesale producer, but not on the initial allocation of capital.

Financial intermediaries raise funds from households by offering deposits that pay the real risk-free rate, and make loans in real terms to entrepreneurs to finance the capital stock acquired for production purposes. Hence, deposits are not only guaranteed, but also inflation-protected in this case. Individual wholesale producers can default on their loan contract obligations, but financial intermediaries can always determine their true capital returns (that is, determine the realization of the idiosyncratic shock) after paying a verification cost. The banks monitor the wholesale producers that default, pay the verification costs when a default occurs and seize all their revenues and their remaining assets (capital).[8]

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[7] Tobin's q is equal to 1 in steady state and, therefore, does not enter into the definition of the leverage ratio in steady state.

[8] Loan contracts are enforced under limited liability, so the bank cannot appropriate more than the value of the collateral

In equilibrium, entrepreneurs—who are assumed to be risk-neutral—borrow up to the point where the expected real return to capital equals the cost of external financing through loans,

$$\mathbb{E}_t\left[\widehat{r}^k_{t+1}\right] \approx \vartheta\left(\widehat{q}_t + \widehat{k}_{t+1} - \widehat{n}_{t+1}\right) + \widehat{r}_{t+1}, \tag{13}$$

where the real cost of external financing through loans is different from the real risk-free rate because it prices the costs and probability of default among wholesale producers. The composite coefficient is characterized as $\vartheta \equiv \left(\frac{\upsilon'\left(\gamma_n^{-1}\right)\gamma_n^{-1}}{\upsilon\left(\gamma_n^{-1}\right)}\right)$. The parameter $\upsilon'\left(\gamma_n^{-1}\right) \geq 0$ is the first-order derivative of the external financing premium with respect to the entrepreneur's leverage ratio γ_n^{-1} in steady state. Hence, the composite parameter ϑ can be interpreted as the elasticity of the external financing premium with respect to the entrepreneur's leverage ratio evaluated in steady state. The lower the entrepreneur's gearing (i.e. the closer $\gamma_n^{-1} \equiv \frac{K}{N}$ is to one), the lower the associated probability and costs of default will be.

The financial intermediaries—which are also assumed to be risk-neutral—price into their loan contracts the probability and costs of default, so an endogenous spread arises between the real cost at which banks fund themselves through household deposits and the real cost of external funding through loans faced by the entrepreneurs. As shown in Bernanke *et al.* (1999), the external financing premium or spread over the real risk-free rate demanded by the financial intermediaries is a function of the leverage ratio of the entrepreneur-borrowers in a given period, $\widehat{q}_t + \widehat{k}_{t+1} - \widehat{n}_{t+1}$, where $\widehat{n}_{t+1}$ denotes the net worth (or equity) of the entrepreneurs at the end of time t and $\widehat{q}_t + \widehat{k}_{t+1}$ the total value of their assets (the value of the stock of capital).

The balance sheet of the entrepreneurs requires the real value of the stock of capital to be equal to real net worth (equity) plus the real amount in borrowed funds (loans),

$$\widehat{q}_t + \widehat{k}_{t+1} \approx \gamma_n \widehat{n}_{t+1} + (1-\gamma_n)\,\widehat{l}_{t+1}, \tag{14}$$

where $\widehat{l}_{t+1}$ denotes the total loans in real terms provided by the financial intermediaries to fund the stock of capital, $\widehat{k}_{t+1}$, at time t. As a result, the leverage or gearing ratio of the entrepreneurs becomes proportional to the entrepreneurs' debt-to-equity ratio, i.e.

$$\widehat{q}_t + \widehat{k}_{t+1} - \widehat{n}_{t+1} \approx (1-\gamma_n)\left(\widehat{l}_{t+1} - \widehat{n}_{t+1}\right). \tag{15}$$

Hence, the more indebted the entrepreneurs become or the less equity they have at stake in any given period, the costlier it gets for them to fund their stock of capital with bank loans.

The assumption is that banks are perfectly competitive and that the real deposits held by households must be equal to the total loanable funds in real terms supplied to the entrepreneurs in every period, i.e.

$$\widehat{l}_t \approx \widehat{d}_t,$$

where $\widehat{d}_t$ represents the real value of the households' deposits.

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assets (capital) and earned profits of the defaulting firm.

The aggregate real net worth of the entrepreneurs accumulates according to the following law of motion,

$$\widehat{n}_{t+1} \approx \zeta \left(\frac{\beta^{-1}}{\gamma_n} \right) \left(\widehat{r}^k_t - \widehat{r}_t \right) + \widehat{r}_t + \widehat{n}_t, \tag{16}$$

where $0 < \zeta < 1$ is interpreted as a *survival rate* for entrepreneurs in the same spirit as Bernanke *et al.* (1999). Equation (16) indicates that the net worth (or equity) of the entrepreneurs, $\widehat{n}_{t+1}$, accumulates over the previous period net worth, $\widehat{n}_t$, at the risk-free rate, $\widehat{r}_t$, plus a proportional share of the spread earned on the returns to capital, $\widehat{r}^k_t - \widehat{r}_t$, adjusted by the steady state gearing or leverage ratio γ_n^{-1}, the steady state real interest rate β^{-1}, and the survival rate ζ.

Taking the bankruptcy costs as negligible, the conventional resource constraint can be approximated as in Bernanke *et al.* (1999), i.e.

$$\widehat{y}_t \approx \gamma_c \widehat{c}_t + \gamma_x \widehat{x}_t + \gamma_{c^e} \widehat{n}_{t+1}, \tag{17}$$

where $0 < \gamma_c < 1$ denotes the household's consumption share in steady state, $0 < \gamma_x < 1$ is the investment share, and $0 \leq \gamma_{c^e} < 1$ is the entrepreneur's consumption share.[9] By construction, it must be the case that $\gamma_c \equiv 1 - \gamma_x - \gamma_{c^e}$. Bernanke *et al.* (1999) assume that the consumption of entrepreneurs is proportional to their net worth, as reflected in (17).

The main simplification I have introduced to the financial accelerator model comes from excluding government consumption entirely, while in Bernanke *et al.* (1999) government consumption is modeled as an exogenous shock. I contend that this variation does not fundamentally alter the financial accelerator mechanism developed in Bernanke *et al.* (1999), which I investigate here in connection with monetary policy. However, to make the data consistent with the model, output must be measured as private market output (i.e., excluding government compensation of employees). I leave the investigation of the role of fiscal policy and its interplay with credit market imperfections for future research.

A more substantive departure from the seminal paper comes from replacing the monetary policy rule of Bernanke *et al.* (1999) and setting the nominal short-term rate—rather than the real interest rate—as the monetary policy instrument. In line with most of the current monetary literature, I assume that the central bank follows a standard Taylor (1993)-type reaction function using the short-term nominal rate, $\widehat{i}_t$, as its policy instrument and responding to fluctuations in inflation and output (the dual mandate), $\widehat{\pi}_t$ and $\widehat{y}_t$.

Thus, monetary policy is determined by the following expression,

$$\widehat{i}^{AR}_{t+1} = \rho_i \widehat{i}^{AR}_t + (1 - \rho_i) \left[\psi_\pi \left(\widehat{p}_t - \widehat{p}_{t-4} \right) + \psi_y \widehat{y}_t \right] + \widehat{m}_t, \tag{18}$$

where $\psi_\pi \geq 1$ and $\psi_y \geq 0$ regulate the sensitivity of the policy rule to inflation and output fluctuations and $0 \leq \rho_i < 1$ is the interest rate smoothing parameter. In keeping with Taylor's (1993) convention, I set the monetary policy inertia to $\rho_i = 0$, and I use the annualized short-term interest rate as the policy instrument,

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[9] The entrepreneur's consumption share is chosen to be small enough such that this modification of the standard resource constraint does not have a significant direct effect on the aggregate dynamics of the model.

$\widehat{i}_t^{AR}$, on the left-hand side of the rule,[10] i.e.

$$\widehat{i}_{t+1}^{AR} \approx 4\widehat{i}_{t+1}, \tag{19}$$

and the inflation rate over the previous four quarters on the right-hand side, i.e.

$$(\widehat{p}_t - \widehat{p}_{t-4}) \approx \widehat{\pi}_t + \widehat{\pi}_{t-1} + \widehat{\pi}_{t-2} + \widehat{\pi}_{t-3}. \tag{20}$$

The monetary policy shock, $\widehat{m}_t$, follows an $AR(1)$ process of the following form,

$$\widehat{m}_t = \rho_m \widehat{m}_{t-1} + \varepsilon_t^m, \tag{21}$$

where ε_t^m is a zero mean, uncorrelated and normally-distributed innovation. The parameter $-1 < \rho_m < 1$ determines the persistence of the policy shock. I assume that monetary and TFP shocks are uncorrelated.

I also experiment with an alternative specification of the policy rule in which the inflation rate is the annualized quarter-over-quarter inflation rate, i.e.

$$\widehat{i}_{t+1}^{AR} = \psi_\pi \widehat{\pi}_t^{AR} + \psi_y \widehat{y}_t + \widehat{m}_t, \tag{22}$$

where $\widehat{\pi}_t^{AR} \approx 4\widehat{\pi}_t$. This alternative specification is much closer to the way in which the Taylor rule is specified in most quantitative and theoretical models but is not fully consistent with the preferred measure of inflation in Taylor (1993). Bernanke *et al.* (1999) characterize monetary policy in terms of a feedback rule on the real interest rate of the following form,

$$\widehat{r}_{t+1} = \rho_i \widehat{r}_t + (1 - \rho_i)\, \psi_\pi \widehat{\pi}_t + \widehat{m}_t, \tag{23}$$

which, using the definition of Fisherian real interest rate, can be re-expressed as follows,

$$\widehat{i}_{t+1} = \rho_i \widehat{i}_t + (1 - \rho_i)\left(\psi_\pi \widehat{\pi}_t + \mathbb{E}_t\left[\widehat{\pi}_{t+1}\right]\right) + \rho_i \left(\mathbb{E}_t\left[\widehat{\pi}_{t+1}\right] - \mathbb{E}_{t-1}\left[\widehat{\pi}_t\right]\right) + \widehat{m}_t. \tag{24}$$

Clearly this is a much different specification of the monetary policy rule, than the one envisioned in Taylor (1993). In this policy rule, the central bank does not respond to fluctuations in output at all (i.e. $\psi_y = 0$), and it responds instead to a combination of inflation and inflation expectations. However, the response to inflation expectations is not only to the level, $\mathbb{E}_t\left[\widehat{\pi}_{t+1}\right]$, but also to the slope, $\mathbb{E}_t\left[\widehat{\pi}_{t+1}\right] - \mathbb{E}_{t-1}\left[\widehat{\pi}_t\right]$.

Log-linearized Equilibrium Conditions of the Frictionless Model. The frictionless allocation, where neither nominal rigidities nor financial frictions play a role in the dynamics of the model, offers a natural point of reference to evaluate the strength of the financial accelerator mechanism developed in Bernanke *et al.* (1999). Up to a first-order approximation, the dynamics of the model without frictions differ from those of the financial accelerator model only in the specification of a small subset of the equilibrium conditions.

On the one hand, the Phillips curve equation in (4)—which emerges under Calvo price stickiness in the

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[10] The measure of output in the Taylor rule is detrended and computed in the data as the deviation of actual output from trend in percentage over the trend. In that case, whether output is expressed at annualized rates or not becomes inconsequential.

model of Bernanke *et al.* (1999)—is one such equilibrium condition. On the other hand, equation (13) which determines the optimal allocation of capital and is affected by the external financing premium is another one. Equation (16) defines the equity (or net worth) of the entrepreneurs as an added state variable due to the fact that the spread charged on loans to fund the entrepreneurs' stock of capital is a function of the leverage in the balance sheet of the borrowers (the entrepreneurs).

The frictionless allocation can be approximated with essentially the same log-linearized equilibrium conditions assuming that: (a) the share of firms that cannot re-optimize in every period is negligible (i.e. $\alpha \cong 0$) in order to approximate a flexible price environment, (b) the gross external financing premium in steady state is 1 (i.e. $\upsilon\left(\gamma_n^{-1}\right) = 1$), and (c) the elasticity of the premium relative to the entrepreneur's leverage ratio evaluated in steady state is zero (i.e. $\upsilon'\left(\gamma_n^{-1}\right) = 0$ or $\vartheta = 0$). These assumptions ensure that it becomes efficient and optimal to accumulate capital to the point where the expected real return on capital equals the real risk-free rate.

The financial accelerator model also distinguishes between two types of agents, households and entrepreneurs. Entrepreneurs are risk-neutral agents that decide on the capital that should be accumulated for the purpose of wholesale production and on how to fund that stock of capital. In the frictionless model, the funding costs between internal and external sources are equalized (and the predictions of the Modigliani-Miller theorem hold), so the distinction between the two agents becomes superfluous. The labor share of entrepreneurs in the production function is small (but guarantees them an income stream in every period). The steady state consumption share of the entrepreneurs is also small. So, without significant loss of generality, the entrepreneurs can be ignored in the model by imposing $\varrho = 0$ and $\gamma_{c^e} = 0$ in order to approximate the frictionless allocation.

These modifications on the choice of the structural and composite parameters of the financial accelerator model of Bernanke *et al.* (1999) suffice to characterize an approximation to the frictionless allocation that gives some perspective on the impact of the financial mechanism and its ability to account for the U.S. cyclical performance over the Great Moderation period.

3 Model Parameterization

3.1 Structural Parameters

In this section I describe the choice of the parameter values which are summarized in Table 1. I follow the literature as closely as possible in my parameterization, with special emphasis to keep the model comparable to that of Bernanke *et al.* (1999) and consistent with the U.S. dataset described in the Appendix. I assume that the discount factor, β, equals 0.99, which is consistent with an annualized real rate of return of 4%. The (inverse of the) leverage or gearing ratio of the entrepreneurs, γ_n, is set at 0.5 and the entrepreneur's survival rate in each quarter, ζ, is chosen to be 0.9728. These last two parameters do not affect the aggregate dynamics of the frictionless model described in the previous section.

[Insert Table 1 about here]

I set the intertemporal elasticity of substitution, σ, to 1. I set the parameter, η, on the leisure preferences to be equal to the intertemporal elasticity of substitution σ. Given that preferences are additively separable in consumption and leisure, these assumptions ensure that preferences on both consumption and leisure are logarithmic and, therefore, that the model is consistent with a balanced growth path. The elasticity of Tobin's q with respect to the investment-to-capital ratio, given by the composite coefficient $\chi\delta$, is taken to be 0.25. All of these parameter choices are identical to the ones made by Bernanke *et al.* (1999).

Setting $\eta = 1$ implies that the Frisch elasticity of labor supply, $\varphi \equiv \eta\left(\frac{1-H}{H}\right)$, is uniquely determined by the share of hours worked in steady state, H. As can be seen in Figure 1, there is a break in the ratio of quarterly hours worked relative to hours available (assuming 1300 hours available per quarter) during the 1980s.[11] I calibrate the ratio of hours worked in steady state, H, to the average for the period between $1984 : I$ and $2009 : IV$ which is equal to 0.276. This parameterization implies that the Frisch elasticity of labor supply, $\varphi \equiv \eta\left(\frac{1-H}{H}\right)$, is set to 2.62 which is slightly below the elasticity of 3 favored by Bernanke *et al.* (1999).

[Insert Figure 1 about here]

The capital share, $(1 - \psi - \varrho)$, is set to 0.284 which corresponds to the average private capital share of annual income for the period between 1954 and 2008 in the U.S. dataset.[12] I choose the same tiny share of entrepreneurial labor, ϱ, of 0.01 as in Bernanke *et al.* (1999) for the financial accelerator model and I set this share to 0 for the frictionless model. As a result, the household's labor share, ψ, becomes equal to 0.706 in the financial accelerator model. This value is consistent with the evidence in the U.S. dataset but noticeably higher than the value of 0.64 used by Bernanke *et al.* (1999). In the frictionless case, the households' labor share becomes 0.716.

The quarterly depreciation rate, δ, is set to 0.012 which corresponds to the average quarterly depreciation rate for the aggregate stock of capital during the period between 1984 and 2008.[13] In turn, this implies an annualized depreciation rate of approximately 4.72%. This value is consistent with the U.S. dataset I put together, but is only half the value of 0.025 picked by Bernanke *et al.* (1999). As can be seen in Figure 2, the depreciation rates are higher during the Great Moderation period (specially in equipment and software). In the past $2-3$ years, the spike in the depreciation rate is mainly accounted for by housing. Given this depreciation rate value, the adjustment cost parameter, χ, is set at 21.19 in order to preserve the same elasticity of Tobin's q with respect to the investment-to-capital ratio (i.e. $\chi\delta = 0.25$) used by Bernanke *et al.* (1999).

[Insert Figure 2 about here]

The investment share, γ_x, is a composite parameter that depends—among other things—on the elasticity of substitution across varieties, $\theta > 1$. The elasticity θ does not appear anywhere else in the log-linearization of the equilibrium conditions. Rather than parameterizing the value of θ directly, I simply set the investment

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[11] The average ratio of hours worked for the post-Korean War period between $1954 : I$ and $2009 : IV$ is 0.262. The average for the sub-period between $1954 : I$ and $1983 : IV$ is 0.250, while the average for the sub-period between $1984 : I$ and $2009 : IV$ is 0.276. For more details on the dataset, see the Appendix and the companion files.

[12] There are no apparent structural breaks between the Great Moderation period and the entire post-Korean War sample. The average capital share for the post-Korean War period between 1954 and 2008 is 0.284. The average for the sub-period between 1954 and 1983 is similar at 0.281, while the average for the sub-period between 1984 and 2008 is also close at 0.288. For more details on the dataset, see the Appendix and the companion files.

[13] The average quarterly depreciation rate for the post-Korean War period between 1954 and 2008 is 0.010. The average for the sub-period between 1954 and 1983 is similar at 0.009, while the average for the sub-period between 1984 and 2008 is a little higher at 0.012. For more details on the dataset, see the Appendix and the companion files.

share to 0.1705, which corresponds to the average quarterly investment share for the period between 1954 : I and 2009 : IV.[14] Figure 3 illustrates the evolution of the investment share and its components over this period. I choose a tiny share of entrepreneurial consumption, γ_{c^e}, of 0.01 for the financial accelerator model and set this share to 0 in the frictionless model. As a result, the household's consumption share, γ_c, becomes equal to 0.8195 in the accelerator model and 0.8295 in the frictionless model.

[Insert Figure 3 about here]

I set the response of the monetary policy rule to fluctuations in inflation, ψ_π, to 1.5 and the response to fluctuations in output, ψ_y, to 0.5 to be consistent with the prescriptions of Taylor (1993). The steady state external finance premium, $\upsilon\left(\gamma_n^{-1}\right) \equiv \frac{R^k}{R}$, is set to 1.00903 in the financial accelerator model, which corresponds to the average quarterly ratio between the gross rate on Baa corporate bonds and the (effective) Fed Funds rate for the period between 1984 : I and 2009 : IV. For more details, see Figure 4 which plots that ratio as well as its historical average.[15] This rate is consistent with a historical spread, $R^k - R$, of 344 basis points at an annualized rate. This is a bit higher than the 200 basis points that Bernanke *et al.* (1999) calculated on the basis of the historical average spread between the prime lending rate and the six-month Treasury bill rate. In the frictionless model, the steady state external financing premium is set to 1 and—accordingly—the spread becomes equal to 0.

[Insert Figure 4 about here]

In the frictionless model, I set the Calvo price stickiness parameter, α, to 0.001 in order to approximate the flexible price allocation and the steady state slope of the external finance premium, $\upsilon'\left(\gamma_n^{-1}\right) \equiv \frac{\partial \upsilon\left(\gamma_n^{-1}\right)}{\partial \gamma_n^{-1}}$, to 0 in order to shut down the financial frictions of the model. Replacing the policy reaction function based on the real interest rate postulated by Bernanke *et al.* (1999) with a nominal interest rate rule à la Taylor (1993) has significant implications for the determinacy of the financial accelerator model.

As can be seen in Figure 5, the range of values for the Calvo price stickiness parameter, α, and for the steady state slope of the external finance premium, $\upsilon'\left(\gamma_n^{-1}\right) \equiv \frac{\partial \upsilon\left(\gamma_n^{-1}\right)}{\partial \gamma_n^{-1}}$, that guarantees the existence and uniqueness of the solution of the financial accelerator model can—in practice—be very limited. Interestingly as well, the specification of a Taylor rule responding to year-over-year inflation as in (18) results in a noticeably smaller determinacy region than the specification presented in (22) responding to annualized quarter-over-quarter inflation (which is closer to the inflation measure often used in quantitative and theoretical papers in the literature).

[Insert Figure 5 about here]

The Calvo price stickiness parameter, α, is assumed to be 0.75 in Bernanke *et al.* (1999). This implies that the average price duration is 4 quarters. Given that degree of nominal rigidity and the Taylor rule in

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[14] There are no apparent structural breaks between the Great Moderation period and the entire post-Korean War sample. The average investment share for the post-Korean War period between 1954 : I and 2009 : IV is 0.1705. The average for the sub-period between 1954 : I and 1983 : IV is similar at 0.1709, while the average for the sub-period between 1984 : I and 2009 : IV is also close at 0.17. For more details on the dataset, see the Appendix and the companion files.

[15] I compute the ratio using data on the (effective) Federal Funds rate (period average) and Moody's Seasoned Baa Corporate Bond yield. The rates are reported in annualized percentages, so I divide them by 400. These rates are net rates, so I add 1 to both in order to obtain the gross rate. Then I calculate the ratio between the gross rate on Baa corporate bonds and the (effective) Fed Funds rate.

(18), determinacy can only be attained whenever the steady state slope of the external finance premium, $\upsilon'\left(\gamma_n^{-1}\right) \equiv \frac{\partial \upsilon\left(\gamma_n^{-1}\right)}{\partial \gamma_n^{-1}}$, takes a value above 1.59. That implies that a 1% increase in the leverage ratio of the entrepreneurs, $\left(\frac{\Delta \gamma_n^{-1}}{\gamma_n^{-1}}\right)$, is on average associated with a bit more than a 315 basis points increase in the interest rate ratio, $\left(\frac{\Delta \frac{R^k}{R}}{\frac{R^k}{R}}\right)$.

This fact about determinacy has not gone entirely unnoticed. Meier and Müller (2006) estimated a similar model and found that the composite coefficient $\vartheta \equiv \left(\frac{\upsilon'\left(\gamma_n^{-1}\right)\gamma_n^{-1}}{\upsilon\left(\gamma_n^{-1}\right)}\right)$ was 0.0672. Therefore, given my choice of the leverage ratio, γ_n^{-1}, and the external financing premium, $\upsilon\left(\gamma_n^{-1}\right)$, it must be the case that the coefficient $\upsilon'\left(\gamma_n^{-1}\right)$ is equal to 0.0339. That implies that a 1% increase in the leverage ratio, $\left(\frac{\Delta \gamma_n^{-1}}{\gamma_n^{-1}}\right)$, is on average associated with a 6.72 basis points increase in the interest rate ratio, $\left(\frac{\Delta \frac{R^k}{R}}{\frac{R^k}{R}}\right)$. Meier and Müller (2006) report that the slope of the Phillips curve, $\lambda_p \equiv \left(\frac{(1-\alpha_p\beta)(1-\alpha_p)}{\alpha}\right)$, is estimated to be 0.0034. These authors set the time discount factor, β, to be 0.99. Hence, the implied Calvo price stickiness parameter must be $\alpha_p = 0.9478$, so the average duration of a pricing spell under those conditions is approximately four years and three quarters. This finding, however, is consistent with the shape of the determinacy region plotted in Figure 5 and their estimates of the slope of the external financing premium.

In my exploration of the financial accelerator model, I use two different combinations of the Calvo parameter and the slope of the external finance premium. In one, I keep the Bernanke *et al.* (1999) assumption that the Calvo parameter α is equal to 0.75 and pick the smallest possible slope $\upsilon'\left(\gamma_n^{-1}\right)$ at 1.59 that is consistent with determinacy (independently of whether I specify monetary policy as in (18) or as in (22)). That implies a rather conventional average pricing spell of 4 quarters often, found in most New Keynesian models, but a very high sensitivity of the external finance premium to changes in the leverage of the entrepreneurs.

In the other combination, which I consider my benchmark parameterization, I take the estimate of the slope $\upsilon'\left(\gamma_n^{-1}\right)$ at 0.0339 found by Meier and Müller (2006), which is closer to what Bernanke *et al.* (1999) would have chosen. But, instead of imposing a very high Calvo parameter to guarantee determinacy, I select a much lower price stickiness parameter than in Bernanke *et al.* (1999) and Meier and Müller (2006) at 0.3. This parameterization ensures the determinacy of the solution and implies an average price duration of 1.43 quarters with a less sensitive external finance premium. My choice of the Calvo parameter is also compatible with a growing body of empirical literature (specially micro estimates) that suggests an average duration of 4 quarters may be overstated for the U.S. The determinacy region is potentially much different under the specification of the policy rule chosen by Bernanke *et al.* (1999) and that explains why they can reconcile a model with low spreads and higher degree of price stickiness.

3.2 Shock Processes

The sample I investigate here is chosen to coincide with the dating of the Great Moderation period. While different authors date the start of the Great Moderation at different times, most authors agree that the large decline in volatility began in 1984. McConnell and Pérez-Quirós (2000) estimate a break date of $1984 : I$ using quarterly real output growth data between $1953 : II$ and $1999 : II$. I use the same starting quarter for my sample of the Great Moderation as McConnell and Pérez-Quirós (2000), which avoids most of the structural breaks in the data prior to the mid-1980s, which I already noted in subsection 3.1.

Since the model abstracts from population growth, the Solow residuals need to be inferred from capital, hours worked and private output series expressed in per capita terms. For exact details on the calculation of the U.S. Solow residual, see the dataset in the Appendix. Taking the Solow residual, S_t, in units—rather than percentages—as my measure of TFP, I linearly detrend the series in logs by OLS for the period between $1983 : IV$ and $2009 : IV$. The estimates of the linear trend imply that,

$$\ln (S_t) 100 \;=\; \underset{(0.2563)}{55.2498} + \underset{(0.0042)}{0.1943} t + \widehat{s}_t, \; R^2 = 0.9541,$$

where the standard errors are always reported in parenthesis below the estimates. Then, I fit the detrended Solow residual series in logs to an $AR(1)$ process and I obtain that,

$$\widehat{s}_t \;=\; \underset{(0.0526)}{0.8561} \widehat{s}_{t-1} + \widehat{\varepsilon}^s_t, \; \sigma\left(\widehat{\varepsilon}^s_t\right) = 0.6893, \; R^2 = 0.7201.$$

This estimated process characterizes the TFP shock dynamics described in (9), under the conventional assumption that all agents know about these shock dynamics and factor them into their decision-making process.

Figure 6 illustrates the behavior of the trend and the actual series for both the Solow residual in logs and private output in logs. This plot shows that there is an apparent break in both series prior to the Great Moderation period (from $1984 : I$ onwards). It also suggests that the growth trend has been noticeably higher for private output than for the Solow residual (a fact perhaps accounted for by the contribution of other factors, e.g., a trend decline in the relative price of capital goods).[16]

[Insert Figure 6 about here]

I define the monetary policy rule in the spirit of Taylor (1993), where the monetary policy instrument is the (effective) Federal Funds rate in percent per annum. As in Taylor (1993), the central bank reacts to the percentage inflation rate over the previous four quarters and to the percent deviation of real GDP from a log-linear trend (where the trend of private output is estimated independently with data for the Great Moderation period only). I also maintain the parametric assumptions of Taylor (1993) implying that the response to fluctuations in inflation, ψ_π, is 1.5, the response to fluctuations in detrended output, ψ_y, is 0.5, and the interest rate smoothing parameter, ρ_i, is 0. All the sources on U.S. monetary policy rates are described in the Appendix.

The Taylor (1993) implied annualized rates (in percentages), $i^{AR\%,TR}_{t+1}$, are calculated with the following mathematical formula,

$$i^{AR\%,TR}_{t+1} \equiv k + \left(\frac{\overline{P^* - P^*_{-4}}}{P^*_{-4}}\right) 100 + 1.5 \left(\left(\frac{P^*_t - P^*_{t-4}}{P^*_{t-4}}\right) 100 - \left(\frac{\overline{P^* - P^*_{-4}}}{P^*_{-4}}\right) 100 \right) + 0.5 \left(\left(\frac{Y_t - \overline{Y}_t}{\overline{Y}_t}\right) 100 \right), \tag{25}$$

where $\left(\frac{P^*_t - P^*_{t-4}}{P^*_{t-4}}\right) 100$ is the rate of inflation over the previous four-quarters in percentages, $\left(\frac{\overline{P^* - P^*_{-4}}}{P^*_{-4}}\right) 100$ is

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[16] When the trends are estimated independently for the Great Moderation period between $1983 : IV$ and $2009 : IV$, I observe that the year-over-year growth rate of the output trend in levels is 1.34%, while the year-over-year growth rate of the Solow residual trend in levels is 0.78%. When the trends are estimated jointly for the Great Moderation period, I find that the year-over-year growth rate for both the output and Solow residual trends in levels is 1.06%.

the inflation target in percentages, and $\left(\frac{Y_t-\overline{Y}_t}{\overline{Y}_t}\right)100$ is the percentage deviation of real private output (i.e. Y_t) from its trend (i.e. $\overline{Y}_t$). If both the inflation rate and the detrended output are on target (i.e. if $\left(\frac{P_t^*-P_{t-4}^*}{P_{t-4}^*}\right) = \overline{\left(\frac{P^*-P_{-4}^*}{P_{-4}^*}\right)}$ and $\left(\frac{Y_t-\overline{Y}_t}{\overline{Y}_t}\right) = 0$), then the Taylor rate would be equal to $i_t^{AR\%,TR} \equiv k + \overline{\left(\frac{P^*-P_{-4}^*}{P_{-4}^*}\right)}100$. Taylor (1993) defines the constant k to be equal to the long-run real (annualized) interest rate $r^{AR\%}$ and sets it equal to 2% (i.e. $k = r^{AR\%} = 2$). Taylor (1993) also assumes that the inflation rate target is equal to 2% (i.e. $\overline{\left(\frac{P^*-P_{-4}^*}{P_{-4}^*}\right)}100 = 2$). Therefore, the long-run nominal rate must be equal to 4% (i.e. $\bar{i}^{AR\%,TR} = 4$).

I derive the monetary policy deviations $\widehat{m}_t$ using exactly the same formula as in (25) to calculate the Taylor rates and the same parameterization as Taylor (1993), i.e.

$$i_{t+1}^{AR\%} \approx 4 + 1.5\left(\left(\frac{P_t^*-P_{t-4}^*}{P_{t-4}^*}\right)100 - 2\right) + 0.5\left(\left(\frac{Y_t-\overline{Y}_t}{\overline{Y}_t}\right)100\right) + \widehat{m}_t, \tag{26}$$

but some caveats are in order. First, the conventional assumption underlying the class of models with nominal rigidities that I investigate here is that the long-run inflation rate is 0. Given that, the real and nominal interest rates must coincide along the balanced growth path—assuming that the unconditional mean of the deviations between the (effective) Fed Funds rate and the Taylor rates $\overline{m}$ is 0 as well. This implies that the steady state nominal rate $\bar{i}^{AR\%}$ and the steady state real rate $r^{AR\%}$ are equal to 4% annualized by consistency with my parameterization of the time discount factor, β, at 0.99. In other words, the interpretation of the long-run rates and their quantification differs from those postulated by Taylor (1993).

Second, while Taylor (1993) assumes the inflation target to be 2%, I observe that the actual inflation average over the Great Moderation period is 3.06% (or 3.12% if I exclude the last two years of the sample). To treat the data on inflation and extract the cyclical component, I assume that the inflation rate moves around the inflation target of 2% set by Taylor (1993)—instead of demeaning the data— in spite of the higher average inflation for the Great Moderation period, i.e.

$$\left(\frac{P_t-P_{t-4}}{P_{t-4}}\right)100 = \left(\frac{P_t^*-P_{t-4}^*}{P_{t-4}^*}\right)100 - 2,$$

where $\left(\frac{P_t-P_{t-4}}{P_{t-4}}\right)100$ denotes the cyclical inflation rate. Then, I re-express equation (26) as follows,[17]

$$i_{t+1}^{AR\%} \approx 4 + 1.5\left(\left(\frac{P_t-P_{t-4}}{P_{t-4}}\right)100\right) + 0.5\left(\left(\frac{Y_t-\overline{Y}_t}{\overline{Y}_t}\right)100\right) + \widehat{m}_t. \tag{28}$$

Alternatively, one could attempt to extend the benchmark model to allow for steady state inflation to be different than zero, which could have a non-trivial impact on short-run dynamics. But even if that extension was pursued, the issue regarding the consistency between the target inflation rate and the long-run inflation rate would still remain open. I leave those questions on the dynamics of the model in an environment where long-run inflation is non-zero for future research.

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[17] Equation (28) can be re-written instead as,

$$i_{t+1}^{AR\%} \simeq 4 + 1.5\left(\widehat{p}_t - \widehat{p}_{t-4}\right) + 0.5\widehat{y}_t + \widehat{m}_t, \tag{27}$$

given the fact that $x \simeq \ln(1+x)$ for small enough x, where $\left(\widehat{p}_t - \widehat{p}_{t-4}\right)$ is the log-deviation of year-over-year inflation from the zero-inflation steady state and $\widehat{y}_t$ is the log-deviation of detrended output.

Consistency between the model definitions and the data is maintained throughout the paper. For instance, I define real private output to be real GDP excluding government compensation of employees to be consistent with the model which excludes government altogether. I calculate the relevant inflation rate in terms of the consumption (nondurables and services) price index for the same reason. My derivation of the inflation rate, the deviations of real GDP from trend, and the monetary policy residuals uses the same data and the same concepts are used everywhere else in the model, even though Taylor (1993)'s preferred measures are in fact the real GDP and the GDP deflator.

Monetary policy shocks are defined by the residual $\widehat{m}_t$, implied by the deviations between the (effective) Federal Funds rate and the policy rule in (26). The performance of the rule is illustrated in Figure 7. As can be seen, even though I have used different data sources than those preferred by Taylor (1993), the long-held view that the rule provides a good description of the first part of chairman Greenspan's tenure at the helm of the Federal Reserve between 1987 and 1998 remains unchanged.

[Insert Figure 7 about here]

The implicit assumption all along is that the monetary policy deviations are non-systematically biased in one particular direction (i.e. on average $\widehat{m}_t$ is expected to be approximately equal to 0). The average of the policy deviations for the period between $1987 : I$ and $1998 : IV$ is, in fact, 0.1%. However, the average for the entire Great Moderation period is -0.64%, reflecting the impact of a period of low interests after 1998. A number of qualifications need to be made regarding the conduct of monetary policy during the full sample period of the Great Moderation and about the interpretation of the monetary shocks derived in this way.

First, I am surely missing some transition dynamics in the first half of the 80s. As noted before, the 70s and part of the 80s was a convulsive period of time that saw significant structural and trend changes, none of which is fully captured by the model as it stands. Implicitly it is being assumed that the new trends for the entire period were already known at the onset of the Great Moderation. The transition dynamics could, perhaps, account for some of the discrepancies between the Taylor rule and the (effective) Fed Funds rate at the beginning of the period. I do not explore the issue further in the paper and, therefore, treat the resulting deviations as purely exogenous monetary shocks.

Second, there is an apparent systematic downward deviation from the rule after 1998. This coincided in time roughly with the aftermath of the Asian Crisis of 1997, the LTCM bailout in 1998, the 9/11 events and the subsequent recession of 2001. It has resulted in a prolonged period of time where the Federal Funds rate has been kept too low relative to the prescriptions of the Taylor (1993) rule. This fact has been noted and extensively discussed before, but the model laid down here allows me to investigate its implications for the U.S. business cycle.

However, these systematic deviations of the policy rule could be indicative of a change in monetary policy regime that occurred in the late 90s, leading to an environment with systematically lower interest rates. Many factors can contribute to such a regime change, for instance, a change in the trade-off between fighting inflation and promoting sustainable growth, a change in the long-run inflation target or a change in the long-run real rates.

Distinguishing whether the deviations from the rule are exogenous after 1998 or reflect some sort of policy shift (or regime change) is probably one of the most substantive challenges to determine the contribution that monetary policy has had to the U.S. business cycle over this period. I leave the exploration of that issue for future research, and here I treat those deviations as realizations coming from the same exogenous process for monetary policy shocks as prior to 1998. I also assume that economic agents did not perceive those deviations as implying a regime shift for monetary policy (and would still expect the average policy deviation to return to zero as more data is added to the sample).

Finally, there is the crucial issue of the role of the zero-lower bound for monetary policy, specially over the past 2 years. Based on my dataset for the U.S. economy and my characterization of the Taylor rule, the prescribed rate should have become negative in the first quarter of 2009 hitting a low point of -3.59% in the third quarter of 2009. The model that I work with is unconstrained and, therefore, entails that no agent incorporates in its decision-making the practical fact that nominal rates are bounded below by zero.[18] I will leave the exploration of the zero-lower bound for further research. Instead, the deviations between the unconstrained Taylor rate and the constrained (effective) Federal Funds rate are viewed as realizations of the same exogenous monetary policy shock process.

With all those caveats in mind about what constitutes a monetary policy shock, I fit the series of Taylor rule deviations to an $AR(1)$ process and I obtain,

$$\widehat{m}_t \;=\; \underset{(0.0365)}{0.9095}\widehat{m}_{t-1} + \widehat{\varepsilon}_t^m,\ \sigma\left(\widehat{\varepsilon}_t^m\right) = 0.8288,\ R^2 = 0.8578.$$

This estimated process characterizes the dynamics of the monetary policy shock described in (21). I maintain the conventional assumption that all agents know about these shock dynamics and factor them into their decision-making process. After the derivation of a realization for the TFP and monetary policy shock processes, I finally close the model with the estimation of each one of those processes. See Figure 8 for an illustration of both stochastic processes.

[Insert Figure 8 about here]

4 Simulation and Quantitative Findings

Given some initial conditions, the linearized equilibrium conditions and the stochastic shock processes described in section 2 constitute a fully specified linear rational expectations model. In this paper I investigate the strengths and weaknesses of the financial accelerator mechanism to account for the business cycle fluctuations observed in the U.S. data during the Great Moderation period (since $1984 : I$ onwards following the dating of McConnell and Pérez-Quirós, 2000). I focus my attention primarily on real private output per capita, share of hours worked per capita and (year-over-year) inflation, since the path of these variables often provides a useful gauge of the model's overall performance. I also ask how significant the contribution of monetary policy is to the business cycle in the context of the financial accelerator model and against the backdrop of the Great Moderation experience.

To answer these questions, I first derive the policy functions implied by the linear rational expectations model laid out in section 2.[19] I use those policy functions to map the realizations of the detrended U.S. Solow

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[18] Unless some unorthodox measures are put in place by central banks that I am not considering here.

[19] All the policy functions used in my simulations are derived using the software package Dynare. The parameterization satisfies the Blanchard-Kahn conditions, so a solution exists and is unique.

residual in logs and the U.S. monetary policy deviations presented in subsection 3.2—and also discussed in the Appendix—into measures of the cyclical behavior of real private output per capita, the share of hours worked per capita and inflation. I subsequently compare those model simulations against the U.S. data. To initialize each simulation, I assume that the economy is growing at (or near) its balanced growth path at the starting quarter.

Prior to the Great Moderation period, $1979:IV$ stands out as the latest quarter when actual real private output per capita is approximately equal to its potential (as implied by the log-linear trend estimated for the period $1983:IV-2009:IV$). Hence, I take that quarter to be the initial period in all the simulations. All endogenous state variables of the model are set to zero in $1979:IV$. For every subsequent quarter, the state variables are simulated using the realizations of the detrended log of the Solow residual and the monetary policy deviations obtained from the U.S. data. I only report the simulated series from $1984:I$ onwards.

I run a number of policy experiments and counterfactual simulations intended to gauge the strength of the financial accelerator mechanism, the contribution of TFP versus monetary shocks over the cycle, and the sensitivity of the predictions to some key modelling assumptions. In order to test the robustness of the results, I specifically explore changes to the benchmark specification of the model. More concretely, I investigate the role of the inflation rate measure (year-over-year versus quarter-over-quarter rates) to which monetary policy reacts, the degree of nominal rigidities, and the sensitivity of the external finance premium to fluctuations in the leverage ratio of entrepreneurs-borrowers.

4.1 A Point of Reference: The RBC Model

To establish a point of reference, I simulate the frictionless model (the standard RBC model) and compare it against the data in Figure 9 under the assumption that the central bank's monetary policy can be well-approximated by the Taylor (1993) rule introduced in equation (18).[20] The frictionless model tracks reasonably well the path of detrended real private output per capita during the Great Moderation period, with a correlation between the data and the model simulation of 0.47 (or 0.58 for the subsample between $1984:I$ and $2007:IV$). The standard deviation of detrended real private output per capita for the period is 2.54% (or 2.05% up to $2007:IV$), while the standard deviation of output in the simulation is 1.70% (or 1.59% excluding the last two years of the simulation). The persistence (measured with the first-order autocorrelation) in the data is 0.97 (or 0.96 up to $2007:IV$), while in the simulation is 0.85 (or 0.84 up to $2007:IV$).

Arguably the most obvious and significant discrepancy between the model and the data arises after $2008:I$, where the decline of the Solow residual below trend reverses itself pushing the simulated output series upwards with it, while in fact real detrended output per capita continues to decline until the end of 2009. One candidate of explanation that has been forcefully argued is that financial frictions—which are missing in the RBC framework—may have contributed to the apparent disconnect between TFP and output and could reconcile the output declines and Solow residual increases observed in the data. One of the most popular models that accounts for the role of financial frictions explicitly in a general equilibrium setting is the Bernanke *et al.* (1999) model that I subsequently investigate.

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[20] The RBC model is subject to both TFP and monetary policy shocks. However, monetary shocks only have an impact on the nominal variables due to monetary policy neutrality in this environment.

The RBC model, however, has more difficulties accounting for the observed fluctuations in the share of hours worked per capita and in inflation. The frictionless model has little power in tracking the path of demeaned hours worked during the Great Moderation period, with a correlation between the data and the model simulation of -0.16 (or -0.12 for the subsample between $1984 : I$ and $2007 : IV$). The standard deviation of demeaned hours worked for the period is 3.27% (or 3.03% up to $2007 : IV$), while the standard deviation of hours in the simulation is only 0.54% (or 0.50% excluding the last two years of the simulation). The low volatility of hours worked in the RBC model is, in fact, a problem already recognized in the literature. As it happens with real output, the reversal in the decline of the Solow residual below trend also pulls the simulated hours worked upwards since 2008 unlike what can be observed in the U.S. data. In turn, the persistence in the data is 0.96 (even for the sub-sample up to $2007 : IV$), while in the simulation is 0.84 (or 0.83 up to $2007 : IV$).

When looking at the (year-over-year) cyclical inflation rate of the consumption (nondurables and services) price index, the frictionless model simulation is able to attain a correlation with the data of 0.32 (or 0.21 for the subsample between $1984 : I$ and $2007 : IV$). The standard deviation of the cyclical inflation rate for the Great Moderation period is 1.10% (or 0.95% up to $2007 : IV$), while the standard deviation of inflation in the simulation is much higher at 3.09% (or 2.77% excluding the last two years of the simulation). The model also predicts a period of deflation in the early 1980s that never quite materialized (whenever monetary policy appears to have systematically erred on the side of higher interest rates) and a period of higher than realized inflation for the most part after 1998 (whenever monetary policy systematically erred on the side of lower interest rates). In turn, the persistence in the data is 0.87 (or 0.90 up to $2007 : IV$), while in the simulation is 0.92 (or 0.94 up to $2007 : IV$).

[Insert Figure 9 about here]

These findings give some perspective and set the stage for a further exploration of the financial accelerator model of Bernanke *et al.* (1999).

4.2 Claim 1: The Strength of the Mechanism

The benchmark financial accelerator model assumes a low degree of price stickiness (i.e. $\alpha = 0.3$) and a conventional parameterization of the sensitivity of the external finance premium (i.e. $\vartheta \equiv \left(\frac{\upsilon'\left(\gamma_n^{-1}\right)\gamma_n^{-1}}{\upsilon\left(\gamma_n^{-1}\right)} \right) = 0.0672$) implying that *ceteris paribus* a one percent increase in the leverage of borrowers raises the cost of external finance by almost 7 basis points per quarter. The model is also endowed with a Taylor (1993)-type monetary policy rule as described in (18).

In the experiment plotted in Figure 10, I look at the simulation of the benchmark financial accelerator model and compare it against the RBC model and a variant of the benchmark financial accelerator model driven exclusively by TFP shocks in order to gauge the role played by financial frictions (and nominal rigidities) in this environment. All three models are compared against the data to determine the strength of the quantitative findings.

The variant of the financial accelerator model driven with only TFP shocks is also based on the policy rule described in equation (18). However, it involves the joint assumption that the central bank never deviates from the specified monetary policy rule—which is inconsistent with the evidence for the U.S., as noted in Figure 7—and that all agents know (and believe) that the central bank is not going to deviate from that rule. Therefore, the comparison of the model with and without monetary policy shocks provides further insight on the contribution that monetary policy deviations have over the cycle.

Interestingly, I find that during the entire Great Moderation sample period the correlation between the RBC simulation and the simulation of the benchmark financial accelerator model for real private output is 0.89, the correlation between the RBC simulation and the simulation of the benchmark financial accelerator model solely driven by TFP shocks is 0.999, and the correlation between the benchmark financial accelerator model and its variant driven solely by TFP shocks is 0.88. As can be seen in Figure 10, the RBC model simulation for real private output per capita is the least volatile at 1.70% (or 1.59% for the subsample between $1984 : I$ and $2007 : IV$) while the benchmark financial accelerator model—which is nonetheless highly correlated with the RBC model—is more volatile at 2.60% (or 2.44% excluding the last two years of the simulation). The most volatile simulation comes from the benchmark financial accelerator model that includes both TFP and monetary policy shocks reaching 2.93% compared to 2.54% in the data (or 2.58% compared to 2.05% if I exclude the last two years of the sample).

[Insert Figure 10 about here]

While deviations of monetary policy also weaken the correlation between the accelerator model's simulation and the RBC's simulation, a case can be made on the basis of those findings that the financial accelerator mechanism has an amplification effect over the cycle. However, the deviations of monetary policy that I derive are rather modest during the first half of chairman Greenspan's tenure at the Fed (between 1987 and 1998) and the differences between the three models presented are consequently small. In the early part of the 1980s, monetary policy deviations are larger in size—with interest rates above the Taylor-implied rates—but that actually makes it harder for the financial accelerator model to replicate the fact that real private output in the data appears below trend. Similarly, the period of low interest rates after 1998 is notable for the size of the deviations. However, those deviations do not help the financial accelerator model capture the fact that real private output stayed for the most part above trend until 2007. Table 2 also reports the persistence of each simulated series and, in all cases, the first-order autocorrelation appears to be around 0.85. By this measure, the propagation does not appear to be very different across all three models.

During the entire Great Moderation period, the correlation between the RBC simulation and the simulation of the benchmark financial accelerator model for (demeaned) hours worked per capita is 0.86, the correlation between the RBC simulation and the simulation of the financial accelerator model solely driven by TFP shocks is 0.94, and the correlation between the benchmark financial accelerator model and the model driven solely by TFP shocks is 0.70. The simulations of all three model variants are positively and strongly correlated in line with the findings for real private output per capita. However, their ability to fit the data is rather poor as can be inferred from the fact that the correlation between the data on hours worked per capita and the RBC simulation is -0.16, the correlation with the benchmark financial accelerator model is -0.35, and the correlation with the financial accelerator model solely driven by TFP shocks is 0.03.

If one looks only at the standard deviation of hours worked per capita, then the volatility of the RBC model simulation is 0.54% (or 0.50% for the subsample between $1984 : I$ and $2007 : IV$) while the benchmark financial accelerator model is five times more volatile at 2.78% (or 2.47% excluding the last two years of the sample) compared to 3.27% in the data (or 3.03% if I exclude the last two years of the sample). On these grounds, one would be tempted to conclude that the financial accelerator model performs better than the RBC model, while, in fact, they both have serious problems accounting for the empirical evidence.

In the period of high interest rates in the early 1980s, monetary policy deviations result in a negative income/wealth effect that induce higher hours worked. In the period of low interest rates since 1998, monetary policy deviations result in a positive income/wealth effect that induce households to choose to work less. In both instances, these effects make the model unable to match the actual (demeaned) hours worked observed in the data. One possible implication of these findings is that the choice of preferences needs to be revised and that the trade-off between wealth/income effects and substitution effects is in need of further investigation.

During the entire Great Moderation period, the correlation between the RBC simulation and the simulation of the benchmark financial accelerator model for the (year-over-year) cyclical inflation is 0.99, the correlation between the RBC simulation and the simulation of the financial accelerator model solely driven by TFP shocks is 0.41, and the correlation between the benchmark financial accelerator model and the model driven solely by TFP shocks is 0.42. The most surprising fact being the strong correlation between the inflation simulation of the RBC and the financial accelerator models, both of which are driven by a combination of TFP and monetary policy shocks.

Their ability to track the inflation data can be gauged by the fact that the correlation between the data on (year-over-year) cyclical inflation[21] and the RBC simulation is 0.32 (or 0.21 up to $2007 : IV$), the correlation with the benchmark financial accelerator model is 0.36 (or 0.23 up to $2007 : IV$), and the correlation with the benchmark model solely driven by TFP shocks is 0.48 (or 0.55 up to $2007 : IV$).

The correlations between real private output per capita, the share of hours worked per capita and (year-over-year) cyclical inflation also offer another perspective on the performance of the different models. As one can see from Table 2, the correlation between real private output per capita and hours worked per capita is relatively high in all three models (0.90 in the RBC model for the full sample, 0.92 in the benchmark financial accelerator model, and 0.99 in the financial accelerator model driven solely by TFP shocks) compared against 0.73 observed in the data for the entire Great Moderation period. The correlation of real private output per capita and hours worked per capita with inflation, however, is much more difficult to match.

First, I observe that the correlations are significantly different whether one includes the last two years (since $2008 : I$) or not. The empirical correlation between real private output per capita and inflation is 0.09 for the entire sample, but -0.24 if one excludes the last two years. Similarly, the empirical correlation between hours worked per capita and inflation is -0.02 for the entire sample, but -0.33 after excluding 2008 and 2009. This suggests—although is by no means conclusive proof—that the 2007 recession may have displayed some patterns that are unusual given the prior experience since the early 1980s.

Secondly, the RBC model performs better in these two dimensions than the two variants of the financial accelerator model that I consider here—at least for the sub-sample up to 2007. In fact, for the shorter sub-sample the correlation between real private output and inflation in the RBC simulation is -0.35 compared to -0.24 in the data. The correlation between hours worked and inflation is -0.68 compared against -0.33 in the data. In turn, while both correlations are negative in sign for the two variants of the accelerator model, they are much larger in absolute value than those produced by the RBC model. However, adding the last two years to each simulation often results in stronger correlations unlike what can be observed in the data (where the correlations are certainly much weaker).

These results highlight some of the inherent weaknesses of the financial accelerator model, but also

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[21] Cyclical inflation is defined in subsection (3.2) to be equal to the actual inflation rate minus 2% - which corresponds to the long-run inflation target set by Taylor (1993).

indicate that neither variant of the model is capable of successfully explaining the turn of events during the current recession.

[Insert Table 2 about here]
[Insert Table 3 about here]

4.3 Claim 2: The Impact of Nominal Rigidities and the External Finance Premium

The simulations reported here are based on the same Taylor (1993) specification of monetary policy described in equation (18), but now I compare the RBC and the benchmark financial accelerator model against a variant of the financial accelerator with higher nominal rigidities (the average duration of a pricing spell is now 4 quarters) and a much higher sensitivity of the external finance premium to fluctuations in the leverage of the entrepreneurs-borrowers. All models are driven by a combination of the TFP and monetary policy shocks.

As can be seen in Figure 11, whenever the nominal rigidities and financial frictions are enhanced, then the simulations show a reversing of some of the predictions of the benchmark financial accelerator model and the RBC model in periods where the monetary policy deviations are sizeable. For instance, in the early 80s the distortion introduced by price rigidities and the higher costs of external funding result in less hours being worked and output falling below potential in spite of the fact that higher interest rates give households an added incentive to work more.

Since 1998, the policy rates were kept much lower than predicted by the Taylor rule. However, it is only in combination with higher price stickiness and higher external borrowing costs that this policy of low rates translates into a boom in hours worked per capita and real private output per capita (in spite of the fact that productivity falls below trend for much of this period). As could have been expected, the fluctuations of the inflation rate under those conditions are simply too large to compare well with the actual data.

Table 2 gives a broad overview of some of the key moments of the model with high price stickiness and high borrowing costs. I observe that real private output per capita and hours worked are slightly less volatile than for the benchmark parameterization of the financial accelerator model. In fact, the volatility of real private output per capita is 1.77% compared to 2.93% in the benchmark over the entire sample, while the volatility of hours worked per capita is 2.33% compared to 2.78% in the benchmark. In turn, the opposite can be said for cyclical (year-over-year) inflation since the volatility reaches a high of 6.16% compared against 3.22% in the benchmark and 1.10% in the data over the Great Moderation period. If one restricts the sample by eliminating the last two years, the same trends would still show up.

As powerfully illustrated in Figure 11, the excess volatility of inflation is a clear warning signal about the performance of the model with high price stickiness and high borrowing costs. This variant of the benchmark model, however, has an important effect on other moments as well. For instance, for the entire sample I observe that the correlation between real private output per capita and hours worked per capita is 0.73, which is lower than the 0.92 for the benchmark financial accelerator model and exactly matches the 0.73 observed in the U.S. data.

Moreover, the financial accelerator model with high price stickiness and high adjustment costs (where TFP and monetary shocks are combined) reverses the prediction of the benchmark financial accelerator model and the RBC model that real private output and hours worked ought to be negatively correlated with inflation. For the full sample, the correlation between real private output and cyclical inflation becomes 0.36 compared against 0.09 in the data, while the correlation between hours worked and cyclical inflation becomes 0.79 compared against -0.02 in the data.

Similar positive correlations for simulated real private output and hours worked with inflation can be found if I restrict the sample to end in 2007, while in the data those correlations appear to be significant and negative. One could argue on the basis of these observations that a change in the specification of the financial frictions (or credit market imperfections) may help the apparent change, observed in the data whenever we include the observations from the ongoing recession, in the size and sign of the correlations between real private output and inflation, and between hours worked and inflation.

One potential candidate of explanation is that borrowing costs may have substantially increased during these two years of recession due to constraints on loan supply that resulted from the concurrent banking crisis (the bank lending channel may indeed have been impaired). However, in order to assess that intuition more precisely, one needs to address a fundamental question. Are these increases in borrowing spreads better thought of as endogenous responses, or can they be modelled as random exogenous shocks to the spreads that are treated as unpredictable by the economic agents and orthogonal to their decisions?

If one goes through the route of endogeneizing the bank lending channel, then an extension of the Bernanke *et al.* (1999) framework is clearly needed. If one treats this as an exogenous change of financial regime, then one cannot incorporate some important issues like the possible connection between monetary policy and the banking crisis into the discussion. Besides that, one still needs to deal with the problem of how to infer the Markov-switching process driving these regime changes (and how these processes affect the likely outcomes, not only after a banking crisis unfolds, but also before it does in normal times). Similarly, one still needs to deal with another problem posed by how to handle the fact that the parameter space for which a determinate solution of the financial accelerator model exists can be severely limited. All of these questions are left for future research.

[Insert Figure 11 about here]

4.4 Claim 3: The Impact of the Monetary Policy Rule

Another thought experiment that one could consider is whether the different measurements of the rate of inflation have much to do with the economic performance of monetary policy rules. That's the underlying theme exploited and illustrated in Figure 12. There are many ways in which this question could have been addressed, but I decided to restrict myself to just one very specific issue: whether measuring inflation in terms of year-over-year growth rates or annualized quarter-over-quarter rates matters much. Most of the theoretical literature, after all, describes the reaction of policy-makers to inflation in terms of quarter-over-quarter rates while most of the empirical literature on Taylor rules—including Taylor (1993) himself—looks at the issue in terms of year-over-year inflation rates.

In all simulations I have presented so far, the implicit assumption is that the U.S. monetary policy targets the year-over-year growth rate as explicitly stated in equation (18). One way to address the importance of using annualized quarter-over-quarter growth rates would be by re-estimating the Taylor rule residuals under this alternative inflation rate measure, assuming that the agents in the economy know and believe that the reaction to inflation is set in terms of quarter-over-quarter rates. Only then I could properly re-simulate the model feeding those Taylor rule deviations into the policy functions. The disadvantage of following that path is that it would make it harder to establish the exact contribution of a different measure of inflation since the simulation of the endogenous variables would jointly reflect the change in the rate of inflation used to set monetary policy as well as a different shock process for the perceived exogenous monetary policy deviations. And then, how to disentangle the contribution of one from the other?

Instead, I adopt in this exercise a much more modest thought experiment. I will take as given the monetary policy shock process and assume it is exactly the same one I have used thus far. Then I simply re-simulate the model under the assumption that monetary policy reacts to quarter-over-quarter annualized inflation rates. This is a counterfactual exercise, since it implies that the path of short-term interest rates would no longer be consistent with the actual path even when the rule responds to realized values of real private output and inflation. However, it gives me a sensible quantification of the impact that a change in the monetary policy rule may have had in isolation.

Otherwise, the financial accelerator model that I simulate in this counterfactual corresponds exactly to the same specification of low price stickiness and low sensitivity of the external borrowing costs that I have used to characterize my benchmark parameterization. One would conjecture that such a seemingly small change in the monetary policy rule could not have had major implications for the dynamics of the economy. The surprising thing in this exercise is that just the opposite happens to be true. The plots in Figure 12 illustrate that the benchmark financial accelerator model where monetary policy responds to quarter-over-quarter inflation, in fact, overlaps almost entirely with the simulation of the RBC model. I should point out that the simulation of the RBC model presented here is one where the monetary policy rule still responds to the year-over-year inflation rate as given by equation (18).[22]

All three endogenous variables, real private output per capita, hours worked per capita and year-over-year inflation rates show very similar paths, although the year-over-year inflation rate is much smoother whenever monetary policy responds to quarter-over-quarter inflation instead. My conjecture for this result would be that with low price stickiness and low sensitivity of the external borrowing costs, the financial accelerator model does not differ so much from the RBC model and the amplification effects are modest—if monetary policy responds to quarter-over-quarter changes of inflation. In fact, the conventional wisdom within the New Keynesian literature is that responding to quarter-over-quarter rates is preferable because price stability reduces the costs associated with the distortions caused by nominal rigidities. The smaller sensitivity of the external financing premium, then, adds a nuisance term but does not significantly alter the allocation of resources from the outcome expected by the frictionless RBC model.

Alternatively, responding to a different measure of inflation like the year-over-year growth rate opens the possibility that cyclical price movements from one period to the next may become larger than the policy rule responding to quarter-over-quarter rates would allow. Therefore, this alternative policy rule will amplify the impact of the pricing distortion and potentially influence the leverage of the borrowers to interact with monetary policy, resulting in a stronger combined effect from the nominal rigidities and the financial frictions as implied by the external financing premium.

This counterfactual exercise is just one experiment on a broader set of questions about the role of monetary policy. While most of my previous observations have been based on the interpretation of the discretionary component of monetary policy, this counterfactual comes to show that the systematic part of the policy rule

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[22] However, due to the neutrality of monetary policy in the RBC framework, whether monetary policy targets quarter-over-quarter annualized rates or year-over-year rates is only going to matter for the determination of the inflation path.

can indeed have a major impact on the performance of an economic model and that even apparently minor issues like the measurement of inflation can—in turn—be fundamental for the outcome of that model.

[Insert Figure 12 about here]

5 Concluding Remarks

I presented a version of the Bernanke *et al.* (1999) synthesis model with leveraged borrowers (entrepreneurs), financial frictions and nominal rigidities. I have parameterized the model to be as consistent as possible with Bernanke *et al.* (1999) and with the currently available data for the U.S. I have also derived from the U.S. data a realization for the TFP and the monetary shocks that I subsequently use to simulate this model of U.S. business cycles over the Great Moderation period and until the current recession (from $1984 : I$ until $2009 : IV$).

On the basis of these simulations, I would argue that the characterization of the reaction function of monetary policy has non-trivial implications for the performance of the model and that the interpretation of all monetary policy deviations as shocks is anything but trivial. However, I have found otherwise limited support in favor of the financial accelerator model as a superior framework to account for the U.S. business cycle on real private output per capita, hours worked per capita and year-over-year inflation during the Great Moderation period and—specially—during the current recession. In fact, in some dimensions it became clear that a plain vanilla RBC model gets closer to accounting for the path of the endogenous variables observed in the data than the financial accelerator model does. However, neither model seems to account well for the 2007 recession, although there are indications that a higher sensitivity of the external financing premium could help to explain the data over the past $2 - 3$ years better.

One can look at these broad results in two different ways. One can take the view that they cast the implications of the financial accelerator model in a slightly less positive light and, therefore, that this model—and variants of it—are perhaps not yet ready for policy evaluation and analysis at the level we would like them to be. That's a reasonable perspective to ponder, but I would argue that it is still premature to claim on the basis of quantitative results like the ones presented here that the financial accelerator model is incompatible with the data or that it should be discarded.

Another more sympathetic view would be that—indeed—there is a financial friction at play and it is still relevant to account for it. The puzzle is, therefore, worse than we thought because some source of randomness or another feature of the structural transmission mechanism that has not been explicitly modelled may be needed in order to bridge the gap between the model and the data—especially in periods where discretionary monetary policy may have played a larger role like after 1998. The problem could, in turn, be that monetary policy itself and monetary policy shocks in particular are not well-understood in this framework (e.g., if one estimates that the monetary policy regime may have shifted over time).

While this line of arguments creates more questions than it answers, it also implies that more work still needs to be done to help us better understand the role that credit market imperfections play on real economic activity and its interactions with monetary policy. My hope is that this paper will not be viewed as a closing chapter on the subject, but as an effort to direct attention towards a more quantitative evaluation of the question and to encourage further development and integration of financial features on monetary models.

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Tables and Figures

Table 1: Benchmark Calibration.

Parameters			Financial Accelerator		RBC
Intertemporal discount factor	β	=	0.99	BGG (1999)	same
Elasticity of intertemporal substitution	σ	=	1	BGG (1999)	same
Coefficient of Risk Aversion on Leisure	η	=	1	BGG (1999)	same
Steady State Share of Hours Worked	H	=	0.276	Data (1984:I-2009:IV)	same
Capital share	$1-\psi-\varrho$	=	0.284	Data (1954-2008)	same
Entrepreneurs' labor share	ϱ	=	0.01	BGG (1999)	0
Depreciation rate	δ	=	0.012	Data (1984-2008)	same
Adjustment cost parameter	χ	=	21.19	BGG (1999)	same
Entrepreneurs' "survival rate"	ζ	=	0.9728	BGG (1999)	−
Entrepreneurs' (inverse) leverage ratio	γ_n	=	0.5	BGG (1999)	−
Steady state external finance premium	$\upsilon\left(\gamma_n^{-1}\right)$	=	1.00903	Data (1984:I-2009:IV)	1
Steady state slope of external finance premium	$\upsilon'\left(\gamma_n^{-1}\right)$	=	0.0339 / 1.59	Meier-Müller (2006) / Other	0
Calvo price stickiness	α	=	0.3 / 0.75	Other / BGG (1999)	0.001
Entrepreneurs' consumption share	γ_{c^e}	=	0.01	−	0
Investment share	γ_x	=	0.1705	Data (1954:I-2009:IV)	same
Taylor Rule Parameters					
Sensitivity to inflation	ψ_π	=	1.5	Taylor (1993)	same
Sensitivity to detrended output	ψ_y	=	0.5	Taylor (1993)	same
Shock Process Parameters					
Persistence of the TFP shock	ρ_s	=	0.8561	Data (1983:IV-2009:IV)	same
Volatility of the TFP shock	σ_s	=	0.6893	Data (1983:IV-2009:IV)	same
Persistence of the monetary policy shock	ρ_m	=	0.9095	Data (1983:IV-2009:IV)	same
Volatility of the monetary policy shock	σ_m	=	0.8288	Data (1983:IV-2009:IV)	same

This table defines the benchmark parameterization of the financial accelerator and the RBC models used in my simulations.

Table 2: Simulated versus Empirical Moments.

			Benchmark		High EFP & Price Stickiness	
	Data	RBC	BGG (a)	BGG, TFP (a)	BGG (b)	BGG, TFP (b)
Std. Deviations						
$\sigma(\widehat{y}_t)$	2.54 (2.05)	1.70 (1.59)	2.93 (2.58)	2.60 (2.44)	1.77 (1.76)	0.66 (0.63)
$\sigma(\widehat{h}_t)$	3.27 (3.03)	0.54 (0.50)	2.78 (2.47)	1.75 (1.63)	2.33 (2.01)	0.94 (0.87)
$\sigma(\widehat{p}_t - \widehat{p}_{t-4})$	1.10 (0.95)	3.09 (2.77)	3.22 (2.89)	1.53 (1.45)	6.16 (5.45)	4.38 (4.17)
Autocorrelation						
$\rho(\widehat{y}_t, \widehat{y}_{t-1})$	0.97 (0.96)	0.85 (0.84)	0.86 (0.86)	0.85 (0.84)	0.92 (0.93)	0.80 (0.78)
$\rho(\widehat{h}_t, \widehat{h}_{t-1})$	0.96 (0.96)	0.84 (0.83)	0.89 (0.90)	0.84 (0.83)	0.90 (0.93)	0.87 (0.87)
$\rho(\widehat{p}_t - \widehat{p}_{t-4}, \widehat{p}_{t-1} - \widehat{p}_{t-5})$	0.87 (0.90)	0.92 (0.94)	0.86 (0.89)	0.81 (0.79)	0.92 (0.95)	0.93 (0.94)
Correlations						
$\sigma(\widehat{y}_t, \widehat{h}_t)$	0.73 (0.68)	0.90 (0.87)	0.92 (0.89)	0.99 (0.99)	0.73 (0.74)	−0.80 (−0.79)
$\sigma(\widehat{y}_t, \widehat{p}_t - \widehat{p}_{t-4})$	0.09 (−0.24)	−0.48 (−0.35)	−0.82 (−0.77)	−0.97 (−0.97)	0.36 (0.37)	−0.68 (−0.65)
$\sigma(\widehat{h}_t, \widehat{p}_t - \widehat{p}_{t-4})$	−0.02 (−0.33)	−0.74 (−0.68)	−0.97 (−0.96)	−0.95 (−0.94)	0.79 (0.82)	0.90 (0.90)

These moments are based on the Taylor (1993) specification of the monetary policy rule reacting to changes in the year-over-year inflation rate. The moments are calculated for detrended real private output per capita, demeaned hours worked and cyclical inflation - computed as the deviation from a 2 percent target. The full sample covers the period between 1984:I and 2009:IV. Inside parenthesis I report the moments for the sub-sample between 1984:I and 2007:IV. The first-order autocorrelations are computed starting in 1983:IV.

This table reports the theoretical moments for each series given my parameterization. All statistics on simulations are computed after each series is H-P filtered (smoothing parameter=1600), but the results are virtually the same without H-P filtering the series. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

Table 3: The Correlations between the Model Simulations and the Data.

			Benchmark		High EFP & Price Stickiness	
	Data	RBC	BGG (a)	BGG, TFP (a)	BGG (b)	BGG, TFP (b)
Data	1	0.47 (0.58)	0.29 (0.42)	0.48 (0.60)	0.47 (0.47)	0.56 (0.65)
RBC		1	0.89 (0.87)	0.999 (0.999)	0.34 (0.46)	0.95 (0.94)
BGG (a)			1	0.88 (0.86)	−0.13 (−0.02)	0.80 (0.78)
BGG, TFP (a)				1	0.36 (0.49)	0.95 (0.95)
BGG (b)					1	0.44 (0.55)
BGG, TFP (b)						1

These correlations are based on the Taylor (1993) specification of the monetary policy rule reacting to changes in the year-over-year inflation rate. The correlations correspond to detrended real private output per capita and are for the entire period between 1984:I and 2009:IV. Inside parenthesis I also report the correlations for the sub-sample between 1984:I and 2007:IV.

This table reports the theoretical moments for each series given my parameterization. All statistics on simulations are computed after each series is H-P filtered (smoothing parameter=1600), but the results are virtually the same without H-P filtering the series. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

			Benchmark		High EFP & Price Stickiness	
	Data	RBC	BGG (a)	BGG, TFP (a)	BGG (b)	BGG, TFP (b)
Data	1	−0.16 (−0.12)	−0.35 (−0.31)	0.03 (0.10)	0.47 (0.40)	0.04 (−0.07)
RBC		1	0.86 (0.83)	0.94 (0.93)	−0.66 (−0.60)	−0.88 (−0.86)
BGG (a)			1	0.70 (0.64)	−0.93 (−0.93)	−0.64 (−0.55)
BGG, TFP (a)				1	−0.46 (−0.34)	−0.95 (−0.95)
BGG (b)					1	0.46 (0.32)
BGG, TFP (b)						1

These correlations are based on the Taylor (1993) specification of the monetary policy rule reacting to changes in the year-over-year inflation rate. The correlations correspond to demeaned hours worked and are for the entire period between 1984:I and 2009:IV. Inside parenthesis I also report the correlations for the sub-sample between 1984:I and 2007:IV.

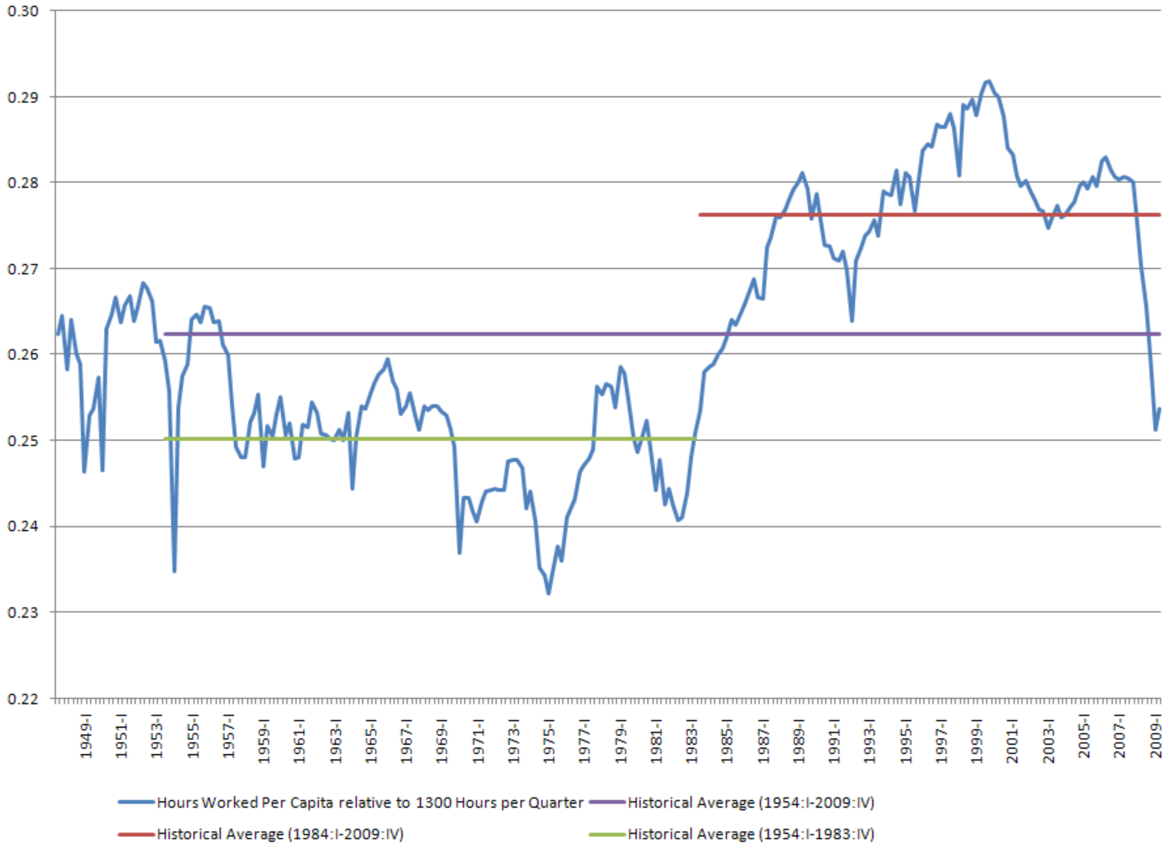
This table reports the theoretical moments for each series given my parameterization. All statistics on simulations are computed after each series is H-P filtered (smoothing parameter=1600), but the results are virtually the same without H-P filtering the series. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

			Benchmark		High EFP & Price Stickiness	
	Data	RBC	BGG (a)	BGG, TFP (a)	BGG (b)	BGG, TFP (b)
Data	1	0.32 (0.21)	0.36 (0.23)	0.48 (0.55)	0.27 (0.30)	0.34 (0.43)
RBC		1	0.99 (0.99)	0.41 (0.28)	0.87 (0.87)	0.50 (0.43)
BGG (a)			1	0.42 (0.30)	0.82 (0.84)	0.47 (0.42)
BGG, TFP (a)				1	0.60 (0.51)	0.85 (0.83)
BGG (b)					1	0.80 (0.76)
BGG, TFP (b)						1

These correlations are based on the Taylor (1993) specification of the monetary policy rule reacting to changes in the year-over-year inflation rate. The correlations correspond to the cyclical component of year-over-year inflation - computed as the deviation from a 2 percent target. Inside parenthesis I also report the correlations for the sub-sample between 1984:I and 2007:IV.

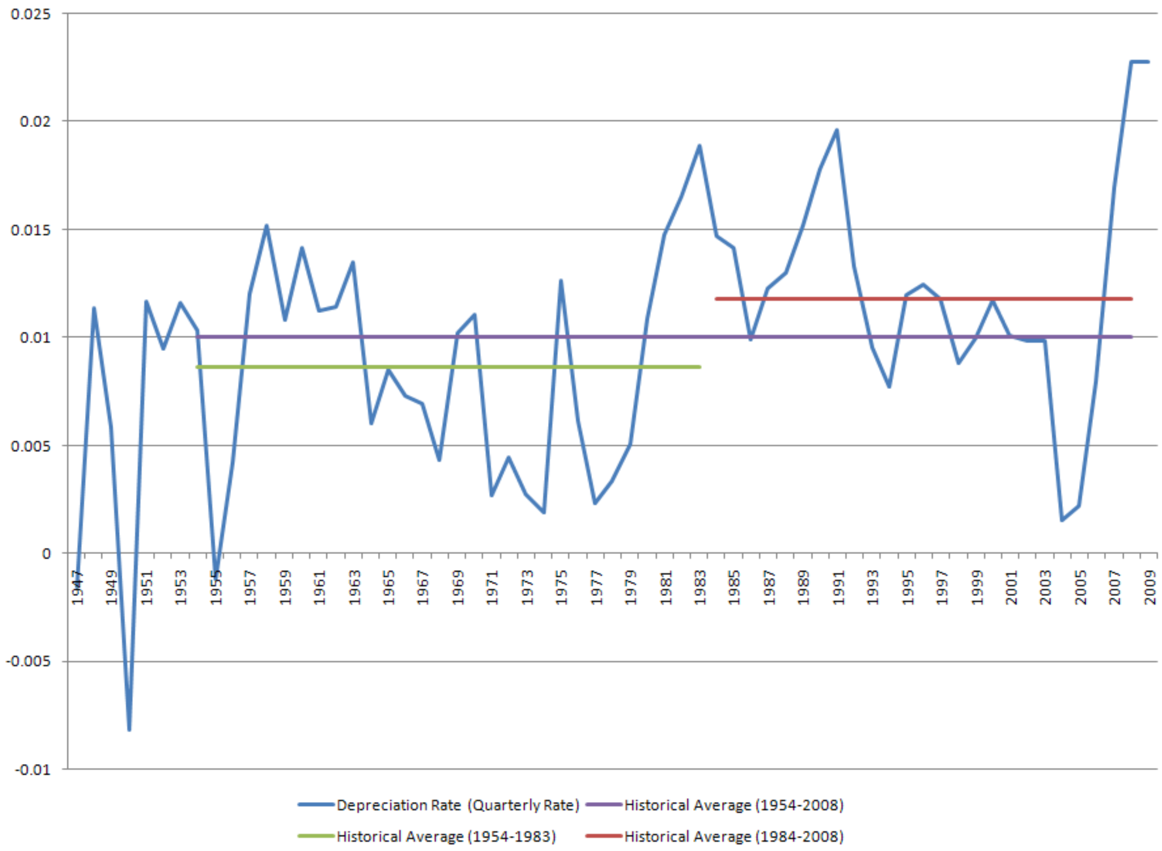
This table reports the theoretical moments for each series given my parameterization. All statistics on simulations are computed after each series is H-P filtered (smoothing parameter=1600), but the results are virtually the same without H-P filtering the series. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

Figure 1: Ratio of U.S. Hours Worked (1948:I-2009:IV).

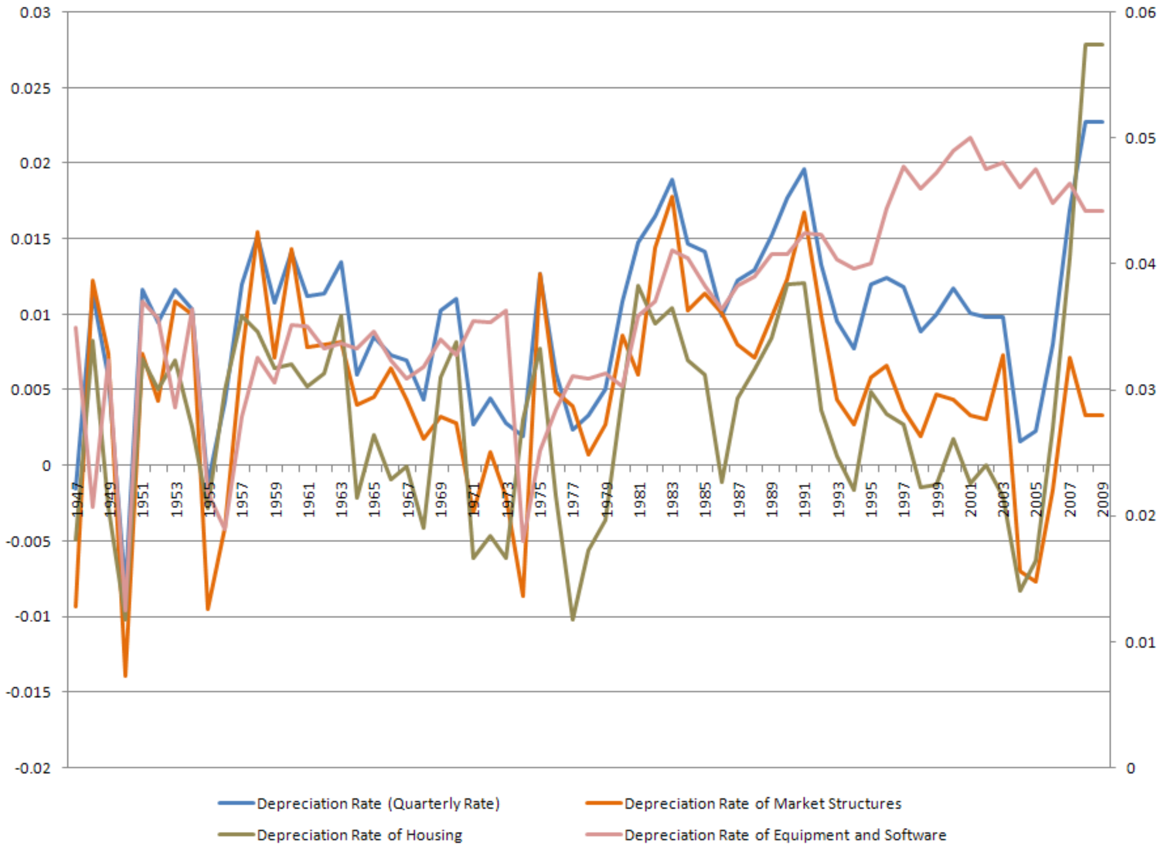


This graph plots the ratio of hours worked per capita over a total of 1300 hours available per quarter. The historical averages of the series are also included. For more details on data sources, see the Appendix 'Dataset: U.S. TFP'.

Figure 2: U.S. Quarterly Depreciation Rates (1947-2009).

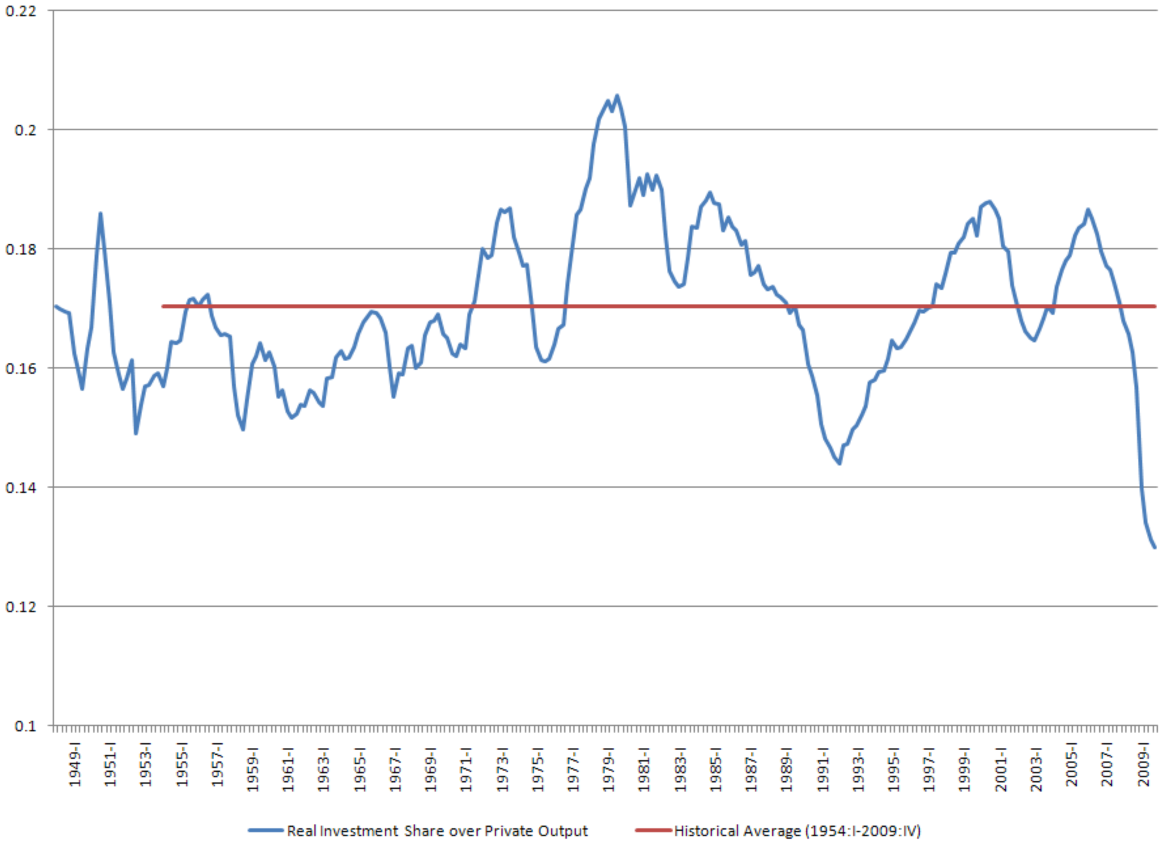


This graph plots the U.S. quarterly depreciation rate on the aggregate stock of capital, allowing those rates to vary in every year. The historical averages of the series are also included. For more details on data sources, see the Appendix 'Dataset: U.S. TFP'.

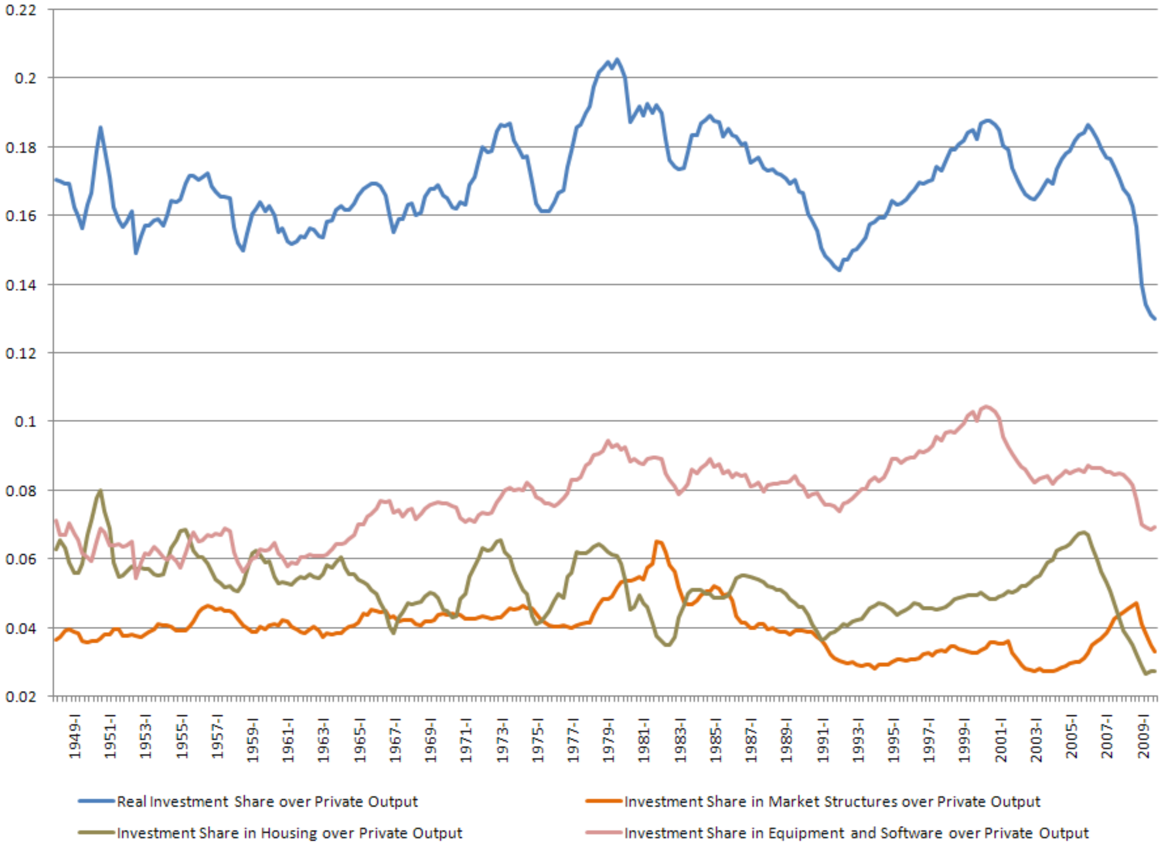


This graph plots the U.S. quarterly depreciation rate on the aggregate stock of capital, allowing those rates to vary in every year. The quarterly depreciation rates for market structures, housing and equipment and software are also included. The aggregate stock of capital is the sum of the stocks of those three types of capital. For more details on data sources, see the Appendix 'Dataset: U.S. TFP'.

Figure 3: U.S. Quarterly Investment Shares (1948:I-2009:IV).

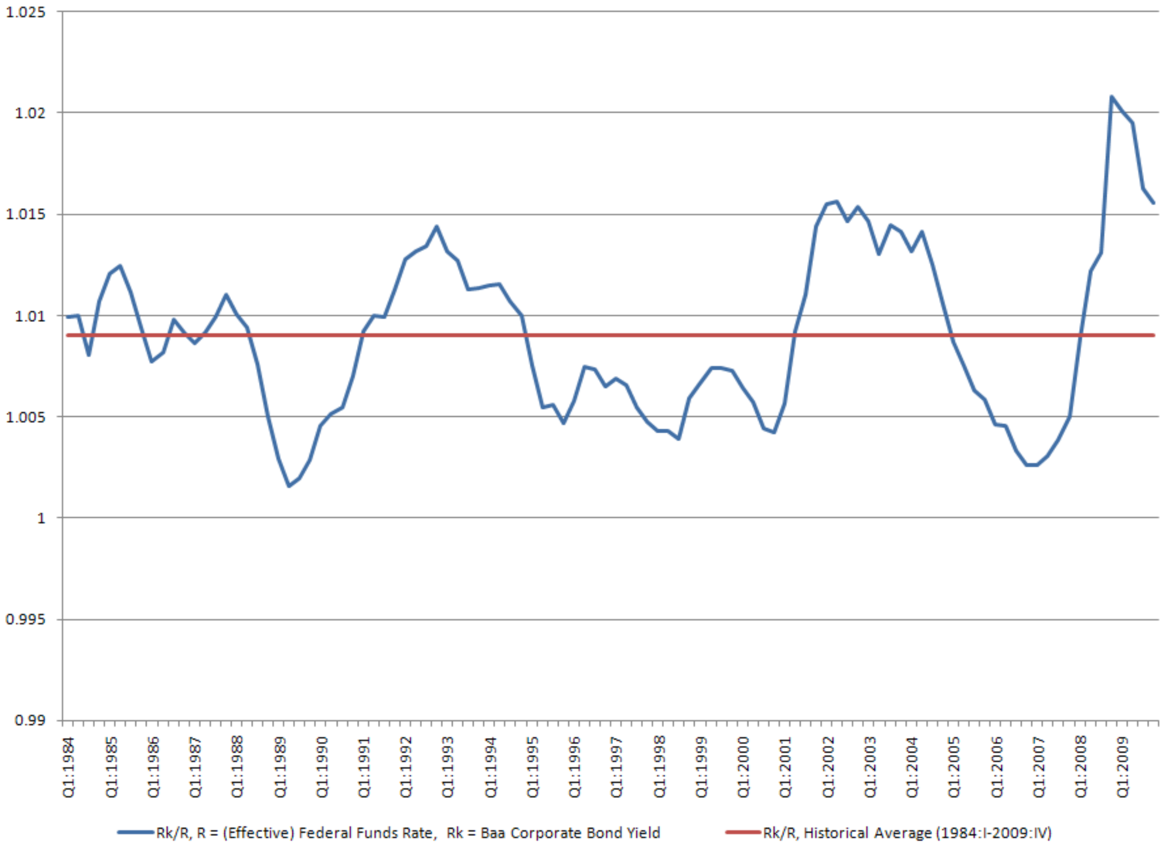


This graph plots the U.S. quarterly aggregate investment share. The historical average of the series is also included. For more details on data sources, see the Appendix 'Dataset: U.S. TFP'.



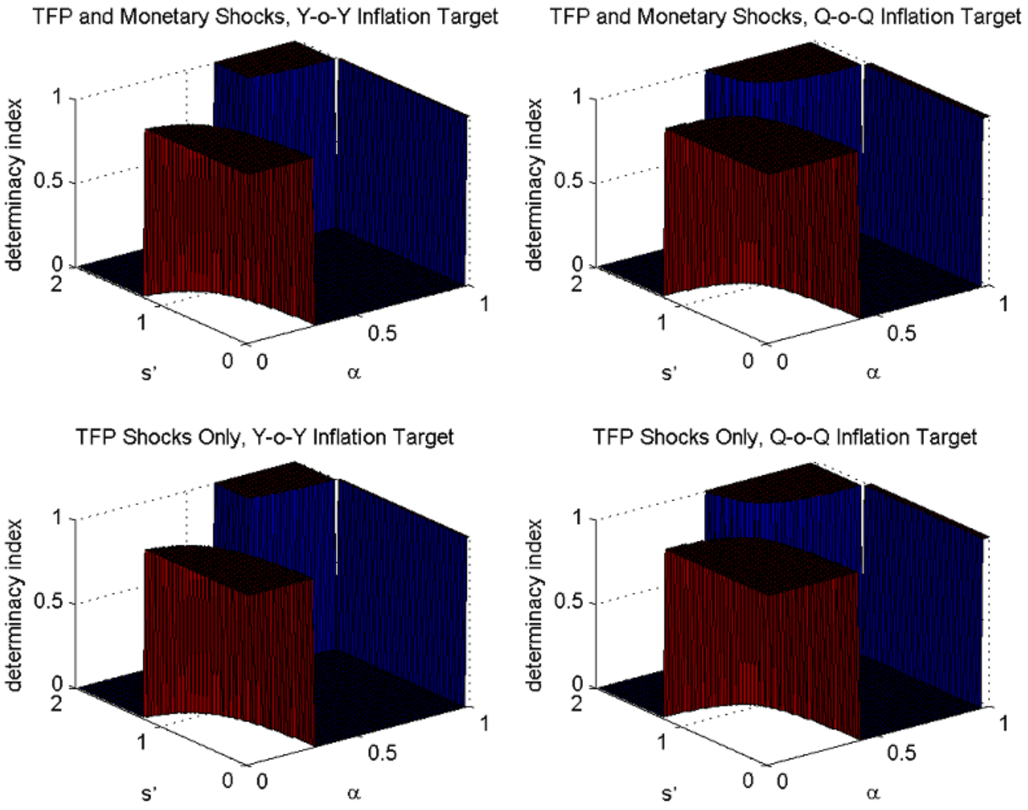
This graph plots the U.S. aggregate investment share. The investment shares on market structures, housing and equipment and software are also included. The aggregate stock of capital is the sum of the stocks of those three types of capital. For more details on data sources, see the Appendix 'Dataset: U.S. TFP'.

Figure 4: Ratio between the Gross Rate on Baa Corporate Bonds and the (Effective) Fed Funds Rate.



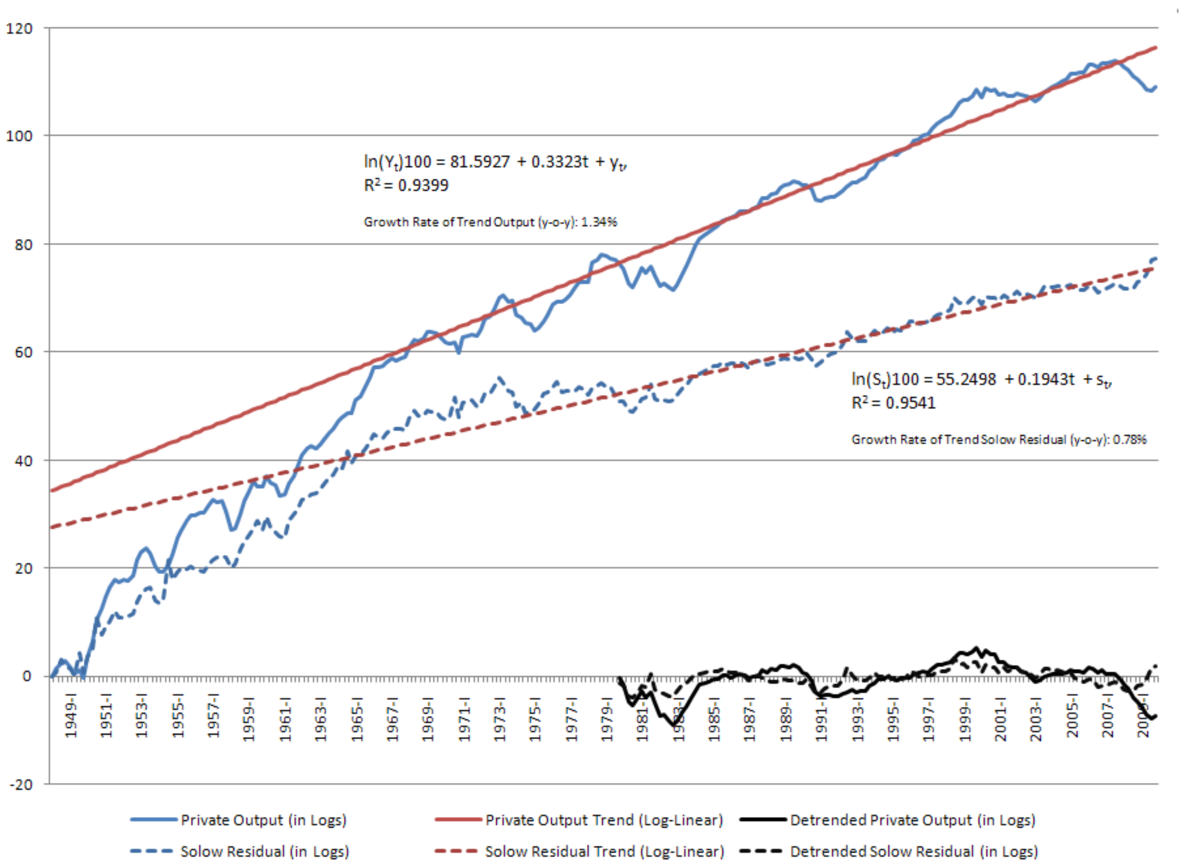
This graph plots the ratio between the gross rate on Moody's seasoned Baa corporate bonds and the (effective) Federal Funds rate, both expressed at quarterly rates. U.S. quarterly depreciation rate on the aggregate stock of capital, allowing those rates to vary in every year. The historical averages of the series are also included. For more details on data sources, see the Appendix 'Dataset: U.S. Monetary Policy'.

Figure 5: Determinacy Region for the Accelerator Model.



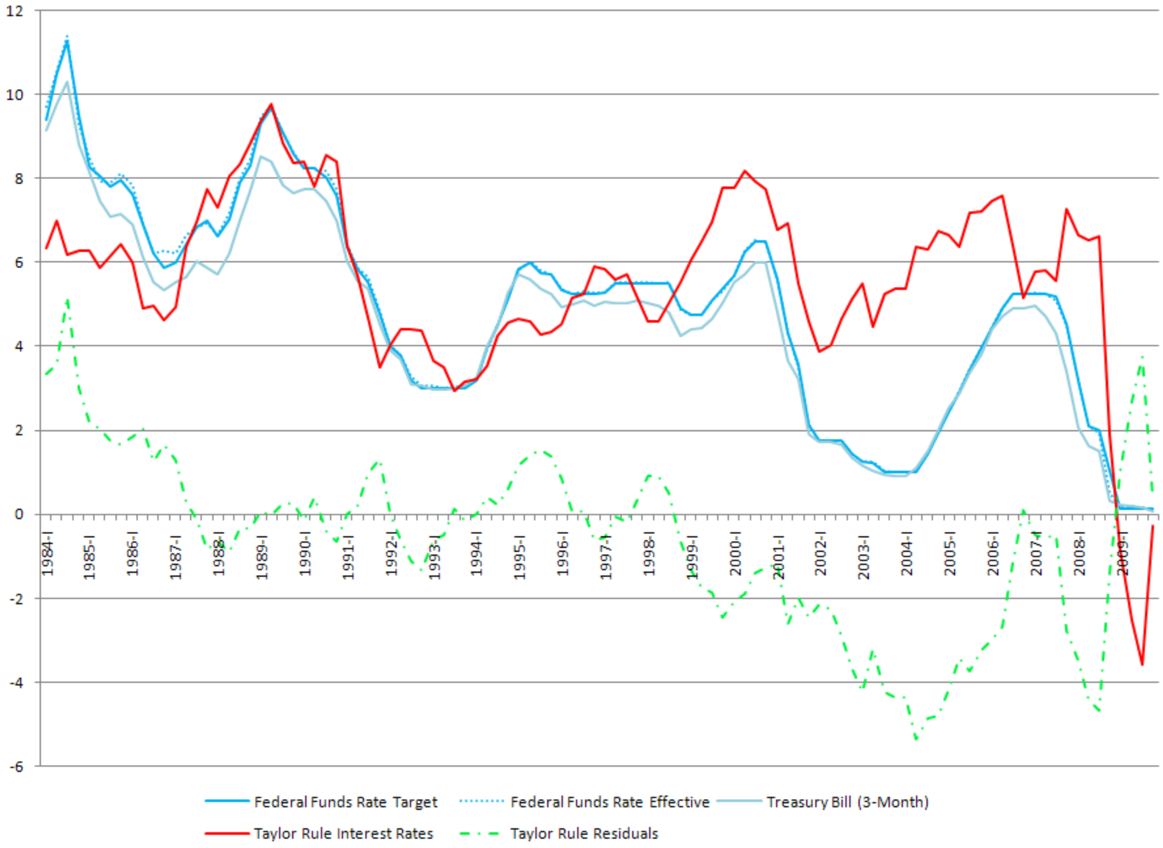
These graphs plot a determinacy index that takes the value of zero if the Blanchard-Kahn conditions of the model are satisfied at a given point of the parameter space spanned by the Calvo parameter and the steady state slope of the external finance premium and zero otherwise. The index is plotted after an extensive grid search, and it describes the determinacy region of the model under four possible scenarios: depending on whether the dynamics are driven by TFP shocks only or a combination of TFP and monetary shocks, and depending on whether the monetary policy rule reacts to changes in the year-over-year inflation rate or the (annualized) quarter-over-quarter inflation rate. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulations.

Figure 6: Output and Solow Residual, Actual versus Trend.



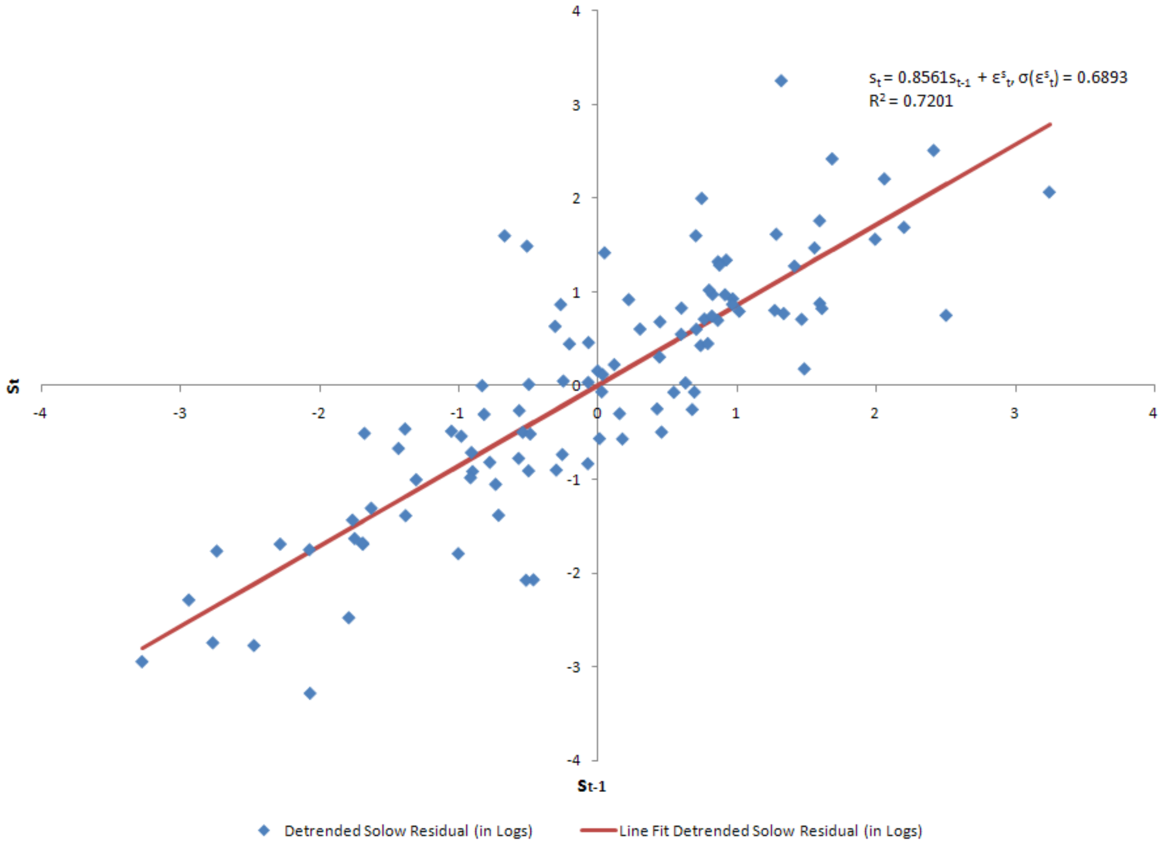
This graph plots the U.S. Solow residual and the U.S. real private output in logs. I also include the log-linear trend estimated for both series over the Great Moderation period (1984:I-2009:IV) and the corresponding detrended variables. For more details on data sources, see the Appendixes 'Dataset: U.S. TFP' and 'Dataset: U.S. Monetary Policy'.

Figure 7: The U.S. Taylor Rule for Monetary Policy.

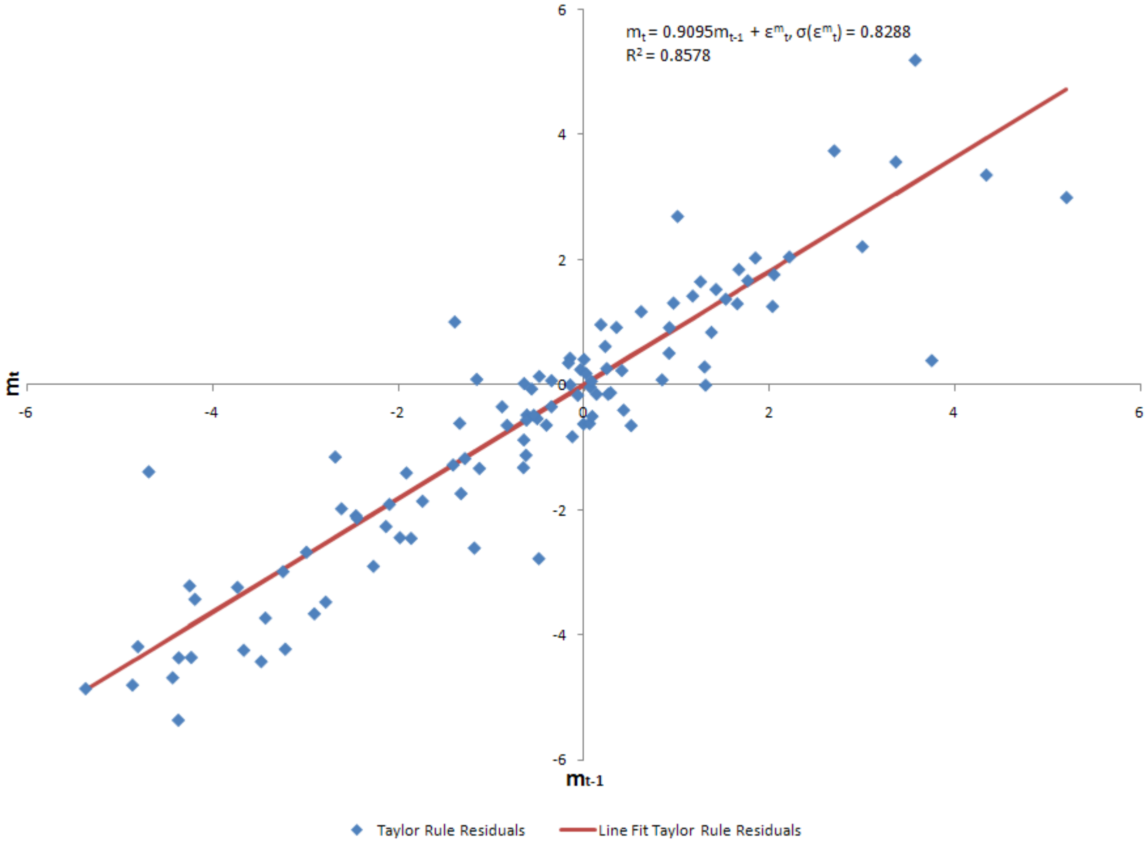


This graph plots the Federal Funds rate target, the Federal Funds rate effective, and the (3-month) Treasury Bill. It also includes the Taylor rule rates based on the Taylor (1993) specification of the monetary policy rule reacting to changes in the year-over-year inflation rate and the Taylor rule residuals defined as the difference between the Federal Funds rate effective and the Taylor rule rates. For more details on data sources, see the Appendix 'Dataset: U.S. Monetary Policy'.

Figure 8: The U.S. TFP and Monetary Policy Shock Processes.

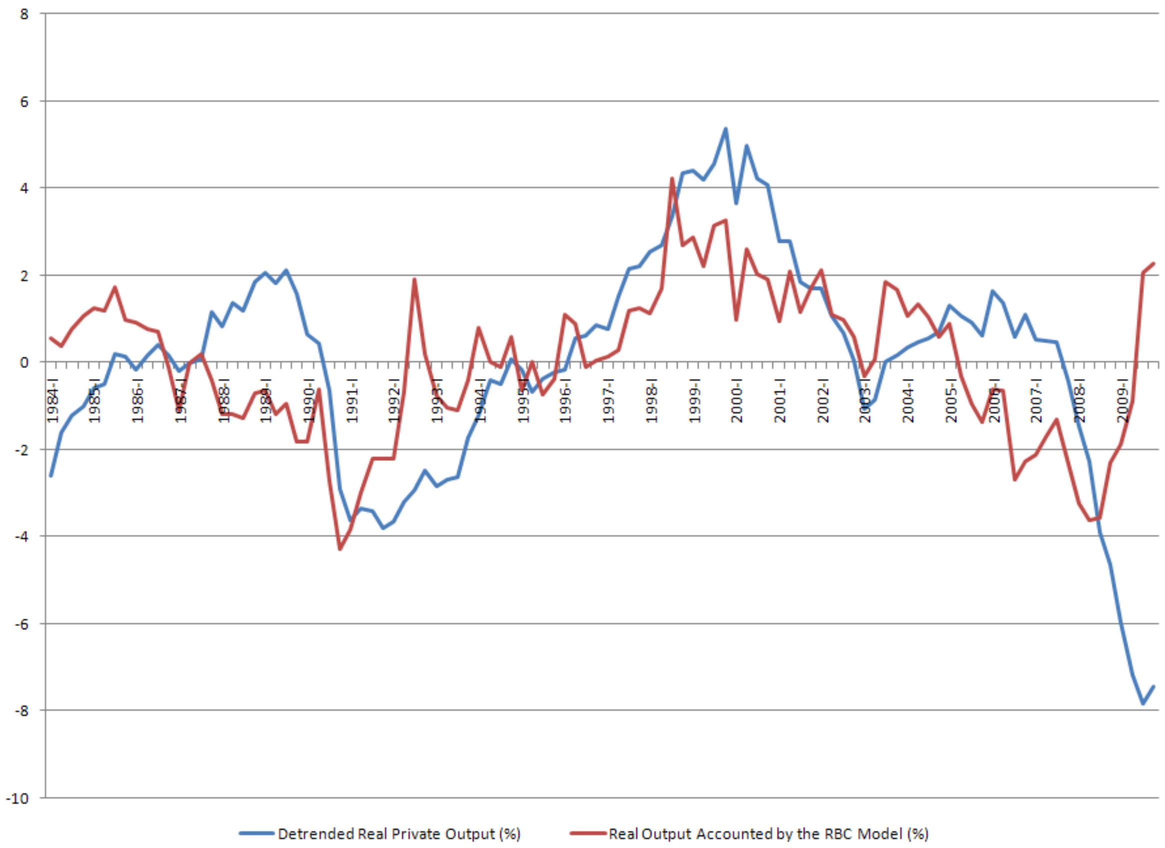


This graph plots the fit of an AR(1) process estimated on the detrended U.S. Solow residual (in logs). For more details on data sources, see the Appendix 'Dataset: U.S. TFP'.

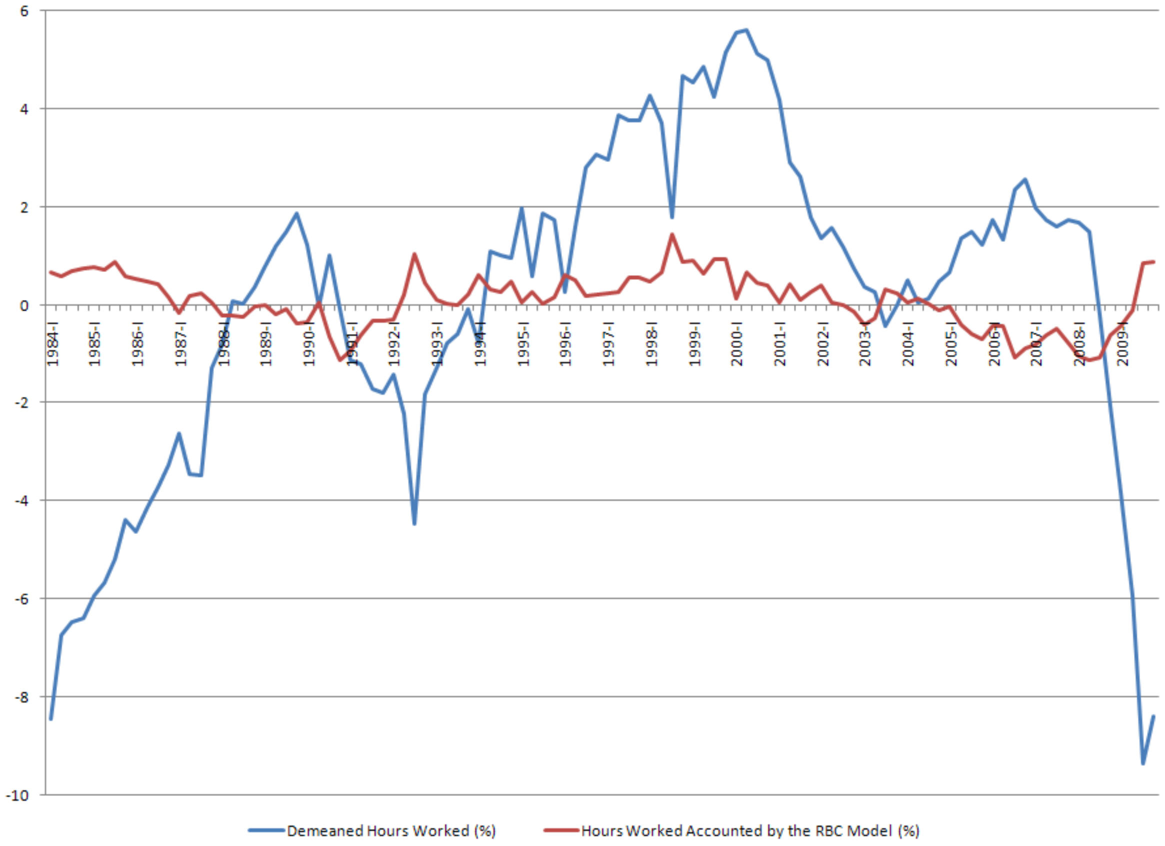


This graph plots the fit of an AR(1) process estimated on the U.S. monetary policy deviations, defined as the difference between the Federal Funds rate effective and the Taylor rule rates. For more details on data sources, see the Appendix 'Dataset: U.S. Monetary Policy'.

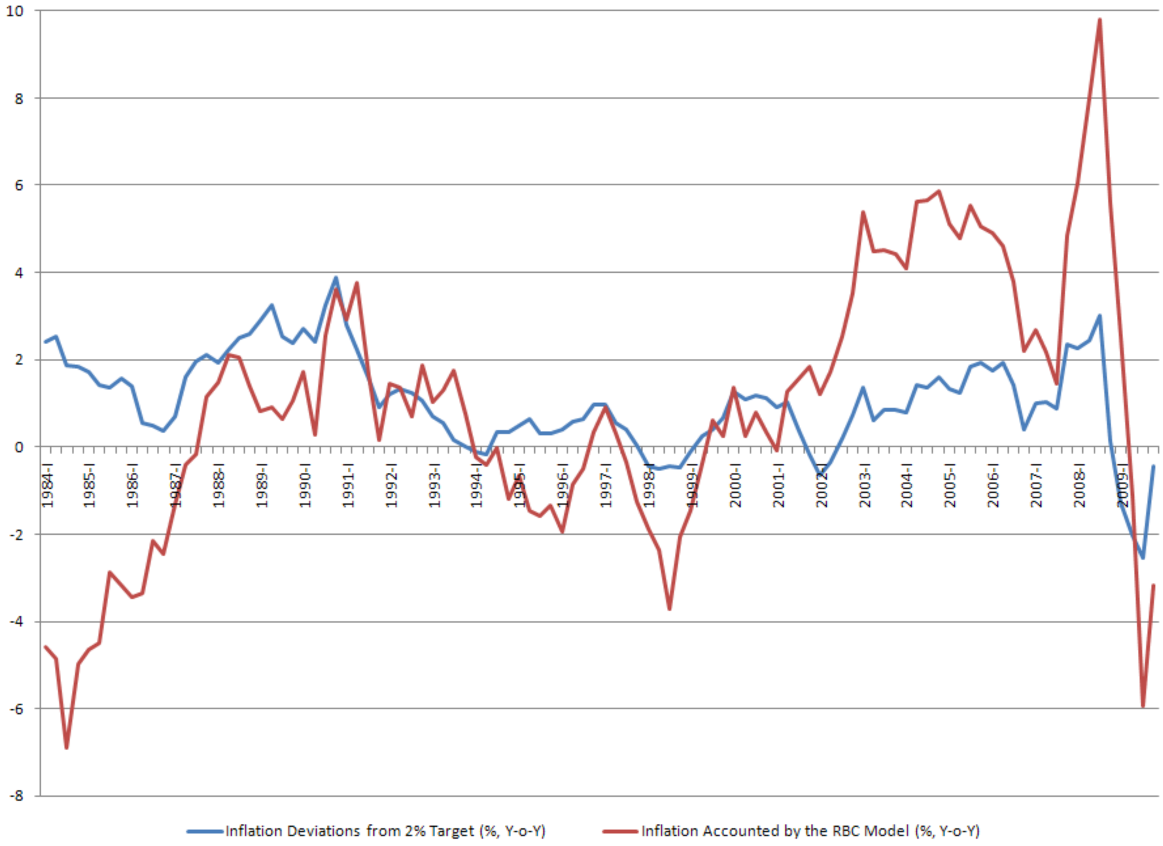
Figure 9: Comparing the RBC Model against the Data.



These simulations correspond to detrended real private output per capita and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of real output simulated with the RBC model. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

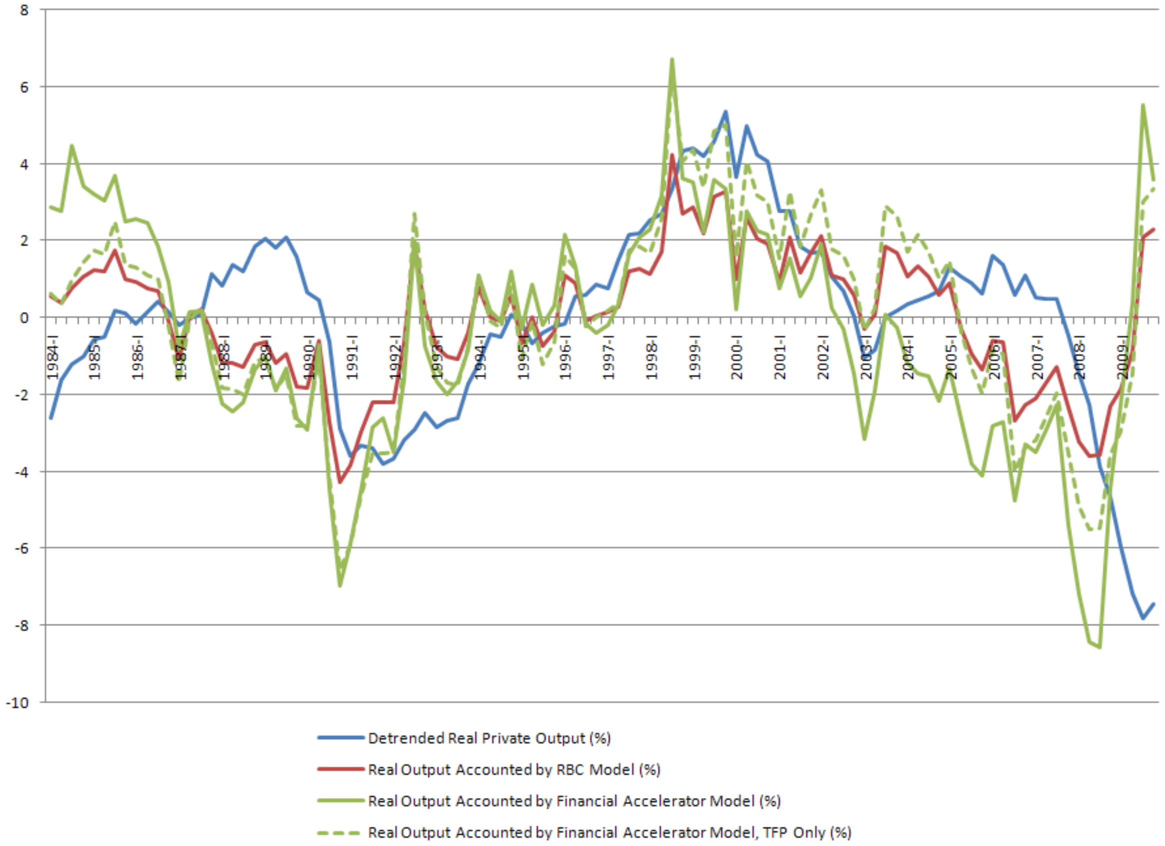


These simulations correspond to demeaned hours worked and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of hours worked simulated with the RBC model. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

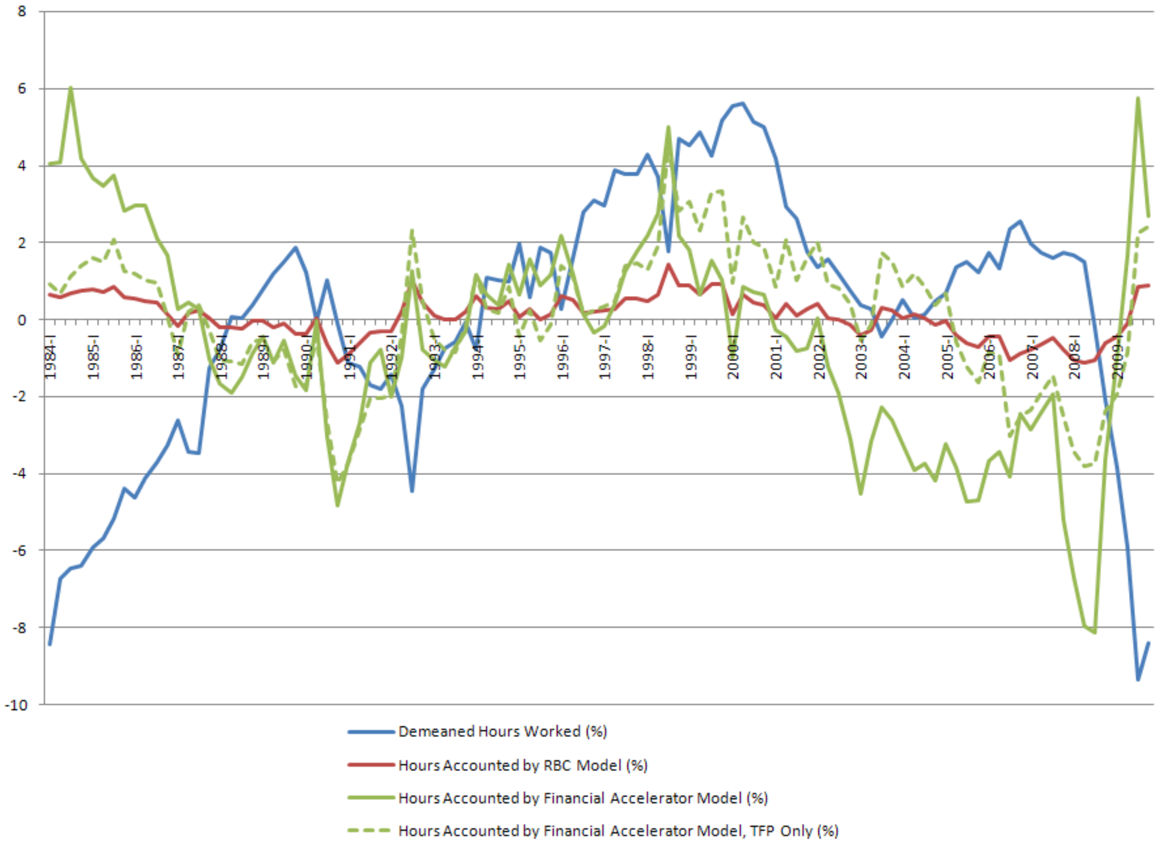


These simulations correspond to the cyclical component of year-over-year inflation - computed as the deviation from a 2 percent target - and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of year-over-year inflation simulated with the RBC model. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

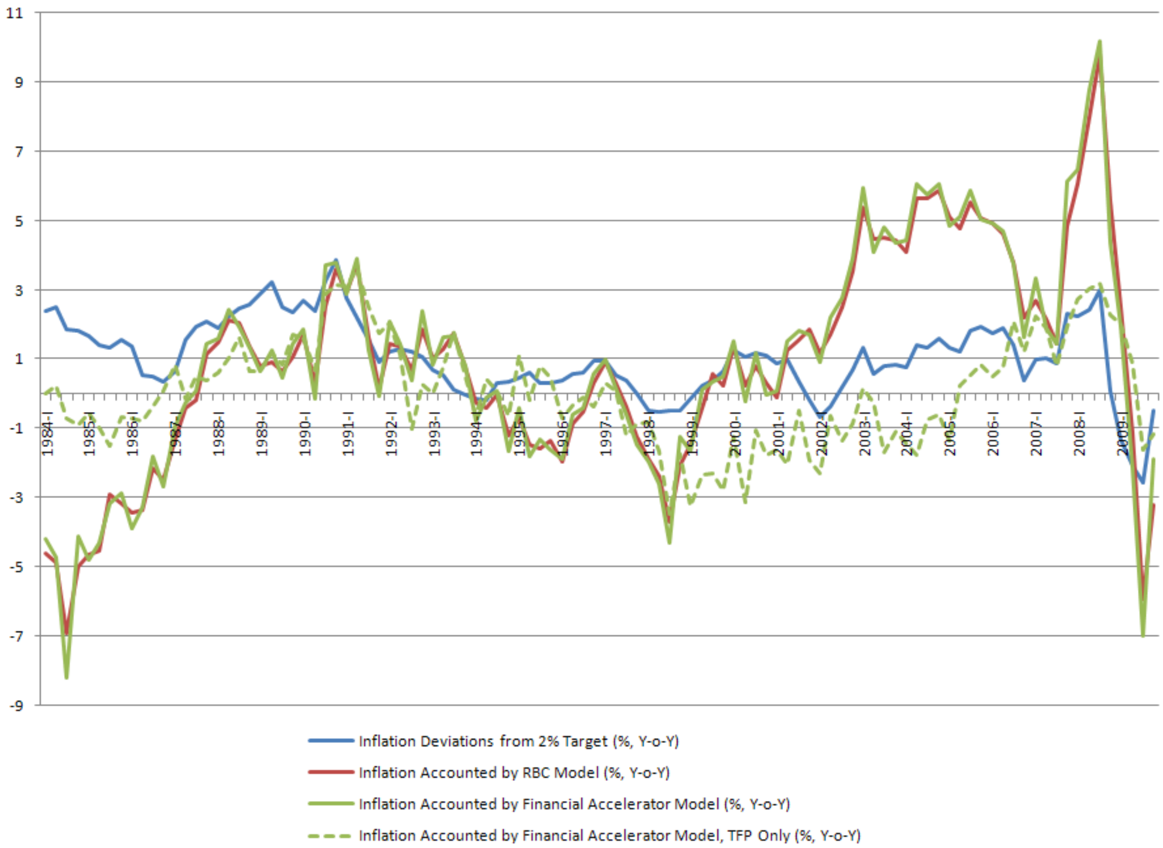
Figure 10: Comparing the Benchmark Accelerator Model with Low EFP and Price Stickiness to the Data.



These simulations correspond to detrended real private output per capita and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of real output simulated with the RBC model, with the financial accelerator model and with a variant of the financial accelerator model subject only to TFP shocks. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

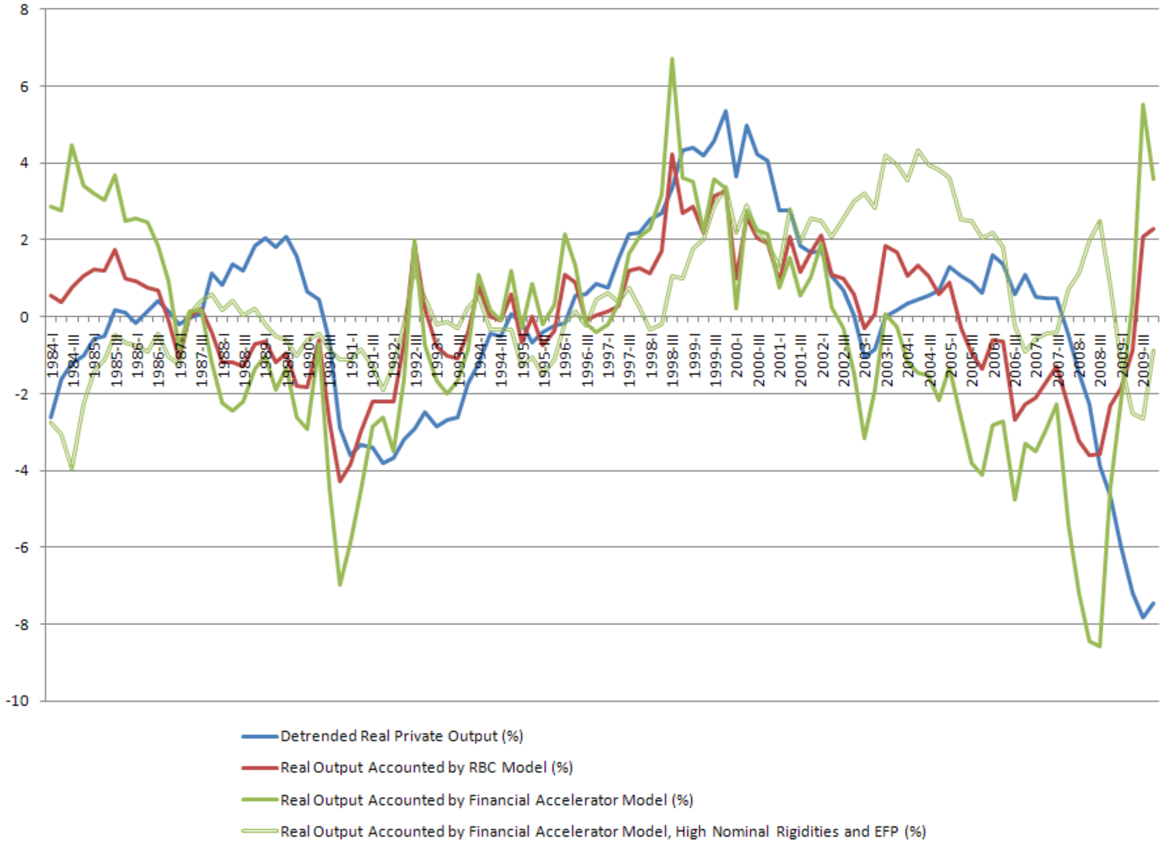


These simulations correspond to demeaned hours worked and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of hours worked simulated with the RBC model, with the financial accelerator model and with a variant of the financial accelerator model subject only to TFP shocks. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

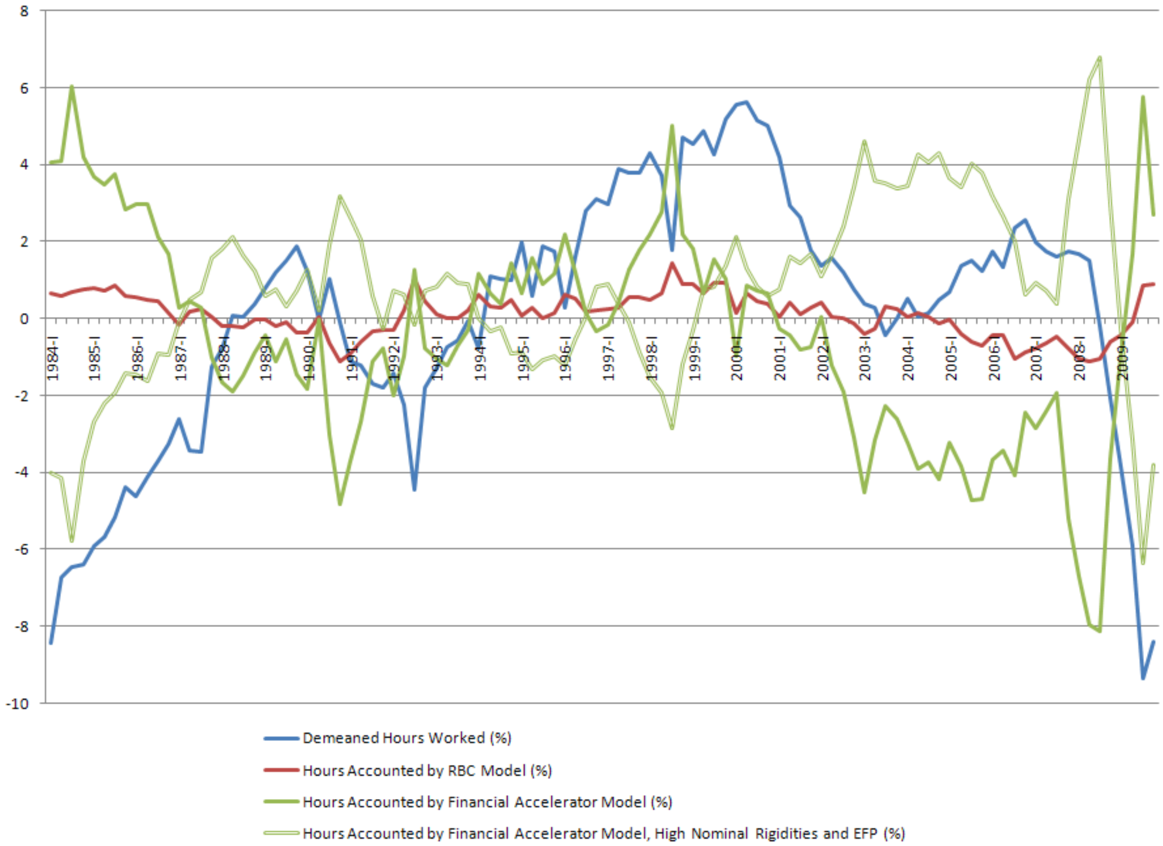


These simulations correspond to the cyclical component of year-over-year inflation - computed as the deviation from a 2 percent target - and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of year-over-year inflation simulated with the RBC model, with the financial accelerator model and with a variant of the financial accelerator model subject only to TFP shocks. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

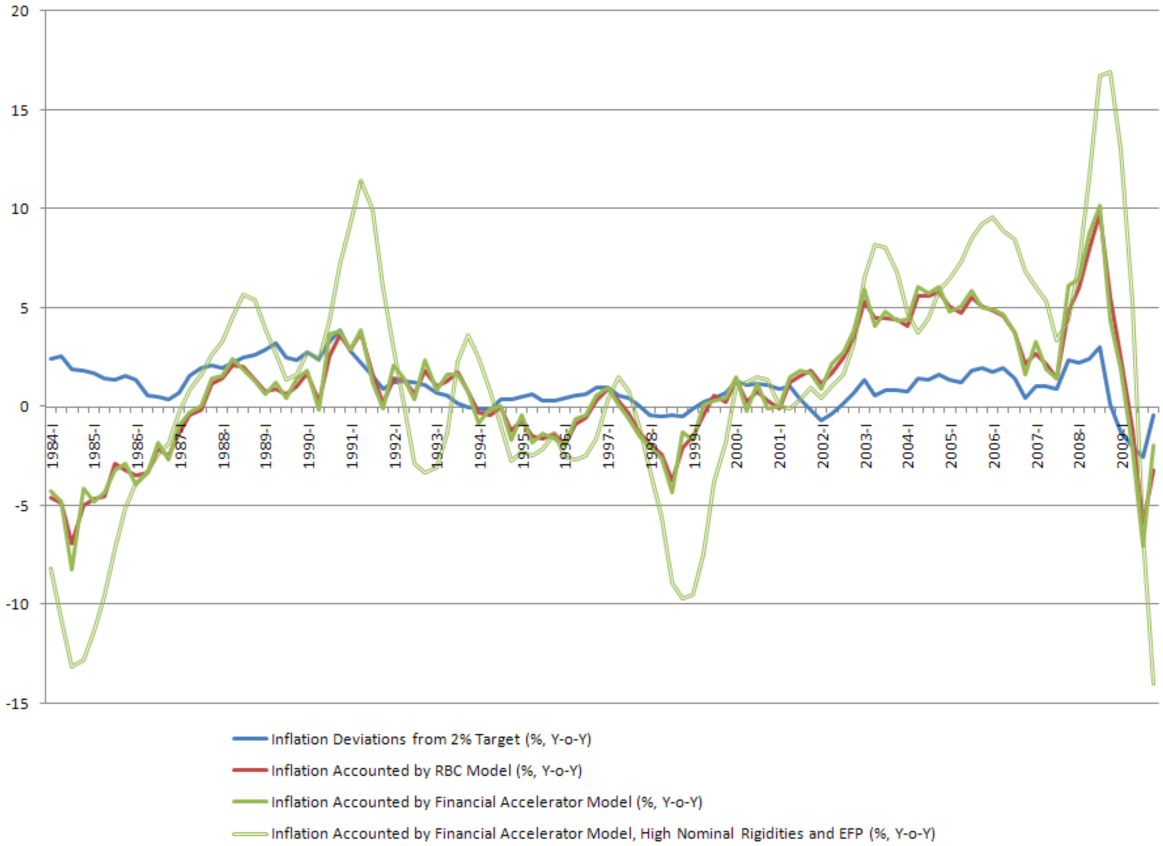
Figure 11: Comparing the Accelerator Model with High EFP and Price Stickiness to the Data.



These simulations correspond to detrended real private output per capita and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of real output simulated with the RBC model, with the financial accelerator model and with a variant of the financial accelerator model subject to higher nominal rigidities and a higher sensitivity of the external financing premium to the leverage of the borrowers (entrepreneurs). I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

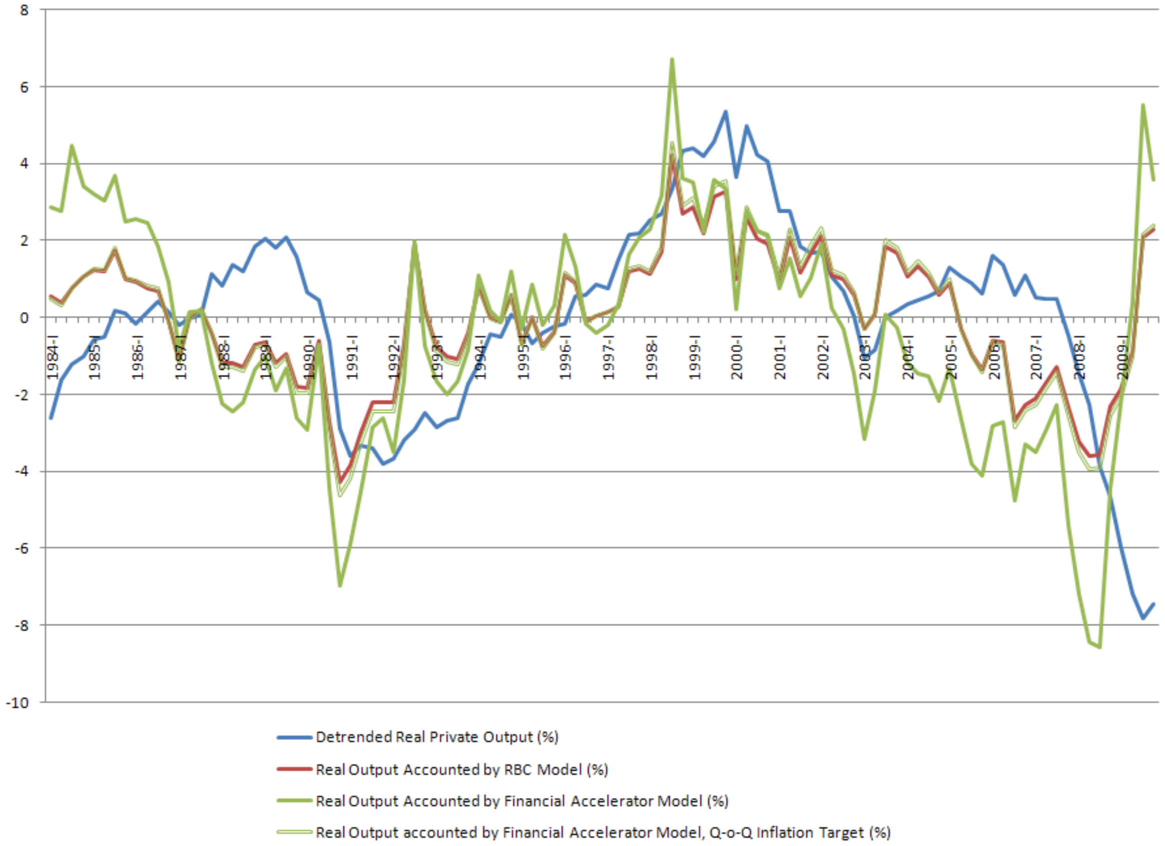


These simulations correspond to demeaned hours worked and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of hours worked simulated with the RBC model, with the financial accelerator model and with a variant of the financial accelerator model subject to higher nominal rigidities and a higher sensitivity of the external financing premium to the leverage of the borrowers (entrepreneurs). I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

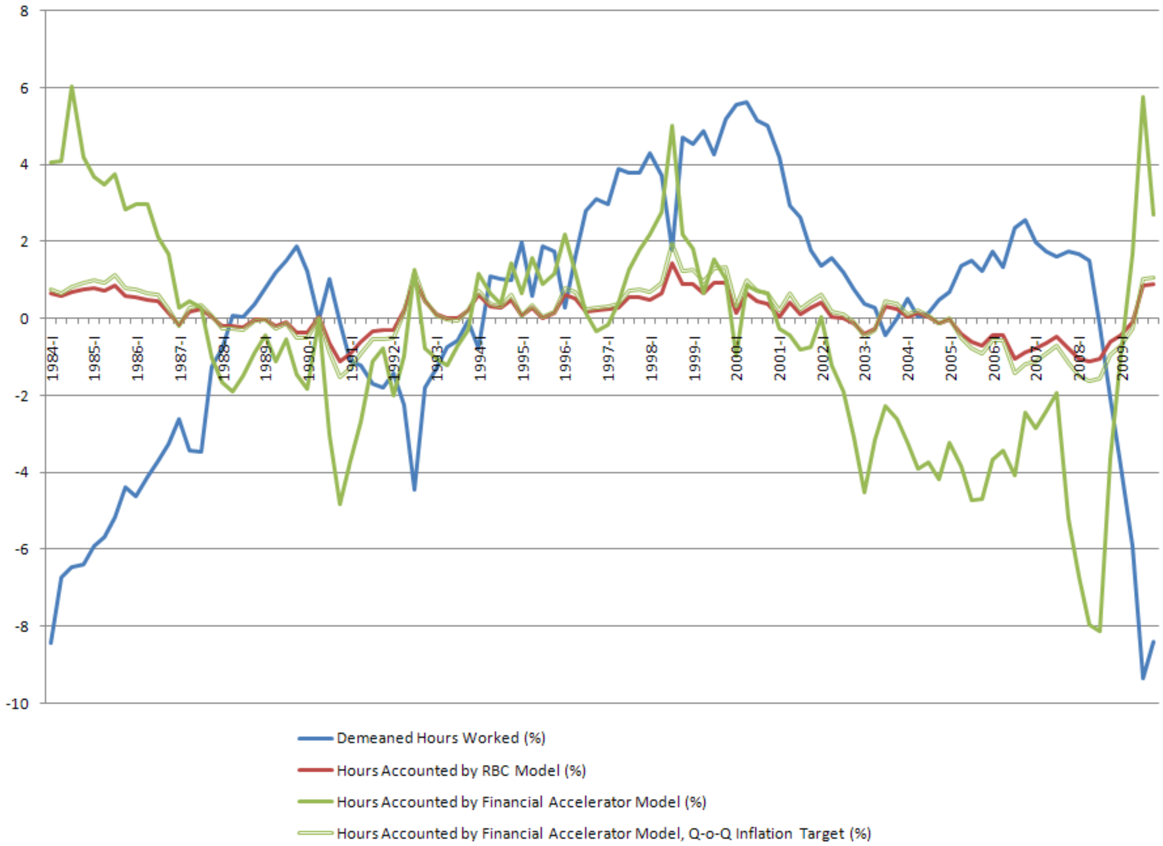


These simulations correspond to the cyclical component of year-over-year inflation - computed as the deviation from a 2 percent target - and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of year-over-year inflation simulated with the RBC model, with the financial accelerator model and with a variant of the financial accelerator model subject to higher nominal rigidities and a higher sensitivity of the external financing premium to the leverage of the borrowers (entrepreneurs). I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

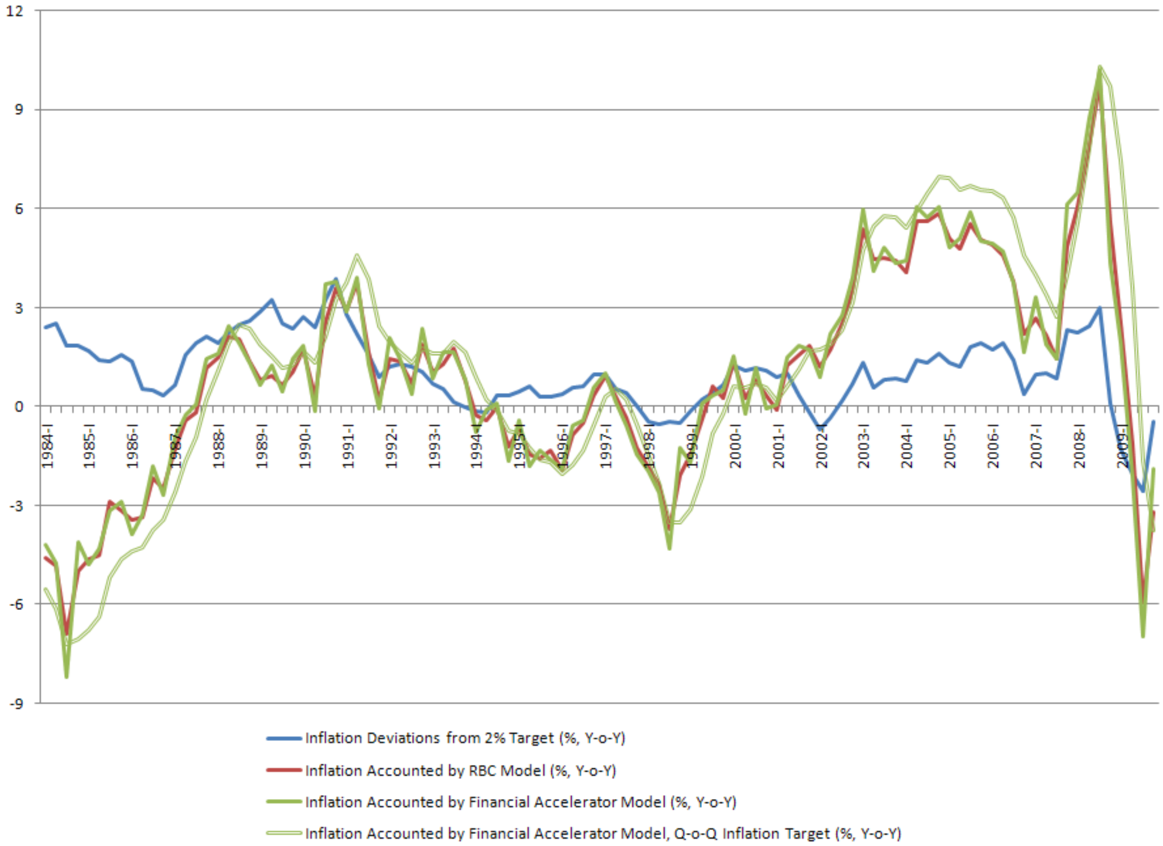
Figure 12: Comparing the Accelerator Model with Quarter-over-Quarter Inflation Targeting to the Data.



These simulations correspond to detrended real private output per capita and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of real output simulated with the RBC model, with the financial accelerator model and with a variant of the financial accelerator model where monetary policy reacts to the (annualized) quarter-over-quarter rate of inflation instead of reacting to year-over-year inflation. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.



These simulations correspond to demeaned hours worked and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of hours worked simulated with the RBC model, with the financial accelerator model and with a variant of the financial accelerator model where monetary policy reacts to the (annualized) quarter-over-quarter rate of inflation instead of reacting to year-over-year inflation. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.



These simulations correspond to the cyclical component of year-over-year inflation - computed as the deviation from a 2 percent target - and describe the entire period between 1984:I and 2009:IV. The graph plots the actual data against the path of year-over-year inflation simulated with the RBC model, with the financial accelerator model and with a variant of the financial accelerator model where monetary policy reacts to the (annualized) quarter-over-quarter rate of inflation instead of reacting to year-over-year inflation. I use Matlab 7.4.0 and Dynare v3.065 for the stochastic simulation.

Appendix

A The Log-Linearized Model

As a notational convention, all variables identified with lower-case letters and a caret on top are expressed in logs and in deviations relative to the their steady state values.

A.1 The Financial Accelerator Model

Aggregate Demand Equations.

$$\begin{aligned}
\widehat{y}_t &\approx \gamma_c \widehat{c}_t + \gamma_x \widehat{x}_t + \gamma_{c^e} \widehat{n}_{t+1}, \\
\widehat{c}_t &\approx \mathbb{E}_t \left[\widehat{c}_{t+1} \right] - \sigma \widehat{r}_{t+1}, \\
\mathbb{E}_t \left[\widehat{r}^k_{t+1} \right] &\approx \vartheta \left(\widehat{q}_t + \widehat{k}_{t+1} - \widehat{n}_{t+1} \right) + \widehat{r}_{t+1}, \ \vartheta \equiv \left(\frac{\upsilon' \left(\gamma_n^{-1} \right) \gamma_n^{-1}}{\upsilon \left(\gamma_n^{-1} \right)} \right), \\
\widehat{r}^k_t &\approx (1-\epsilon) \left(\widehat{mc}_t + \widehat{y}_t - \widehat{k}_t \right) + \epsilon \widehat{q}_t - \widehat{q}_{t-1}, \ \epsilon \equiv \left(\frac{(1-\delta)}{\left(\frac{1-\psi}{1-\psi-\varrho} \right) \upsilon \left(\gamma_n^{-1} \right) \beta^{-1} + (1-\delta)} \right), \\
\widehat{q}_t &\approx \chi \delta \left(\widehat{x}_t - \widehat{k}_t \right),
\end{aligned}$$

Aggregate Supply Equations.

$$\begin{aligned}
\widehat{y}_t &\approx \widehat{s}_t + (1-\psi-\varrho) \widehat{k}_t + \psi \widehat{h}_t, \\
\widehat{mc}_t &\approx \frac{1}{\varphi} \widehat{h}_t + \frac{1}{\sigma} \widehat{c}_t - \left(\widehat{y}_t - \widehat{h}_t \right), \ \varphi \equiv \eta \left(\frac{1-H}{H} \right), \\
\widehat{\pi}_t &\approx \beta \mathbb{E}_t \left[\widehat{\pi}_{t+1} \right] + \left(\frac{(1-\alpha\beta)(1-\alpha)}{\alpha} \right) \widehat{mc}_t,
\end{aligned}$$

Evolution of the State Variables.

$$\begin{aligned}
\widehat{k}_{t+1} &\approx (1-\delta) \widehat{k}_t + \delta \widehat{x}_t, \\
\widehat{n}_{t+1} &\approx \zeta \left(\frac{\beta^{-1}}{\gamma_n} \right) \left(\widehat{r}^k_t - \widehat{r}_t \right) + \widehat{r}_t + \widehat{n}_t,
\end{aligned}$$

Monetary Policy Rule.

$$\begin{aligned}
\widehat{r}_{t+1} &= \widehat{i}_{t+1} - \mathbb{E}_t \left[\widehat{\pi}_{t+1} \right], \\
\widehat{i}_{t+1} &= \left[\psi_\pi \widehat{\pi}_t + \psi_y \widehat{y}_t \right] + \widehat{m}_t,
\end{aligned}$$

Shock Processes.

$$\begin{aligned}
\widehat{s}_t &= \rho_s \widehat{s}_{t-1} + \varepsilon^s_t, \\
\widehat{m}_t &= \rho_m \widehat{m}_{t-1} + \varepsilon^m_t.
\end{aligned}$$

A.2 The Frictionless Model

Aggregate Demand Equations.

$$\begin{aligned}
\widehat{y}_t &\approx \gamma_c \widehat{c}_t + \gamma_x \widehat{x}_t, \\
\widehat{c}_t &\approx \mathbb{E}_t\left[\widehat{c}_{t+1}\right] - \sigma \widehat{r}_{t+1}, \\
\mathbb{E}_t\left[\widehat{r}^k_{t+1}\right] &\approx \widehat{r}_{t+1}, \\
\widehat{r}^k_t &\approx (1-\epsilon)\left(\widehat{mc}_t + \widehat{y}_t - \widehat{k}_t\right) + \epsilon \widehat{q}_t - \widehat{q}_{t-1},\ \epsilon \equiv \left(\frac{(1-\delta)}{\beta^{-1} + (1-\delta)}\right), \\
\widehat{q}_t &\approx \chi\delta\left(\widehat{x}_t - \widehat{k}_t\right),
\end{aligned}$$

Aggregate Supply Equations.

$$\begin{aligned}
\widehat{y}_t &\approx \widehat{s}_t + (1-\psi)\widehat{k}_t + \psi \widehat{h}_t, \\
\widehat{mc}_t &\approx \frac{1}{\varphi}\widehat{h}_t + \frac{1}{\sigma}\widehat{c}_t - \left(\widehat{y}_t - \widehat{h}_t\right),\ \varphi \equiv \eta\left(\frac{1-H}{H}\right), \\
\widehat{\pi}_t &\approx \beta \mathbb{E}_t\left[\widehat{\pi}_{t+1}\right] + \left(\frac{(1-\alpha\beta)(1-\alpha)}{\alpha}\right)\widehat{mc}_t,
\end{aligned}$$

Evolution of the State Variables.

$$\widehat{k}_{t+1} \approx (1-\delta)\widehat{k}_t + \delta \widehat{x}_t,$$

Monetary Policy Rule.

$$\begin{aligned}
\widehat{r}_{t+1} &= \widehat{i}_{t+1} - \mathbb{E}_t\left[\widehat{\pi}_{t+1}\right], \\
\widehat{i}_{t+1} &= \left[\psi_\pi \widehat{\pi}_t + \psi_y \widehat{y}_t\right] + \widehat{m}_t,
\end{aligned}$$

Shock Processes.

$$\begin{aligned}
\widehat{s}_t &= \rho_s \widehat{s}_{t-1} + \varepsilon^s_t, \\
\widehat{m}_t &= \rho_m \widehat{m}_{t-1} + \varepsilon^m_t.
\end{aligned}$$

B Dataset: U.S. TFP[23]

The calculations of U.S. Total Factor Productivity (TFP) are based on a few key assumptions that can be summarized as follows,

$$
\begin{aligned}
\text{Production Function} &: \; Y_t = A_t \left(K_t\right)^{\alpha} \left(\gamma^t H_t\right)^{1-\alpha}, \\
\text{Solow Residual} &: \; \begin{array}{l} S_t \equiv A_t \left(\gamma^{1-\alpha}\right)^t, \; A_t = A_{t-1}^{\rho} V_t, \; |\rho| < 1, \\ A_0 = \overline{A}_0, \; \ln\left(V_t\right) \sim N\left(0, \sigma_v^2\right), \end{array} \\
\text{Law of Motion for Capital in Structures} &: \; K_{st} = \left(1-\delta_y\right) K_{st-1} + Q_{st-1} I_{st-1}, \; K_{s0} = \overline{K}_{s0}, \\
\text{Law of Motion for Capital in Equipment and Software} &: \; K_{et} = \left(1-\delta_y\right) K_{et-1} + Q_{et-1} I_{et-1}, \; K_{e0} = \overline{K}_{e0}, \\
\text{Law of Motion for Capital in Housing} &: \; K_{ht} = \left(1-\delta_y\right) K_{ht-1} + Q_{ht-1} I_{ht-1}, \; K_{h0} = \overline{K}_{h0}, \\
\text{Total Capital} &: \; K_t = K_{st} + K_{et} + K_{ht},
\end{aligned}
$$

where H_t denotes Total Hours Worked. The factor multiplying investment, Q_{it} for all $i \in \{s, e, h\}$, reflects the relative price of investment in units of consumption. In order to compute $X_{it} \equiv Q_{it} I_{it}$ for all $i \in \{s, e, h\}$ such that it accounts for changes in these relative prices in the evolution of investment, I deflate the nominal investment series by the consumption (nondurables and services) deflator.

Since the model abstracts from population changes, then output, capital and hours worked should be expressed in per capita terms. I denote the population size as L_t and define the per capita variables of interest as,

$$
\begin{aligned}
y_t &\equiv \frac{Y_t}{L_t}, \; k_t \equiv \frac{K_t}{L_t}, \; h_t \equiv \frac{H_t}{L_t}, \\
k_{st} &\equiv \frac{K_{st}}{L_t}, \; k_{et} \equiv \frac{K_{et}}{L_t}, \; k_{ht} \equiv \frac{K_{ht}}{L_t}.
\end{aligned}
$$

The same transformation can be done to I_{it} and X_{it} for all $i \in \{s, e, h\}$, but these variables do not affect the derivation of the Solow residual. The strategy is to derive the depreciation rates δ_y, the capital income share α and the stock of capital K_t from aggregate variables. Afterward, I calculate all those variables in per capita terms (i.e., y_t, k_t and h_t) dividing them by the population size. It follows from the Cobb-Douglas production function assumption that,

$$
\begin{aligned}
y_t &= A_t \left(\gamma^{1-\alpha}\right)^t \left(k_t\right)^{\alpha} \left(h_t\right)^{1-\alpha} = S_t \left(k_t\right)^{\alpha} \left(h_t\right)^{1-\alpha}, \\
S_t &= \left(\gamma^{1-\alpha}\right)^{\rho} \left(\left(\gamma^{1-\alpha}\right)^t\right)^{1-\rho} \left(S_{t-1}\right)^{\rho} V_t,
\end{aligned}
$$

---

[23] I follow two main sources to construct this dataset for U.S. TFP: Cociuba, Prescott and Ueberfeldt (2009) on hours worked and Gomme and Rupert (2007) for everything else.

and,

$$\begin{aligned}
\ln(S_t) &= \ln(y_t) - \alpha \ln(k_t) - (1-\alpha)\ln(h_t), \\
\ln(S_t) &= \rho(1-\alpha)\ln(\gamma) + (1-\rho)(1-\alpha)\ln(\gamma)t + \\
&\quad + \rho\ln(S_{t-1}) + \ln(V_t).
\end{aligned}$$

In other words, the Solow residual is unchanged by re-expressing all variables in per capita terms.

The relative price of investment Q_{it} for all $i \in \{s, e, h\}$ is also unaffected by re-expressing everything else in per capita terms. The implicit assumption is that the relative prices also have a common trend component, i.e.

$$Q_{it} = \left(\gamma_q\right)^t Q_{it}^* \text{ for all } i \in \{s, e, h\},$$

which is consistent with a well-defined balanced growth path (see, e.g., Gomme and Rupert, 2007). The implication, however, is that the growth rate of output (i.e. $\frac{y_{t+1}^{BGP}}{y_t^{BGP}} = g$) may differ from the growth rate of the Solow residual (i.e. $\frac{S_{t+1}^{BGP}}{S_t^{BGP}} \equiv \gamma^{1-\alpha}$). Similar to Gomme and Rupert (2007), it can be shown that,

$$g = \gamma\left(\gamma_q\right)^{\frac{\alpha}{1-\alpha}}.$$

I do not impose this strong relationship on the data, but use it to motivate that the linear detrending of output and the Solow residual does not have to share a common trend.

Under the maintained assumption of an aggregate Cobb-Douglas production function and perfect competition, the capital share in the production function α can be computed as the ratio of all capital income sources divided by output. I assume that the capital share is invariant and estimate it using the average of the $1954 - 2008$ period (the post-Korean War period).

The timing convention for capital implies that K_t is the stock of capital accumulated at the end of quarter $t-1$ that becomes available for production during quarter t. The same can be said regarding K_{it} for all $i \in \{s, e, h\}$. The stock of capital available at the beginning of the quarter K_t is what is needed to derive the Solow residual S_t rather than the stock of capital accumulated over the quarter K_{t+1} - which only becomes available in the next quarter. The annual stock of capital measures used in my calculations are year-end estimates. Consistent with the timing convention noted here, I assume that it must be equal to the capital available for production during the first quarter of the next year.

Furthermore, let me suppose that t denotes the first quarter of a given year y. Then, the capital available in the next four quarters can be expressed as,

$$\begin{aligned}
\text{Second Quarter, Year } y\ (t+1) &: \quad K_{it+1} = (1-\delta_y)K_{it} + X_{it}, \\
\text{Third Quarter, Year } y\ (t+2) &: \quad K_{it+2} = (1-\delta_y)K_{it+1} + X_{it+1}, \\
\text{Fourth Quarter, Year } y\ (t+3) &: \quad K_{it+3} = (1-\delta_y)K_{it+2} + X_{it+2}, \\
\text{First Quarter, Year } y+1\ (t+4) &: \quad K_{it+4} = (1-\delta_y)K_{it+3} + X_{it+3},
\end{aligned}$$

which can be written recursively as the following quartic equation,

$$K_{it+4} = K_{it}(1-\delta_y)^4 + X_{it}(1-\delta_y)^3 + X_{it+1}(1-\delta_y)^2 + X_{it+2}(1-\delta_y) + X_{it+3}.$$

A solution to this quartic equation gives the quarterly depreciation rate δ_y on a given year. While the depreciation rates are invariant within a year, I allow them to vary from one year to the next in my calculations of the quarterly stock of capital.

B.1 Average Hours Worked

Total Hours Worked per Quarter. Source: U.S. Department of Labor, Bureau of Labor Statistics (BLS), http://www.bls.gov/cps/

1. Go to the BLS webpage http://data.bls.gov/cgi-bin/srgate. Insert code "LNU02005054" to get (Unadj.) Average Hours, Total At Work, All Industries. Insert code "LNU02005053" to get (Unadj.) Number Employed, At Work. Both data series are at monthly frequency covering the period from July 1947 to December 2009.

2. Convert the monthly data into data on a quarterly basis (by averaging the monthly numbers).

3. The series obtained are seasonally-adjusted using the Census X-12, multiplicative seasonal adjustment.

4. Total hours worked per quarter are given by the persons at work on a quarterly basis times the average hours worked per week on a quarterly basis times $\frac{52}{4}$.

Population per Quarter. Source: U.S. Department of Labor, Bureau of Labor Statistics (BLS). Employment and Earnings - Household Survey (Tables A-13 and A-22)

1. Go to Haver Analytics and download the following BLS series:

Employment and Earnings - Household Survey, Selected Labor Statistics by Sex and Detailed Age Group (NSA, Monthly, Thous): Civilian Noninstitutional Population: 16 Years and Over (LN16N@USECON); Civilian Noninstitutional Population: 65 Years and Over (LN65N@USECON).

2. Compute quarterly data of Population 16 and over and Population 65 and over by averaging over the monthly data.

3. Obtain quarterly civilian noninstitutional population ages 16 to 64 by substracting one series from the other.

4. The series obtained is seasonally-adjusted using the Census X-12, multiplicative seasonal adjustment.

Average Hours Worked per Quarter. Average Hours Worked per Quarter per capita can be computed by dividing the total civilian hours worked by the civilian noninstitutional population (16-64 years old). The quarterly hours worked per capita can also be divided by $\frac{5200}{4}$ ($\frac{52}{4}$ weeks per quarter times 100 productive hours per week) to express the per capita hours worked as a ratio.

B.2 Capital's Share of Income[24]

Source: U.S. Department of Commerce, Bureau of Economic Analysis (BEA), National Income and Wealth Division. National Income and Product Accounts, Domestic Product and Income (Table 1) and Supplemental Tables (Table 7)

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[24] The concept of output that is relevant in the model excludes government labor income. NIPA includes an imputed capital income flow for owner occupied housing. However, it omits the corresponding labor income flows. This omission can upward bias the estimate of the capital income share α. I exclude housing imputed rents only for the purpose of computing a more precise estimate of the capital's share of income, but do not introduce any further corrections or make any other adjustments to account for this omission.

1. Go to Haver Analytics and download the following BEA series:

Domestic Product and Income: Table 1.12, National Income by Type of Income (Bil. \$, Annual): Compensation of Employees, Paid (YCOMPA@USNA); Government Wages and Salaries (YLWSGA@USNA); Rental Income of Persons, with Capital Consumption Adjustments (YRIA@USNA); Corporate Profits with Inventory Valuation and Capital Consumption Adjustments (YCPA@USNA); Net Interest and Miscellaneous Payments on Assets (YNIA@USNA).

Domestic Product and Income: Table 1.3.5, Gross Value Added by Sector, (Bil. \$, Annual): Gross Value Added: General Government (GDPGGA@USNA).

Domestic Product and Income: Table 1.7.5, Relation of Gross Domestic Product, Gross National Product, Net National Product, National Income, and Personal Income (Bil. \$, Annual): Gross National Product (GNPA@USNA); Net National Product (NNPA@USNA).

Domestic Product and Income: Table 1.9.5, Net Value Added by Sector (Bil. \$, Annual): General Government: Net Domestic Product (GGNDPA@USNA).

Supplemental Tables: Table 7.4.5, Housing Sector Output, Gross and Net Value Added (Bil. \$, Annual): Gross Housing Value Added (HGNPA@USNA); Housing: Compensation of Employees (HYCOMPA@USNA); Housing: Rental Income of Persons with Capital Consumption Adjustments (HYRA@USNA); Housing: Corporate Profits with Inventory Valuation and Capital Consumption Adjustments (HYCPA@USNA); Housing: Net Interest (HYNIA@USNA); Net Housing Value Added (HNHPA@USNA).

2. Calculate nominal labor income, Y^{LP}, as compensation of employees minus housing compensation minus government compensation. [Y^{LP} = YCOMPA@USNA - HYCOMPA@USNA - YLWSGA@USNA]. Calculate nominal capital income including depreciation, Y^{KP_d}, as rental income with capital consumption adjustments plus corporate profits with inventory valuation and capital consumption adjustments minus housing rental income with capital consumption adjustments minus housing corporate profits with inventory valuation and capital consumption adjustments minus housing net interests plus depreciation. Compute depreciation as (gross national product minus gross value added by the general government minus gross housing value added) minus (net national product minus net domestic product by the general government minus net housing value added). [Y^{KP_d} = YRIA@USNA + YCPA@USNA + YNIA@USNA - HYRA@USNA - HYCPA@USNA - HYNIA@USNA + (GNPA@USNA - GDPGGA@USNA - HGNPA@USNA) - (NNPA@USANA - GGNDPA@USNA - HNHPA@USNA)].

3. Compute the capital's share of income for each year as,

$$\alpha = \frac{Y^{KP_d}}{Y^{LP} + Y^{KP_d}}.$$

Calculate the average for the period 1954 – 2008 (the entire sample after the Korean War) in order to pin down the capital and labor shares in the production function (through the parameter α). Treat α as time-invariant.

B.3 Depreciation Rate[25]

Source: U.S. Department of Commerce, Bureau of Economic Analysis (BEA), National Income and Wealth Division. National Income and Product Accounts, Domestic Product and Income (Table 1) and "Fixed Assets and Consumer Durable Goods" (formerly called Fixed Reproducible Tangible Wealth in the U.S.), Capital Stock (Tables 4 and 5)

1. Go to Haver Analytics and download the following BEA series:

Domestic Product and Income: Table 1.1.5, Gross Domestic Product (Bil. $, Annual): Personal Consumption Expenditures: Nondurable Goods (CNA@USNA); Personal Consumption Expenditures: Services (CSA@USNA).

Domestic Product and Income: Table 1.1.6, Real Gross Domestic Product (Bil. Chn. 2005. $, Annual): Real Personal Consumption Expenditures: Nondurable Goods (CNHA@USNA); Real Personal Consumption Expenditures: Services (CSHA@USNA).

"Fixed Assets and Consumer Durable Goods," Capital Stock: Tables 4.1, 4.2 and 4.3, Net Stock of Private Fixed Nonresidential Assets by Legal Form and Industry, Year-end Estimates at Current Cost (Bil. $, Annual): Net Stock: Private Fixed Nonresidential Structures (EPNS@capstock); Net Stock: Private Fixed Nonresidential Equipment and Software (EPNE@capstock).

"Fixed Assets and Consumer Durable Goods," Capital Stock: 5.1, 5.2 and 5.3, Net Stock of Private Fixed Nonresidential Assets by Legal Form and Industry, Year-end Estimates at Current Cost (Bil. $, Annual): Net Stock: Private Residential Fixed Assets (EPR@Capstock).

2. Construct the annual consumption (nondurables and services) price deflator. Add the nominal personal consumption expenditures for nondurables and services (CNA@USNA + CSA@USNA). Add the real personal consumption expenditures for nondurables and services (CNHA@USNA + CSHA@USNA). Then, divide the nominal personal consumption expenditures by the real and multiply the ratio by 100.

3. Construct the annual (year-end) stock of real capital on structures, equipment and software, and housing. Use the annual (nominal) stocks of capital at current cost for each category (EPNS@capstock, EPNE@capstock and EPR@capstock) and divide them by the annual consumption price deflator computed before[26].

4. The depreciation rates for each one of the three categories (structures, software and equipment and housing) are computed using an Excel add-in, quartic solver. The quartic solver can be downloaded here: http://www.tushar-mehta.com/excel/software/polynomials/index.html. The solver returns eight numbers (in the complex plane) that solve the formula,

$$a_4 d^4 + a_3 d^3 + a_2 d^2 + a_1 d + a_0 = 0.$$

The quartic equation was derived at the beginning of this section. In order to calculate the depreciation rate in a given year with the quartic solver, take first the deflated year-end stock of capital for the previous year

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[25] The quarterly real investment series used to solve the quartic equation are derived as in the next sub-section, but they are expressed at quarterly -rather than annualized- rates. In other words, the series of quarterly annualized investment divided by the quarterly consumption price deflator must also be divided by 4. Since there is no estimate of year-end capital for the year 2009, I cannot compute the depreciation rate for that year. Instead, I simply use the same depreciation rates as in the year 2008.

[26] Divide the price deflator by 100 to express it in units -rather than percentages- prior to computing the stock of real capital.

that is available for production during the first quarter of that year to be $a_4 \, (\equiv K_{it})$. $a_3 \, (\equiv X_{it})$ represents the real investment in the first quarter of the year, $a_2 \, (\equiv X_{it+1})$ is the real investment in the second quarter, $a_1 \, (\equiv X_{it+2})$ is the real investment in the third quarter, and $a_0 \equiv (X_{it+3} - K_{it+4})$ is the difference between the real investment in the fourth quarter and the deflated year-end stock of capital available for production during the first quarter of the next year. The depreciation rate for that year is computed as $\delta_y = 1 - d$. For more details on finding the appropriate solution, see Gomme and Rupert (2007).

B.4 Quarterly Stock of Capital

Source: U.S. Department of Commerce, Bureau of Economic Analysis (BEA), National Income and Wealth Division. National Income and Product Accounts, Domestic Product and Income (Table 1)

1. Go to Haver Analytics and download the following BEA series:

Domestic Product and Income: Table 1.1.5, Gross Domestic Product (Bil. \$, Quarterly, SAAR): Personal Consumption Expenditures: Private Nonresidential Investment: Structures (FNS@USNA); Private Nonresidential Investment: Equipment and Software (FNE@USNA); Private Residential Investment (FR@USNA); Personal Consumption Expenditures: Nondurable Goods (CN@USNA); Personal Consumption Expenditures: Services (CS@USNA).

Domestic Product and Income: Table 1.1.6, Real Gross Domestic Product (Bil. Chn. 2005. \$, Quarterly, SAAR): Real Personal Consumption Expenditures: Nondurable Goods (CNH@USNA); Real Personal Consumption Expenditures: Services (CSH@USNA).

2. Construct the quarterly consumption (nondurables and services) price deflator. Add the nominal personal consumption expenditures for nondurables and services (CN@USNA + CS@USNA). Add the real personal consumption expenditures for nondurables and services (CNH@USNA + CSH@USNA). Then, divide the nominal personal consumption expenditures by the real and multiply the ratio by 100.

3. Construct the quarterly real investment series for structures, equipment and software, and housing. Use the quarterly (nominal) investment series for each category (FNS@USNA, FNE@USNA and FR@USNA) and divide them by the quarterly consumption price deflator computed before[27]. The real investment sample starts in the first quarter of 1947[28].

4. Construct the quarterly stock of real capital on structures, equipment and software, and housing. Use the deflated year-end stock of capital at current cost for each category for the year 1946, which becomes available for production in the first quarter of 1947, as the starting point (this deflated stock of capital were calculated in the previous sub-section). That stock of capital net of depreciation (using the 1947 depreciation rates) plus the real investment in the first quarter of 1947 gives the capital available for production in the second quarter of 1947. Then, recursively, compute the stock of capital available for production in a given quarter as the sum of the real investment in the previous quarter plus the stock of capital available in the previous quarter net of depreciation. The depreciation rate in each quarter of a given year is the same one calculated for that year (the depreciation rates on an annual basis were calculated in the previous sub-

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[27] Divide the price deflator by 100 to express it in units -rather than percentages- prior to computing the real investment series.

[28] These are the quarterly real investment series that are used to infer the depreciation rates as described in the previous sub-section.

section). The annualized real investment series must be divided by 4 to express them at quarterly rates[29].

5. Construct the quarterly stock of real capital on structures, equipment and software, and housing in per capita terms. Divide the quarterly real stock of capital for each category computed before by the civilian noninstitutional population between the ages of 16 and 64 (which was derived in a previous sub-section). The civilian noninstitutional population is expressed in thousands and must be multiplied by 1000 to express it in individuals. The capital stock and investment are expressed in billions of real 2005 dollars and must be multiplied by 10^9 to express them in units of real 2005 dollars.

B.5 Quarterly Output

Source: U.S. Department of Commerce, Bureau of Economic Analysis (BEA), National Income and Wealth Division. National Income and Product Accounts, Domestic Product and Income (Table 1)

1. Go to Haver Analytics and download the following BEA series:

Domestic Product and Income: Table 1.1.5, Gross Domestic Product (Bil. $, Quarterly, SAAR): Gross Domestic Product (GDP@USNA); Personal Consumption Expenditures: Nondurable Goods (CN@USNA); Personal Consumption Expenditures: Services (CS@USNA).

Domestic Product and Income: Table 1.1.6, Real Gross Domestic Product (Bil. Chn. 2005. $, Quarterly, SAAR): Real Personal Consumption Expenditures: Nondurable Goods (CNH@USNA); Real Personal Consumption Expenditures: Services (CSH@USNA).

Domestic Product and Income: Table 1.12, National Income by Type of Income (Bil. $, Quarterly, SAAR): Government Wages and Salaries (YLWSG@USNA).

2. Construct the quarterly consumption (nondurables and services) price deflator. Add the nominal personal consumption expenditures for nondurables and services (CN@USNA + CS@USNA). Add the real personal consumption expenditures for nondurables and services (CNH@USNA + CSH@USNA). Then, divide the nominal personal consumption expenditures by the real and multiply the ratio by 100[30].

3. Construct the quarterly real output series for the U.S. Subtract nominal government wages and salaries (YLWSG@USNA) from the nominal gross domestic product (GDP@USNA). Divide the nominal output series by the quarterly consumption price deflator computed before[31].

4. Construct the quarterly real output series in per capita terms and at quarterly rates. Divide the quarterly real output series computed before by the civilian noninstitutional population between the ages of 16 and 64 (which was derived in a previous sub-section). The civilian noninstitutional population is expressed in thousands and must be multiplied by 1000 to express it in individuals. The output series is expressed in billions of real 2005 dollars and must be multiplied by 10^9 to express everything in units of real 2005 dollars. Divide the resulting series by 4 to express everything at quarterly -rather than annualized- rates.

---

[29] The capital available for production in the first quarter of year y depends on the investment and the depreciated capital used in the fourth quarter of year $y-1$. Therefore, the relevant depreciation rate to be applied in that case is δ_{y-1} rather than δ_y.

[30] This is the same quarterly deflator used to calculate the quarterly stock of capital in the previous sub-section.

[31] Divide the price deflator by 100 to express it in units -rather than percentages- prior to computing the real output series.

B.6 Solow Residual

1. Construct the quarterly Solow residual using the per capita output, hours worked and capital series constructed before. Use the capital available for production at the beginning of the quarter. Without loss of generality, transform all series into indexes where the first quarter of 1948 takes the value of 100. The average capital share α for the sample period between 1954 and 2008 computed before is 0.284. Compute $(k_t)^{0.284}(h_t)^{0.716}$ based on the indexes for per capita capital k_t and per capita hours worked h_t. Then, calculate the Solow residual index as,

$$S_t = \left(\frac{y_t}{(k_t)^{0.284}(h_t)^{0.716}} \right) 100,$$

where y_t is the per capita real output index.

2. Calculate the Solow residual in logs as,

$$\left(\ln \left(\frac{S_t}{100} \right) \right) 100.$$

B.7 Detrending and Demeaning

1. Fit a linear time trend to the series for the Solow residual in logs and the series for the real output (excluding government) in logs as,

$$\begin{aligned} \ln \left(\frac{S_t}{100} \right) 100 &= \alpha_s + \beta_s t + u_t^s, \\ \ln \left(\frac{Y_t}{100} \right) 100 &= \alpha_y + \beta_y t + u_t^y. \end{aligned}$$

The different slopes are consistent with the economy growing along a balanced growth path. Estimate this linear trends for the sample period $1983 : IV - 2009 : IV$ and a total of 105 observations to account for the fact that there is a clear break in the trend of the Solow residual during the 70s. While growth resumed during the Great Moderation period, it was at a slower pace than in the 50s and 60s. I do not account for that break or model explicitly the transitions implied by that.

2. Estimate an $AR(1)$ process for the detrended Solow residual series without a constant term,

$$u_t^s = \rho_s u_{t-1}^s + \varepsilon_t^s.$$

This characterizes the Solow residual process in our model. Note that by the Frisch-Waugh-Lovell theorem, this two-stage estimation approach should be equivalent to estimating,

$$\ln \left(\frac{S_t}{100} \right) 100 = \alpha_s + \beta_s t + \rho_s \left(\ln \left(\frac{S_{t-1}}{100} \right) \right) 100 + \varepsilon_t^s.$$

3. Demean the Hours Worked series in logs by estimating,

$$\left(\ln \left(\frac{S_t}{100} \right) \right) 100 = \alpha_h + u_t^h.$$

The lack of trend is to be consistent with the theory on hours worked. I also demean the data for the sample period $1983 : IV - 2009 : IV$ and a total of 105 observations. I can estimate an $AR(1)$ process for u_t^y and another for u_t^h in order to illustrate how these variables evolve.

4. Detrend and demean all series further back to $1979 : IV$ with the estimates obtained for the Great Moderation sub-sample $(1984 - 2009)$. Set $1979 : IV$ as the initial period for the simulation of the model because actual output is closest at that point to the trend output that would have prevailed based on the Great Moderation estimates.

C Dataset: U.S. Monetary Policy

Civilian Population. Source: U.S. Department of Labor, Bureau of Labor Statistics (BLS). Employment and Earnings - Household Survey (Tables A-13 and A-22)

1. Go to Haver Analytics and download the following BLS series:

Employment and Earnings - Household Survey, Selected Labor Statistics by Sex and Detailed Age Group (NSA, Monthly, Thous): Civilian Noninstitutional Population: 16 Years and Over (LN16N@USECON); Civilian Noninstitutional Population: 65 Years and Over (LN65N@USECON).

2. Compute quarterly data of Population 16 and over and Population 65 and over by averaging over the monthly data. Obtain quarterly civilian noninstitutional population ages 16 to 64 by subtracting one series from the other.

3. The series obtained is seasonally-adjusted using the Census X-12, multiplicative seasonal adjustment[32].

Output Gap and Inflation Rates. Source: U.S. Department of Commerce, Bureau of Economic Analysis (BEA), National Income and Wealth Division. National Income and Product Accounts, Domestic Product and Income (Table 1)

1. Go to Haver Analytics and download the following BEA series:

Domestic Product and Income: Table 1.1.5, Gross Domestic Product (Bil. \$, Quarterly, SAAR): Gross Domestic Product (GDP@USNA); Personal Consumption Expenditures: Nondurable Goods (CN@USNA); Personal Consumption Expenditures: Services (CS@USNA).

Domestic Product and Income: Table 1.1.6, Real Gross Domestic Product (Bil. Chn. 2005. \$, Quarterly, SAAR): Real Personal Consumption Expenditures: Nondurable Goods (CNH@USNA); Real Personal Consumption Expenditures: Services (CSH@USNA).

Domestic Product and Income: Table 1.12, National Income by Type of Income (Bil. \$, Quarterly, SAAR): Government Wages and Salaries (YLWSG@USNA).

2. Construct the quarterly consumption (nondurables and services) price deflator. Add the nominal personal consumption expenditures for nondurables and services (CN@USNA + CS@USNA). Add the real personal consumption expenditures for nondurables and services (CNH@USNA + CSH@USNA). Then, divide the nominal personal consumption expenditures by the real and multiply the ratio by 100[33].

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[32] This is the same quarterly civilian population calculated in the previous section.

[33] This is the same quarterly deflator used to calculate the quarterly stock of capital in the previous section.

3. Construct the quarterly real output series for the U.S. Subtract nominal government wages and salaries (YLWSG@USNA) from the nominal gross domestic product (GDP@USNA). Divide the nominal output series by the quarterly consumption price deflator computed before[34].

4. Construct the quarterly real output series in per capita terms and at quarterly rates. Divide the quarterly real output series computed before by the civilian noninstitutional population between the ages of 16 and 64 (which was derived previously). The civilian noninstitutional population is expressed in thousands and must be multiplied by 1000 to express it in individuals. The output series is expressed in billions of real 2005 dollars and must be multiplied by 10^9 to express everything in units of real 2005 dollars. Divide the resulting series by 4 to express everything at quarterly -rather than annualized- rates.

5. Construct the year-over-year inflation rate for the consumption (nondurables and services) price deflator in percentages,

$$\pi_t \equiv \left(\frac{P_t - P_{t-3}}{P_{t-3}}\right) 100.$$

Construct a real output (excluding government) index by taking the first quarter of 1948 ($1948 : I = 100$) to be the base. Then, express the output index in logs as,

$$\ln\left(\frac{Y_t}{100}\right) 100.$$

Estimate a linear time trend for the real output index in logs as it was done in the previous section of this appendix (sample: $1983 : IV - 2009 : IV$). The linear trend for real output in logs is,

$$\ln\left(\frac{\overline{Y}_t}{100}\right) 100 = \alpha_y + \beta_y t,$$

which can be transformed in levels as,

$$\overline{Y}_t = 100 \exp\left(\frac{\alpha_y + \beta_y t}{100}\right).$$

6. Define the output gap as the percentage deviation of output relative to its trend, i.e.

$$y_t^g \equiv \left(\frac{Y_t - \overline{Y}_t}{\overline{Y}_t}\right) 100.$$

Federal Funds (Target and Effective), and the Interest Rate Spread. Source: Board of Governors of the Federal Reserve System, "Selected Interest Rates," "Interest Rates Updated Before FRB Publication," H.15 (415); Haver Analytics.

1. Go to Haver Analytics and download the following Federal Reserve Board series:

Selected Interest Rates - FRB H.15 (NSA, Quarterly Average of Daily Data, Yields in Percent Per Annum): Federal Funds (Effective) (FFED@USECON); 3-month Treasury Bills, Secondary Market (Bank-Discount Basis): (FTBS3@USECON); Baa Corporate Bonds, Moody's Seasoned (FBAA@USECON).

2. Go to Haver Analytics and download the following series compiled by Haver itself on the Fed Funds target rate:

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[34] Divide the price deflator by 100 to express it in units -rather than percentages- prior to computing the real output series.

Domestic Interest Rates - FRB Fed Funds Target (NSA, Quarter Average, Yields in Percent Per Annum): Federal Funds target set by the FOMC (FFEDTAR@USECON).

3. Compute the Taylor rule following the same mathematical formula proposed in Taylor (1993),

$$i_t^{TR} \equiv r + \pi_t + \frac{1}{2} y_t^g + \frac{1}{2} \left(\pi_t - \pi \right),$$

where we define π_t as the consumption (nondurables and services) inflation (in percentages) for period t. Implicit in this equation is the notion that the real interest rate is $r \equiv 2\%$ and the long-run inflation target is $\pi \equiv 2\%$. But this would be isomorphic to a formula that implies the long-run inflation is zero and the real interest rate is 4%.

4. Monetary policy shocks according to this rule are computed as the difference between the federal funds rate (effective) and the Taylor-implied rates in every period.

5. I compute the ratio $\frac{R^k}{R}$ with the Baa corporate bonds rate and the Federal Funds rate. First, I divide each series by 400 to express them in units and at quarterly rate (rather than annualized). Second, I add 1 to each observation to characterize the gross rate. Finally, I divide the gross rate on corporate bonds by the gross Federal Funds rate. I compute the historical average over the sample between $1984 : I$ and $2009 : IV$ in order to calibrate the model.