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INfIATION DYNAMICS DURING THE FINANCIAL CRISIS

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Inflation Dynamics during the Financial Crisis*

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Abstract

In this paper, we investigate the effect of financial conditions on price-setting behavior during the 2008-2009 financial crisis. Using confidential, individual producer prices from the Bureau of Labor Statistics, we match these prices to Compustat firm-level data and compare pricing behavior across firms with weak balance sheets relative to firms with strong balance sheets. We find strong evidence that at the peak of the crisis firms with relatively weak balance sheets increased prices while firms with strong balance sheets lowered their prices. We explore the implications of financial distortions on price-setting within the context of a New Keynesian framework that allows for customer markets. In this model, firms have an incentive to set a low price to invest in market share. When financial distortions are severe, firms forgo these investment opportunities and maintain high prices. The model with financial distortions implies a substantial attenuation of price dynamics relative to the baseline model without financial distortions in response to contractionary demand shocks.

JEL Classification:
Keywords:

1 Introduction

In this paper, we investigate the effect of financial conditions on price-setting behavior during the 2008-2009 financial crisis. We do so through the lens of customer-market theory which emphasizes the idea that price-setting is a form of investment that builds the future customer base. As emphasized Gottfries (1991); Bucht, Gottfries, and Lundin (2002), and Chevalier and Scharfstein (1996a), in the presence of financial frictions, firms that face deteriorating balance sheet conditions may raise prices relative to other firms and sacrifice future sales in order to maintain high current

*This research was conducted with restricted access to the Bureau of Labor Statistics (BLS) data. The views expressed here are those of the authors and do not necessarily reflect the views of the BLS, and should also not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of anyone else associated with the Federal Reserve System We thank project coordinators Kristen Reed, Ryan Ogden and Rozi Ulics for their substantial help and effort.

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cash flows. This suggests that financial conditions of firms may have a direct effect on inflation dynamics during periods of financial distress. Importantly, such a mechanism may limit the deflationary spiral that is often associated with financial disruptions. It may also help explain why actual deflationary pressures have been relatively weak despite the size of the economic downturn experienced by the U.S. economy during the 2007-2011 period.

To investigate this hypothesis, we study individual producer prices obtained from the Bureau of Labor Statistics. We match these prices to firm identifiers and compare pricing behavior across firms with weak balance sheets relative to firms with strong balance sheets during the financial crisis and ensuing recession. Results show that, at the peak of the crisis, firms with relatively weak balance sheets set prices in such a way as to produce a twenty percentage point differential in producer-price inflation rate relative to firms with strong balance sheets.

We also exploit the microeconomic nature of our data to study exactly how balance sheet conditions influence individual pricing behavior. Controlling for time and sector fixed effects, we find that firms became more likely to increase prices during the financial crisis, but at the same time, less likely to lower prices relative to before the crisis and after the crisis. Similarly, firms invested into their customers had larger upwards price changes, conditional on adjustment. These results rule out the possibility that financially constrained firms exhibit differential pricing behavior because they are less well-managed and hence less reactive to economic conditions when setting prices. Rather, firms with weak balance sheets appear to actively manage their prices to maintain cash flows in the face of declining demand.[1]

To explore the macroeconomic consequences of financial distortions in a customer-markets framework, we build a general equilibrium model in which firms face costly price adjustment and set prices to actively manage current versus future expected demand. To do so we adopt the "deep habits" model of Ravn, Schmidt-Grohe and Uribe (2006). We augment this model with a simple, tractable model of costly external finance, and explore model implications for the determination of inflation and output in response to demand shocks and financial shocks. Relative to the baseline model with frictionless financial markets, our model implies a significant attenuation

[1]Christiano, Eichenbaum, and Evans (2001) and Christiano, Gust, and Roldos (2004) and the empirical work emphasized by Barth and Ramey (2002) emphasize a "cost channel" whereby firms borrow to finance inputs to production. To the extent that firms with weak balance sheets face higher borrowing costs that rise more sharply relative to other firms during the crisis period, they may pass those costs on to customers in the form of higher prices. Both mechanisms imply less price-cutting for constrained firms relative to unconstrained firms.

of the response of prices to contractionary demand shocks. These results are consistent with the apparent lack of significant deflationary pressure during the recent recession. Furthermore, these findings suggest that financial factors may help explain sluggish price responses more generally.

The rest of the paper is organized as follows. Section 2 describes the microeconomic price data and the matching process with firm-level balance sheet data. Section 3 provides empirical results on aggregate price dynamics and explores the effect of firm-level balance sheet conditions on price-setting at the firm-level. Section 4 presents the general equilibrium model and simulation results. Section 5 concludes.

2 Data Sources and Methods

To understand the interaction between price-setting behavior of firms and the quality of their balance sheets, we create a novel, firm-level dataset that allows a comprehensive analysis of price dynamics with respect not only to prices and the frequency of price changes, but also other key economic determinants of adjustment given by firm-level financial variables. Our dataset is constructed from two sources: (1) firm-level micro price data from the dataset that underlies the Producer Price Index (PPI) published by the Bureau of Labor Statistics (BLS); and (2) data on income of firms and balance sheet statements from the Compustat database.

2.1 Producer Price Micro Data

First, we use confidential PPI micro price data from the BLS.[2] These data are key to our analysis because they allow us to construct firm-level inflation series, overcoming the limitations of working with aggregate price indices, and to analyze firm-level price dynamics directly in conjunction with Compustat firm-level data. This is an important aspect of analysis relative to working with aggregate price series – even if narrowly defined – since price dynamics at the good and firm

[2]The PPI data are described at length for example in Nakamura and Steinsson (2008), Bhattarai and Schoenle (2010) and Goldberg and Hellerstein (2009). The data are representative of the entire US production structure and have the important quality that they are carefully and consistently sampled. In particular, goods within a firm are uniquely identified according to several consistent criteria: their "price-determining" characteristics such as the type of buyer, the type of market transaction, the method of shipment, the size and units of shipment, the freight type, and the day of the month of the transaction. Once a good is identified, prices are consistently collected each month for that very same good and the same customer. Such consistent sampling avoids the problem of having to compute unit prices as is given with many micro data sets. All prices are transaction prices, not list prices as critiqued by Stigler and Kindahl (1970).

level are subject to large idiosyncratic shocks, as argued for example by Nakamura and Steinsson (2008), Bils and Klenow (2004) or Gopinath and Itskhoki (2011). Individual prices contain potentially important information to understand the economics of price adjustment at the unit of the firm.

We emphasize that we focus on the PPI data as opposed to CPI data because producer prices most directly reflect the response of producers to economic fundamentals of the producing firms. The CPI data on the contrary reflect the pricing behavior of non-producing retailers – so-called "outlets" – which are subject to responses by the entire distribution network and therefore behave quite differently in terms of pricing. Moreover, PPI data exclude import prices which are an important part of the CPI and for which no data on financial conditions are available

Our analysis computes firm-level inflation rates and fractions of price changes using approximately 100,000 monthly producer price quotes collected by the BLS from 28,300 firms. Data for our analysis are available from June 2005 through October 2011, incorporating the 2008-2009 financial crisis.

Our measure of firm-level inflation is given by the weighted quarterly average price changes of goods in each firm:

$$\Delta p_{j,t} = \frac{1}{n_j} \sum_{i}^{n_j} w_{i,j,t} \Delta p_{i,j,t} \tag{1}$$

where $\Delta p_{i,j,t}$ denotes quarterly log price changes for each good i in firm j for a specific quarter t, and n_j the number of goods in a firm. The quarterly fraction of firm-level price changes is constructed analogously using a quarterly price change indicator variable instead of the quarterly log price difference.

We construct weights very carefully based on the relative importance weights of the BLS and firm-level value of shipments data recorded by the BLS for computation of the aggregate PPI. We define the within-firm good-level weight $w_{i,j,t}$ as follows:

$$w_{i,j,t} = \bar{w}_{i,j,t} \omega_{j',t} \tag{2}$$

where $\bar{w}_{i,j,t}$ denotes the item relative weight for good i in firm j according to the BLS definition. The second term is an adjustment factor that takes into account the fact that in our subsequent merge more than one BLS firm may fall within the Compustat firm definition j. The adjustment factor is therefore defined as the relative value of shipments weight of one BLS firm with respect to all other BLS firms within the same Compustat firm unit.

2.2 Data on Financial Conditions

Second, we use data from the Compustat database to characterize firm financial conditions. Our sample spans the same time period as our producer price data, 2005 through 2011. Firstly, to account for financial frictions faced by firms, we compute a liquidity ratio for each firm. The liquidity ratio is defined as follows:

$$LIQ_{j,t} = \frac{Cash\ and\ other\ Liquid\ Assets_{j,t}}{Total\ Assets_{j,t}} \tag{3}$$

where total cash and total sales are the respective variables from Compustat for quarter t for firm j. We properly align the timing of the constructed ratio to the calendar quarter. We also compute, as an alternative measure of financial frictions, the interest expense ratio dividing interest expense by total sales, or total assets.[3]

Secondly, motivated by the customer-market theory which emphasizes the idea that price-setting is a form of investment that builds the future customer base,[4] we include into our analysis sales and general administrative expenses (SGAX) of firms as a measure of investment into customers. This directly follows Gourio and Rudanko (2011). We then normalize SGAX by constructing SGAX ratio relative to total sales. As an alternative normalization, we use total assets since they do not fluctuate as much.

2.3 Matched Sample

One contribution of this papers consists in linking the BLS micro price researcher databases at the firm level to outside data. To do this, we apply a matching algorithm based on the algorithm

[3]Other widely used indicators to measure the degree of financial frictions faced by firms include the dividend payout behavior (Carpenter, Fazzari, and Petersen (1994)); firm size (Gertler and Gilchrist (1994) and Carpenter, Fazzari, and Petersen (1998)); the reliance of trade credit (Nilsen (2002)); the presence (or absence) of an external credit rating (Gilchrist and Himmelberg (1995)); the length and/or number of banking relationships Petersen and Rajan (1994); and industrial effects arising from factor intensity differentials (Rajan and Zingales (1998)).

[4]See for example Gottfries (1991); Bucht, Gottfries, and Lundin (2002), Chevalier and Scharfstein (1996a), Klemperer (1987, 1995), Bils (1989), Bagwell (2004), and Gourio and Rudanko (2011)

described by Schoenle (2010). The algorithm works by running a fuzzy matching of the names of firms in the PPI and Compustat databases.[5] After sorting all non-perfect matches in decreasing order of similarity, we can manually select "good" matches in addition to perfect matches.

When we apply the algorithm to the underlying datasets, we successfully match 772 Compustat firms on average per quarter. Given that we have information on 4988 Compustat firms in an average quarter, this implies a matching rate of 16%. We find, in terms of data characteristics, that firms in the matched data tend to be larger than in the original PPI and Compustat datasets. This is not surprising: Large firms are more likely to be sampled into the PPI, and are also more likely to be firms in the Compustat database.

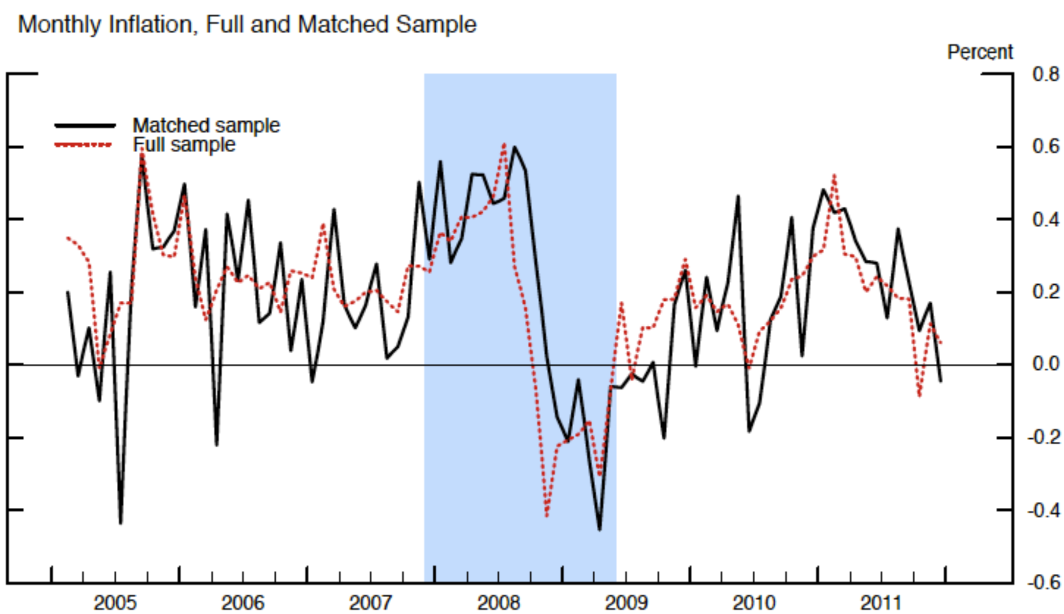

Figure 1: Monthly Producer Price Inflation Rates, Full and Matched PPI Sample

The figure shows monthly inflation rates for the full PPI sample (red dotted line) and our matched sample (black solid line). To construct the series, we first average monthly log price changes within firms, then across firms.

In terms of price-setting, we find that there is no statistically significant difference between average monthly inflation in the full and matched data. At the same time, the frequency of price changes in the matched sample is statistically significantly higher than in the full sample. Table

[5]The steps of the algorithm can be summarized as follows: First, firm names in the PPI and Compustat data are assimilated through a series of string manipulations by means of capitalization, punctuation removal, standardization of terms, and removal of generic terms. Second, a modified string similarity algorithm computes a measure of similarity between base and target firm names. It summarizes the quality of matches using Dice's coefficient $s = 2c/(x_1 + x_2)$ where C is the number of common bigrams, x_1 the number of bigrams in the first string and x_2 the number of bigrams in the second string. Note that when $s = 1$, we have a perfect match.

2 summarizes these results. When we plot the series of aggregate monthly PPI inflation rates in Figure 1, the full and matched sample appear highly correlated in their dynamics. In terms of financial conditions, our matched firms exhibit lower liquidity, SGAX and interest expense ratios. These are statistically significantly different from the full sample as summarized in Table 3.

3 Price Dynamics and Financial Conditions

Aggregate facts: inflation/frequency of adjustment as a function of firm financial conditions.

3.1 Inflation Dynamics

3.2 Frequency of Price Changes

4 Learning from Micro Regressions

In terms of modeling price adjustment, our findings provide direct evidence on the role of firm balance sheets for individual pricing behavior of firms. Clearly, standard Calvo, Taylor or state-dependent models of pricing cannot account for divergent pricing behavior depending on the financing situation of firms. Our results suggest that the conventional modeling approach should be augmented by the inclusion of financial frictions to be able to account for the price dynamics during the recent financial crisis and more generally, at the zero lower bound.

To provide additional evidence on the importance of firm balance sheets for price adjustment, we now turn to microeconomic regression analysis to measure the extent to which firm financial frictions influence the probability and size of price changes after controlling for other observable factors.

4.1 Extensive Margin of Price Adjustment

-Logit model

4.2 Intensive Margin of Price Adjustment

- Heckman correction price change regressions

- sectoral inflation regressions

5 Model

In this section, we construct a general equilibrium model in which monopolistically competitive firms trade off future market shares and current cashflow facing financial friction in obtaining external funds. To motivate the market share competition, we need preferences or institutional features that allow the formation of *customer base* such that "lower prices are a form of investment, an investment in market share" (Rotemberg and Woodford (1991)). To that end, we adapt the good-specific habit model developed by Ravn, Schmitt-Grohe, and Uribe (2006). Switching cost models, for instance, of Klemperer (1987), will serve the same purpose equally well. We chose the good-specific habit model simply for its tractability in a dynamic general equilibrium setting.

5.1 Preferences and Technology

It is assumed that there exists a continuum of households, indexed by $j \in [0,1]$. We assume that each household consumes a variety of consumption goods, indexed by $i \in [0,1]$. The preferences are defined for a habit adjusted consumption bundle, x_t^j and labor, h_t^j

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s U(x_{t+s}^j - \delta_{t+s}, h_{t+s}^j). \tag{4}$$

The consumption/habit aggregator is defined as

$$x_t^j \equiv \left[\int_0^1 \left(\frac{c_{it}^j}{s_{it-1}^{\theta}} \right)^{1-1/\eta} di \right]^{1/(1-1/\eta)}.$$

δ_t is the demand shock that alters the marginal utility of consumption today, and hence the final demand. The habit stock evolves according to

$$s_{it} = \rho s_{it-1} + (1-\rho) c_{it}. \tag{5}$$

The dual problem of cost minimization gives rise to a good specific demand,

$$c_{it}^{j} = \left(\frac{p_{it}}{\tilde{p}_t}\right)^{-\eta} s_{it-1}^{\theta(1-\eta)} x_t^j \tag{6}$$

where $p_{it} \equiv P_{it}/P_t$, the relative price of variety i in terms of $P_t \equiv \left[\int_0^1 P_{it}^{1-\eta} di\right]^{1/(1-\eta)}$ and the externality adjusted composite price index $\tilde{p}_t$ is defined as

$$\tilde{p}_t \equiv \left[\int_0^1 (p_{it} s_{it-1}^{\theta})^{1-\eta} di\right]^{1/(1-\eta)}. \tag{7}$$

We assume that there exists a continuum of monopolistically competitive firms, producing a differentiated variety, indexed by $i \in [0,1]$. Production technology is specified as

$$y_{it} = \left(\frac{A_t}{a_{it}} h_{it}\right)^{\alpha} - \phi, \quad 0 < \alpha \leq 1 \tag{8}$$

where A_t is a TFP shock, which follows an AR(1) process, and a_{it} is an iid idiosyncratic shock, following a log-normal distribution, $\log a_{it} \sim N(-0.5\sigma^2, \sigma^2)$. As indicated by (8), we allow the production technology to be either DRS or CRS. We assume that the production is subject to fixed operating costs, denoted by ϕ, which makes it possible for firms to incur negative incomes.

5.2 Financial Friction

Our model adopt the following two assumptions to introduce financial market friction:

- **Assumption 1**. Capital market friction: External financing is costly. Without loss of generality, we focus on equity financing and we assume that equity finance involves a constant per-unit dilution cost $\varphi \in (0,1)$.

- **Assumption 2**. Timing: Firms make the pricing decision befor the realization of idiosyncratic technology shock. In contrast, dividend/issuance, and hiring decision are made after the realization of the shock.

The assumption that equity financing is the only available financing mode is an innocuous one. On one hand, as shown by Gomes (2001) and Stein (2003), other forms of external financing premium can be replicated by properly parameterized dilution costs. On the other hand, other types of external financing costs would not matter with a frictionless equity market (see Cooley and Quadrini (2001)) as firms can detour credit market friction by simply taking negative dividends.

The situation envisioned in the second assumption can be described as follows: At the beginning of each period, all relevant aggregate information becomes known to the firms. After observing aggregate information, the firms post their pricings, take orders from custormers and plan productions. In the middle of production, idiosyncratic shocks realize. At this point, the firms cannot change their pricing decisions or readjust their production scales. The firms have to plan their production based on expected marginal cost rather than realized one. The assumption implies that the risk-neutral firms provide insurance to risk-averse customers.

For nominal rigidity, we simply assume that the firms face a quadratic cost in adjusting nominal prices, specified as $\gamma/2(P_{it}/P_{it-1} - \bar{\pi})^2 c_t = \gamma/2(\pi_t \cdot p_{it}/p_{it-1} - \bar{\pi})^2 c_t$ (Rotemberg (1982)). In principle, staggered pricing models such as Calvo (1983) would not change the main conclusions. However, for the sake of algebraic simplicity, we choose the convex adjustment cost model.

5.3 Profit Maximization Problem

The firm problem is to maximize the present value of dividend flows, $\mathbb{E}_t[\sum_{s=0}^{\infty} m_{t,t+s} d_{it+s}$. $d_{it}]$ denotes (real) dividend payouts when positive and equity issuance when negative. Assumption 1 implies that when a firm issues a notional amount of equity $d_{it} (< 0)$, actual cash inflow from the issuance is reduced to $-(1-\varphi)d_{it}$. The firm problem is subject to the flow of funds constraint,

$$0 = p_{it}c_{it} - w_t h_{it} - \frac{\gamma}{2}\left(\pi_t \frac{p_{it}}{p_{it-1}} - \bar{\pi}\right)^2 c_t - d_{it} + \varphi \min\{0, d_{it}\}. \tag{9}$$

Given the monopolistic competition, the firm's problem is also subject a demand constraint,

$$\left(\frac{A_t}{a_{it}} h_{it}\right)^{\alpha} - \phi \geq c_{it}. \tag{10}$$

The Lagrangean of the problem can then be expressed as

$$
\begin{aligned}
\mathcal{L} \;=\; & \mathbb{E}_0 \sum_{t=0}^{\infty} m_{0,t} \Bigg\{ d_{it} + \kappa_{it} \left[\left(\frac{A_t}{a_{it}} h_{it} \right)^{\alpha} - \phi - c_{it} \right] \\
& + \xi_{it} [p_{it} c_{it} - w_t h_{it} - \frac{\gamma}{2} \left(\pi_t \frac{p_{it}}{p_{it-1}} - \bar{\pi} \right)^2 c_t - d_{it} + \varphi \min\{0, d_{it}\}] \\
& + \nu_{it} \left[\left(\frac{p_{it}}{\tilde{p}_t} \right)^{-\eta} s_{it-1}^{\theta(1-\eta)} x_t - c_{it} \right] + \lambda_{it} [\rho s_{it-1} + (1-\rho) c_{it} - s_{it}] \Bigg\}
\end{aligned} \tag{11}
$$

where κ_{it}, ξ_{it}, ν_{it} and λ_{it} are the Lagrangean multipliers associated with (10), (9), (6) and (5). It is useful to state the economic meanings of these multipliers. The multiplier to the output constraint κ_{it} measures the shadow value of marginal cost. The multiplier to the flow of funds constraint ξ_{it} measures the shadow value of internal funds. The muliplier to the demand constraint (6), ν_{it} measures the value of marginal sales to the firm. Finally, the multiplier to the law of motion for the habit stock measures the value of marginal habit stock to the firm.

The efficiency conditions are summarized by FOCs[6]:

$$
d_{it} \;:\; \xi_{it} = \{.11/(1-\varphi).. \text{ if } d_{it} \geq 0 \text{ if } d_{it} < 0 \tag{12}
$$

$$
h_{it} \;:\; \kappa_{it} = \xi_{it} a_{it} \frac{w_t}{\alpha A_t} (c_{it} + \phi)^{\frac{1-\alpha}{\alpha}} \tag{13}
$$

$$
c_{it} \;:\; \mathbb{E}_t^a[\nu_{it}] = -\mathbb{E}_t^a[\kappa_{it}] + \mathbb{E}_t^a[\xi_{it} p_{it}] + (1-\rho)\lambda_{it} \tag{14}
$$

$$
\begin{aligned}
s_{it} \;:\; & \lambda_{it} = \rho \mathbb{E}_t\{m_{t,t+1} \lambda_{it+1}\} \\
& \quad + \; \theta(1-\eta) \mathbb{E}_t \left\{ m_{t,t+1} \mathbb{E}_{t+1}^a \left[\nu_{it+1} \frac{c_{it+1}}{s_{it}} \right] \right\}
\end{aligned} \tag{15}
$$

$$
\begin{aligned}
p_{it} \;:\; 0 \;=\; & \mathbb{E}_t^a[\xi_{it}] c_{it} - \eta \frac{\mathbb{E}_t^a[\nu_{it}]}{p_{it}} c_{it} - \gamma \frac{\pi_t}{p_{it-1}} \left(\pi_t \frac{p_{it}}{p_{it-1}} - \bar{\pi} \right) c_t \\
& + \; \gamma \mathbb{E}_t \left[m_{t,t+1} \mathbb{E}_{t+1}^a[\xi_{it}] \pi_{t+1} \frac{p_{it+1}}{p_{it}^2} \left(\pi_{t+1} \frac{p_{it+1}}{p_{it}} - \bar{\pi} \right) c_{t+1} \right]
\end{aligned} \tag{16}
$$

Note that in the last three FOCs, all expressions involving the shadow value of internal funds, ξ_{it}, are kept within an expectation operator, $\mathbb{E}_t^a(\cdot)$. The expectation operator is defined as $\mathbb{E}_t^a[\cdot] \equiv \int_0^\infty \cdot dF(a)$. The information set of the expectation operator includes all aggregate information up to time t except the realization of the idiosyncratic shock. This is necessary because all decisions regarding p_{it}, c_{it} and s_{it} are made before the realization of the idiosyncratic shock. As a result,

[6] Note that in (13), we replace h_{it} by the conditional labor demand $h_{it} = (c_{it} + \phi)^{1/\alpha} \frac{a_{it}}{A_t}$ *after* we derive the FOC.

the firm does not know its own liquidity condition, and has to form an expectation on the value of internal funds, i.e., $\mathbb{E}_t^a[\xi_{it}]$ based on the information on the aggregate state of the economy. In contrast, ξ_{it} and a_{it} enter the efficiency conditions (12) and (13) without the expectation operator since these decisions are made after the realization of the idiosyncratic shock.[7]

The risk-neutrality, the absence of persistence of idiosyncratic shock and the timing convention imply a symmetric equilibrium: all monopolistically competitive firms choose identical relative price ($p_{it} = 1$), production scale ($c_{it} = c_t$), and habit stock ($s_{it} = s_t$). However, the distributions of labor hours, dividend payouts and equity issuance are non-degenerate and depend on the realization of idiosyncratic shock.

After imposing the symmetric equilibrium conditions ($p_{it} = 1$, $c_{it} = c_t$), and dividing the FOC for p_{it} through by $\mathbb{E}_t^a[\xi_{it}]c_{it}$ yields the following Philiips curve under the financial market friction:

$$1 = \gamma\pi_t\left(\pi_t - \bar{\pi}\right) - \gamma\mathbb{E}_t\left[m_{t,t+1}\frac{\mathbb{E}_{t+1}^a[\xi_{it+1}]}{\mathbb{E}_t^a[\xi_{it}]}\pi_{t+1}\left(\pi_{t+1} - \bar{\pi}\right)\frac{c_{t+1}}{c_t}\right] + \eta\frac{\mathbb{E}_t^a[\nu_{it}]}{\mathbb{E}_t^a[\xi_{it}]} \tag{17}$$

As is evident from the above, the financial market modifies the Phillips curve through the term, $\mathbb{E}_t^a[\xi_{it}]$. Under a frictionless financial market, the shadow value of internal funds is always equal to one, and hence $\mathbb{E}_t^a[\xi_{it}] = 1$. This implies that the value of marginal sales $\mathbb{E}_t^a[\nu_{it}]$ is also independent of financial condition, and is determined only by fundamentals of the firms. To see this point, consider the FOC for

$$\mathbb{E}_t^a[\nu_{it}] = 1 - \mathbb{E}_t^a[\kappa_{it}] + (1-\rho)\lambda_t$$

where we impose the symmetric equilibrium conditions ($p_{it} = 1$, $\lambda_{it} = \lambda_t$) and the frictionless financial market condition $\mathbb{E}_t^a[\xi_{it}] = 1$. Since the shadow value of internal funds, both ex ante and ex post, is always equal to one, $\mathbb{E}_t^a[\kappa_{it}] = \mathbb{E}_t^a[a_{it}]\frac{w_t}{\alpha A_t}\left(c_t + \phi\right)^{\frac{1-\alpha}{\alpha}} = \frac{w_t}{\alpha A_t}\left(c_t + \phi\right)^{\frac{1-\alpha}{\alpha}}$ from the FOC for h_{it}. Hence the independence of the marginal value of sales from financial condition. Note that the timining convention plays no role in equilibrium without the assumption of financial market friction. Indeed, the Phillips curve (17) is essentially no different from the one in Ravn, Schmitt-Grohe, Uribe, and Uuskula (2010).

Therefore, to analyze how the financial market friction interacts with pricing/mark-up decisions, it is essential to show how the value of internal funds is determined. To that end, we define

[7] A similar timing convention has been used by Kiley and Sim (2012) in the context of financial intermediation.

an equity issuance trigger a_t^E as the level of idiosyncratic shock that satisfies the flow of funds constraint when $d_{it} = 0$:

$$a_t^E = \frac{c_t}{(c_t + \phi)^{1/\alpha}} \frac{A_t}{w_t} \left[1 - \frac{\gamma}{2} (\pi_t - \bar{\pi})^2\right] \tag{18}$$

Using the equity issuance trigger, the FOC for d_{it} can be expressed as

$$\xi(a_{it}) = \{.11/(1-\varphi)..\ \text{if}\ \ a_{it} \leq a_t^E\ \ \text{if}\ \ a_{it} > a_t^E \tag{19}$$

We define z_t^E as the standardized value of a_t^E, i.e., $z_t^E = \sigma^{-1}(\log a_t^E + 0.5\sigma^2)$. Using the standardized issuance trigger and (19), we can evaluate the shadow value of internal funds as

$$\begin{aligned}\mathbb{E}_t^a[\xi_{it}] &= \int_0^\infty \xi(a) dF(a) = \int_0^{a_t^E} \xi(a) dF(a) + \int_{a_t^E}^\infty \xi(a) dF(a) \\ &= \Phi(z_t^E) + \frac{1}{1-\varphi}[1 - \Phi(z_t^E)] = 1 + \frac{\varphi}{1-\varphi}[1 - \Phi(z_t^E)] \geq 1\end{aligned}$$

The expected shadow value of internal funds is a smooth function of the normalized trigger z_t^E. This is in contrast to (19), which is the realized shadow value. More importantly, the expected shadow value is strictly greater than 1 as long as $\sigma > 0$ and $\varphi > 0$. In other words, the ex ante shadow value is always greater than the frictionless counterpart, 1 as long as the financial market is frictional ($\varphi > 0$) in the presence of idiosyncratic uncertainty ($\sigma > 0$). This makes the firms de facto risk averse in their pricing decision because setting the price too low and taking an imprudently large number of orders exposes the firm to a risk that the firm incurs a negative operating income, which should be covered by costly external financing.

Note that $\partial \mathbb{E}_t^a[\xi_{it}]/\partial A_t \leq 0$ and $\partial \mathbb{E}_t^a[\xi_{it}]/\partial w_t$. This is because $\mathbb{E}_t^a[\xi_{it}]$ is monotonically decreasing in z_t^E, and hence in a_t^E. In the special case of CRS ($\alpha = 1$), one can also see that $\partial \mathbb{E}_t^a[\xi_{it}]/\partial c_t \leq 0$.[8] Since the conditional labor demand is given by $h_{it} = (c_{it} + \phi)^{1/\alpha} a_{it}/A_t$, one can see a strong link between the state of aggregate (average) mark-up and the shadow value of internal funds: When the expected mark-up, $c_t/(w_t h_t) = c_t A_t/[w_t(c_t + \phi)^{1/\alpha}]$ goes up, the probability of external financing $1 - \Phi(z_t^E)$ goes down, and as a result, the shadow value of internal funds goes down.

We now show how the value of internal funds affects the value of marginal sales. In the FOC

[8] If $\alpha < 1$, a_t^E is not monotonically increasing in c_t. However, with a realistic calibration of the model economy, a_t^E is increasing in c_t in the neighborhood of non-stochastic steady state.

for c_{it} (14), we can see that the value of marginal sales is composed of two elements, the current profit and the value of customer base: From (14), after imposing the symmetric equilibrium condition, we have

$$\mathbb{E}_t^a[\nu_{it}] = \underbrace{\mathbb{E}_t^a[\xi_{it}] - \mathbb{E}_t^a[\kappa_{it}]}_{\text{value of current profit}} \quad + \quad \underbrace{(1-\rho)\lambda_{it}}_{\text{value of market share}}$$

To see that the first component is the value of marginal profit, we can substitute (13) in the second term of the above to see

$$\begin{aligned} \mathbb{E}_t^a[\xi_{it}] - \mathbb{E}_t^a[\kappa_{it}] &= \mathbb{E}_t^a[\xi_{it}] - \mathbb{E}_t^a[\xi_{it} a_{it}] \frac{w_t}{\alpha A_t} (c_t + \phi)^{\frac{1-\alpha}{\alpha}} \\ &\equiv \mathbb{E}_t^a[\xi_{it}] - \frac{\mathbb{E}_t^a[\xi_{it} a_{it}]}{\mu(A_t, c_t, w_t)} \end{aligned}$$

where we define $\mu(A_t, c_t, w_t) \equiv \alpha(A_t/w_t)(c_t + \phi)^{\frac{\alpha-1}{\alpha}}$, aggregate (marginal) mark-up. Without the financial market friction, the value of marginal profit is simply given by $1 - 1/\mu(A_t, c_t, w_t)$. The financial friction tilts the way the firm assess the marginal revenue and cost in an important way through the terms $\mathbb{E}_t^a[\xi_{it}]$ and $\mathbb{E}_t^a[\xi_{it} a_{it}]$. We have already shown that the financial friction implies $\mathbb{E}_t^a[\xi_{it}] \geq 1$. The interaction term $\mathbb{E}_t^a[\xi_{it} a_{it}]$ can be evaluated as

$$\mathbb{E}_t^a[\xi_{it} a_{it}] = \int_0^{a_t^E} a dF(a) + \int_{a_t^E}^{\infty} a \frac{dF(a)}{1-\varphi} = 1 + \frac{\varphi}{1-\varphi}[1 - \Phi(z_t^E - \sigma)] \geq 1.$$

where we use a property of lognormal distribution to derive the last expression (see Johnson, Kotz, and Balakrishnan (1994)). Note that $\mathbb{E}_t^a[\xi_{it} a_{it}] \geq \mathbb{E}_t^a[\xi_{it}] \geq 1$. In words, the financial friction elevates both the value of marginal revenue and the value of marginal cost, but more so for the marginal cost, making the firm more conservative in its pricing decision to avoid negative profits. To streamline notations, we define a modified mark-up

$$\tilde{\mu}(A_t, c_t, w_t) \equiv \frac{\mathbb{E}_t^a[\xi_{it}]}{\mathbb{E}_t^a[\xi_{it} a_{it}]} \mu(A_t, c_t, w_t) \leq \mu(A_t, c_t, w_t) \tag{20}$$

To derive a closed form solution for the value of customer base, we define $g_t \equiv c_t/s_{t-1} =$

$(s_t/s_{t-1} - \rho)/(1-\rho)$. One can then verify that the closed form is given by

$$\lambda_t = \theta(1-\eta)\mathbb{E}_t\left[\sum_{s=t}^{\infty}\tilde{\beta}_{t,s}\mathbb{E}^a_{s+1}[\xi_{is+1}]\left[\frac{\tilde{\mu}_{s+1}-1}{\tilde{\mu}_{s+1}}\right]\right].$$

where $\tilde{\beta}_{t,s} \equiv m_{s,s+1}g_{s+1} \cdot_{j=1}^{s-t} [\rho + \theta(1-\eta)(1-\rho)g_{t+j}]m_{t+j-1,t+j}$. The current value of customer base is essentially the expected present value sum of future marginal profits. Substituting the expression for the value of customer base in (14),and using the modified mark-up yields a closed form solution for the value of marginal sales:

$$\mathbb{E}^a_t[\nu_{it}] = \mathbb{E}^a_t[\xi_{it}]\left[\frac{\tilde{\mu}_t-1}{\tilde{\mu}_t}\right] + (1-\rho)\theta(1-\eta)\mathbb{E}_t\left[\sum_{s=t}^{\infty}\tilde{\beta}_{t,s}\mathbb{E}^a_{s+1}[\xi_{is+1}]\left[\frac{\tilde{\mu}_{s+1}-1}{\tilde{\mu}_{s+1}}\right]\right]. \tag{21}$$

This expression shows how the problem of optimal degree of myopia arises in the context of financial friction: Compare the liquidity conditions of the firm measured by the sequence of $\mathbb{E}^a_s[\xi_{is}]$, $s = t, \ldots, \infty$. If today's liquidity condition is direr than what is expected for future, give more weight on the current profit in optimizing mark-up/pricing, optimally giving up on the value of building up customer base for future profits today. In fact, today's liquidity concern sufficiently outweighs tomorrow's concern, we expect that the first term on the right side of (21) will dominate the second term, and the value of marginal sales will move up and down in lockstep with the value of internal funds. We will show this is indeed the case in our simulation exercises under the financial market friction.

Dividing (21) through by $\mathbb{E}^a_t[\xi_{it}]$ and substituting this in (17), we reach our final expression for the Phillips curve,

$$\begin{aligned} 1 \quad = \quad & \gamma\pi_{it}\left(\pi_{it}-\bar{\pi}\right) - \gamma\mathbb{E}_t\left[m_{t,t+1}\frac{\mathbb{E}^a_{t+1}[\xi_{it+1}]}{\mathbb{E}^a_t[\xi_{it}]}\pi_{it+1}\left(\pi_{it+1}-\bar{\pi}\right)\frac{c_{it+1}}{c_{it}}\right] \\ & +\eta\left[\frac{\tilde{\mu}_t-1}{\tilde{\mu}_t}\right] + \eta(1-\rho)\theta(1-\eta)\mathbb{E}_t\left[\sum_{s=t}^{\infty}\tilde{\beta}_{t,s}\frac{\mathbb{E}^a_{s+1}[\xi_{is+1}]}{\mathbb{E}^a_t[\xi_{it}]}\left[\frac{\tilde{\mu}_{s+1}-1}{\tilde{\mu}_{s+1}}\right]\right]. \end{aligned} \tag{22}$$

The left side measures the benefit of increasing marginal unit of price: By increasing one more unit in price, holding demand quantity constant, the firm earns one additional revenue. The right side measures the cost of doing so. The first line of the right side is very close to a canonical New Keynesian Phillips curve, except that the future saving in adjustment cost brought about by today's adjustment is discounted by an additional pricing factor, $\mathbb{E}^a_{t+1}[\xi_{it+1}]/\mathbb{E}^a_t[\xi_{it}]$, which is nothing but the dynamic liquidity ratio of the firm, tomorrow vs today.

The second line shows additional cost of increasing price: By increasing price, the firm loses the profit of the foregone demand, which is captured by the first term of the second line. Furthermore, the firm also loses the cumulative profits associated with the customer base that it could have kept by holding the price level constant, which is captured by the second term of (22). This is why keeping one's price low today becomes an active investment in customer capital. What is important in our purpose is that the financial friction makes it harder for firms to exploit this investment opportunity. When the firm faces a severe liquidity problem, the future benefits of holding market share today is heavily discounted by the financial factor $\mathbb{E}^a_{s+1}[\xi_{is+1}]/\mathbb{E}^a_t[\xi_{it}]$, for $s = t, \cdots, \infty$. Note that it is not the harsh liqudity condition *per se* that leads firms to discount future benefits of customer base today: It is the prospect of improved liquidity condition in the future that induces the firms with poor liquidity condition today to hold the price level fairly constaint or to increase their prices in some situation.

An analogy can be made from investment literature. Myers (1977) showed how debt overhang problem can lead firms to pass up otherwise positive net present value projects. Also, the empirical investment literature, initiated by Fazzari, Hubbard, and Petersen (1988), showed how firm-level investment spendings can be sensitively affected by the current cashflow condition (see also Chirinko (1993) and Gilchrist and Himmelberg (1995)). In our model, the investment is not in the physical capacity of the firm, but in the customer base. However, as shown by Gourio and Rudanko (2011), the customer capital can be as much valuable as firms' physical capital. Finally, our model echoes the theoretical insights of Chevalier and Scharfstein (1996a) regarding the role of financial market friction on the mark-up variation, but generalizes the results in a fully dynamic general equilibrium setting. Our model also can be viewed as a special application to New Keynesian pricing theory of liquidity-based asset pricing (LAPM, Holmstrm and Tirole (2001)).

5.4 The Rest of the Model Economy

The household budget constraint is given by

$$b^j_{t+1} + \int_0^1 p_{it}c^j_{it}di + \int_0^1 p^S_{it}s^j_{F,it+1}di = w_t h^j_t + (1+r_{t-1})b^j_t + \int_0^1 [\max\{d_{it}, 0\} + p^S_{it-1,t}]s^j_{F,it}di$$

where b_t^j is the government bond held by the household j, $s_{F,it}^j$ is the share of firm i held by the household j, $p_{it-1,t}^S$ is the time t value of shares outstanding at time $t-1$, p_{it}^S is the ex-dividend value of equity at time t. The last two are related with each other by an accounting identity, $p_{it}^S = p_{it-1,t}^S + e_{it}$ where e_{it} is the value of new shares issued at time t. The costly equity finance assumption adopted for the production firms implies that $e_{it} = -(1-\varphi)\min\{d_{it}, 0\}$. Using the accounting identity, and the fact that $\int_0^1 p_{it}c_{it}^j di = \tilde{p}_t x_t^j$ from (6), one can rewrite the budget constraint as

$$\begin{aligned} b_{t+1}^j + \tilde{p}_t x_t^j + \int_0^1 p_{it}^S s_{F,it+1}^j di &= w_t h_t^j + (1+r_{t-1})b_t^j \\ &\quad + \int_0^1 [\max\{d_{it}, 0\} + (1-\varphi)\min\{d_{it}, 0\} + p_{it}^S] s_{F,it}^j di. \end{aligned} \tag{23}$$

The above expression makes it clear that the costly equity finance takes the form of sales of new shares at a discount in general equilibrium. Since the owners of old and new shares are the same entity in our general equilibrium, there is no direct wealth effects associated with the costly equity financing: the losses of the old shareholders exactly offset the gains of the new shareholders.

Denoting the multiplier for the budget by Λ_t^j and maximizing (4) subject to (23) yields

$$x_t^j \; : \; \Lambda_t^j \tilde{p}_t = U_x(x_t^j - \delta_t, h_t^j) \tag{24}$$

$$h_t^j \; : \; \Lambda_t^j w_t = -U_h(x_t^j - \delta_t, h_t^j) \tag{25}$$

$$b_{t+1}^j \; : \; \Lambda_t^j = \beta \mathbb{E}_t[\Lambda_{t+1}^j (1+r_t)] \tag{26}$$

$$s_{F,it+1}^j \; : \; \Lambda_t^j = \beta \mathbb{E}_t \left[\Lambda_{t+1}^j \left(\frac{\tilde{d}_{t+1} + p_{t+1}^S}{p_t^S} \right) \right] \tag{27}$$

where $\tilde{d}_{t+1} \equiv \mathbb{E}_{t+1}^a[\max\{d_{it+1}, 0\}] + (1-\varphi)\mathbb{E}_{t+1}^a[\min\{d_{it+1}, 0\}]$, and we use $p_t^S = p_{it}^S$ in our symmetric equilibrium. From (24), we have $\Lambda_t^j = U_x(x_t^j, h_t^j)/\tilde{p}_t$. In our symmetric equilibrium, $\Lambda_t^j = \Lambda_t$, $p_{it} = 1$ and $s_{it-1} = s_{t-1}$, and thus $\tilde{p}_t = s_{t-1}^\theta$. Hence $\Lambda_t = U_x(x_t, h_t)/s_{t-1}^\theta$, and

$$m_{t,t+1} = \beta \frac{U_x(x_{t+1} - \delta_{t+1}, h_{t+1})}{U_x(x_t - \delta_t, h_t)} \frac{s_{t-1}^\theta}{s_t^\theta}.$$

(24) and (25) together imply the following efficiency condition.[9]

$$\frac{w_t}{\tilde{p}_t} = -\frac{U_h(x_t - \delta_t, h_t)}{U_x(x_t - \delta_t, h_t)}.$$

5.5 Monetary Policy

Closing the model is the specification of monetary policy, for which we assume a Taylor-type rule in inflation gap, i.e.,

$$r_t = \max\left\{0, (1 + r_{t-1})^{\rho_r}\left[(1+\bar{r})\left(\frac{\pi_t}{\pi^*}\right)^{\rho_\pi}\right]^{1-\rho_r} - 1\right\}. \tag{28}$$

Two things are worthwhile to mention regarding the particular form of the Taylor rule. First, we assum a policy inertia, $\rho_r \in (0, 1)$. Second, we assume that the policy rate responds only to the inflation gap. The so called divine coincidence in this class of New Keynesian model makes output gap redundant. Moreover, the notion of outgap is debatable. More importantly, the current policy setting makes it straightforward to interpret the main results in the current paper. With this setting, it is a lot more transparent to see that any non-conventional results from the model has nothing to do with particular definition of output gap nor to do with the way the monetary authority responds to the output gap. That said, we note that a non-zero coefficient for output gap does not affect the results in any meaningful way.[10] Third, as is evident from the specification, we allow the policy rate to be bounded below by zero to explore how the role of financial market friction plays out in a binding zero lower bound environment.[11]

[9] In actual implementation of the model, we also assume an adjustmet cost of nominal wage, introducing market power of differentiated labor. But for the simplicity of the model presentation, we skip the discussion. However, one can find the relevant dynamic wage Phillips curve in our online appendix.

[10] We tried the *natural* output gap measure, a measure that is the least controversial in theoretical asepects.

[11] For this type of analysis, we use deterministic simulation routine of Adjemian, Bastani, Juillard, Mihoubi, Perendia, Ratto, and Villemot (2011) to allow a fully nonlinear solution. This is important because the shocks that put the economy under the binding zero lower bound are usually large, and thus place the economy where local dynamics in the neighborhood of non-stochastic steady state may not approximate the non-linear dynamics of the economy well.

6 Simulation Results

6.1 Calibration

There are three sets of parameters in the model: parameters related with preferences and technology; parameters governing the strength of nominal rigidity and monetary policy; parameters determining the strength of financial market friction.

We set the time discounting factor equal to 0.99. We set the deep habit parmeter equal to 0.95 to highlight the firms' incentive to compete on market share. We also choose a fairly persistent habit formation such that only 5 percent of habit stock is depreciated in a quarter. The CRRA parameter is then set equal to one given that the deep habit specification provides enough amount of consumption smoothing. We set the elasticity of labor supply equal to 5. For the aggregate technology shock process, we assume $\rho_A = 0.90$, somewhat lower a value than those employed by real business cycle analysis, given that the model has many different elements of persistent dynamics of the endogenous quantities.

One of the important calibration is the elasticity of substitution: the greater the market power the firm has, the greater incentive to invest in customer capital. Broda and Weinstein (2006) provides a set of point estimates for the elasticity of substitution for the U.S. economy. The estimates hover around 2.1$\sim$4.8, depending on the characteristics of products (commodities vs differentiated goods) and sub-samples (before 1990 vs after 1990). In particular, Broda and Weinstein (2006), using sub-sample after 1990, estimates the median value of the elasticity of differentiated goods as 2.1 for the differentiated products, which are the relevant concept for the deep habit model considered in this paper. Following this, we simply set $\eta = 2$. Ravn, Schmitt-Grohe, Uribe, and Uuskula (2010) also provides a point estimate of 2.48 using their structural estimation method.

Another important calibration of technological parameter is the fixed opearating cost, ϕ. This parameter is jointly determined with the returns to scale parameter α. We set α first, then choose ϕ such that dividend payout ratio (relative to income) hits the post war mean value 2.5 percent in U.S. We find that a decreasing returns to scale model is convenient to highlight the link between the financial market friction and pricing decision, and choose $\alpha = 0.8$. While this degree of returns to scale parameter is not unusual in empirical investment literature based on Compustat data (for

Table 1: Baseline Calibration

Description	Calibration
Preferences and production	
Time discounting factor, β	0.99
Constant relative risk aversion, γ_x	1.00
Deep habit, θ	-0.95
Persistence of deep habit, ρ	0.95
Elasticity of labor supply, $1/\gamma_h$	5.00
Elasticity of substitution, η	2.00
Persistence of technology shock, ρ_A	0.90
returns to scale, α	0.80
Fixed operation cost, ϕ	0.21
Nominal rigidity and monetary policy	
Price adjustment cost, γ_p	10.0
Wage adjustment cost, γ_w	30.0
Monetary policy inertia, ρ^r	0.75
Taylor rule coefficient for inflation gap, ρ^π	1.50
Financial Frictions	
Equity issuance cost, φ	0.30, 0.50
Idiosyncratic volatility (a.r.), σ	0.20
Persistence of financial shock, ρ_φ	0.90

instance, see Hennessy and Whited (2007)), it is true that the model's dynamics is not significantly affected by moving from $\alpha = 1.0$ to $\alpha = 0.8$. In this sense, this is our 'preferred' calibration. With the chosen α, ϕ and η, the average mark-up is determined as 1.19.

Regarding the financial friction, we set the dilution cost φ as 0.30 as in Cooley and Quadrini (2001) when we consider the dilution cost as an exogenous shock process. In this case, we set the persistence of the shock as 0.90. However, in our crisis experiment in which we consider an exterme degree of financial market friction, we use $\varphi = 0.50$ as well. Regarding the volatility of idiosyncratic shock is calibrated as 0.05 at a quarterly frequency, a moderate degree of idiosyncratic uncertainty. With the fixed operation cost calibrated as described above, the combination of $\sigma = 0.05$ and $\varphi = 0.50$ results in $\mathbb{E}^a[\xi_i] = 1.17$.

As for the parameters related with nominal rigidity, we set the adjustment costs of nominal price and wage as $\gamma_p = 10.0$ and $\gamma_w = 30.0$, which are very close to the point estimates of 14.5 and 41.0 by Ravn, Schmitt-Grohe, Uribe, and Uuskula (2010), who show that deep habit model substantially enhances the persistence of inflation dynamics without the help of implausibly large amount of adjustment friction in nominal prices. Finally, we set the inertial Taylor coefficient at a conventional level of 0.75 and the coefficient of inflation gap as 1.5, which is in line with the New Keynesian literature.

6.2 Crisis and Inflation

Our main goal in this paper is to gain insight as to why the massive slack in the production capacity observed in last recession did not lead to a sizable drop in inflation rate, and perhaps an outright deflation sprials much worried both in academia and in policy circle. To study the dynamics of inflation and other endogenous variables in a financial crisis, we performe two thought experiments. In this subsection, we consider a rather extreme calibration which allows us to think about a situation where raising external financing is not impossible, but tremendously costly, and the firms in the model operate mostly with internal cashflows. To implement such a scenario, we set $\varphi = 0.50$, which implies that the dilution effect of new equity is 50 percent. Admittedly, such an extreme situation can be considered only in the middle of financial crisis such as around the time period of Lehman bankuptcy in 2008, where virtually no firms could contemplate raising outside equities to finance operating cost and investment. We study the impact of conventional supply and demand shocks of one standard deviations on the pricing decisions of the firms in this extreme environment.

Figure 2 shows the impact of one standard deviation technology shock both for the economy with the financial friction (solid blue) and for the economy without the financial friction (solid dot red). The negative technology shock leads a sizable drop in economic activity shown in panel (a) and a short burst of inflation in panel (b). These signs are as expected in the standard New Keynesian theory. In panel (a), we can see that the capital market friction in the model generates a mild degree of financial accelerator type propagation.

What is surprising in figure 2 is the differential responses of inflation rate depending on the presence of financial friction. The inflation response is about 40 percent greater with the financial friction. Panel (e)$\sim$(f) of the figure provide an explanation for the differential responses in inflation. In our environment, the news of bad aggregate condition becomes known before pricing decision. Under the financial market friction, the news about the bad technology shock at the

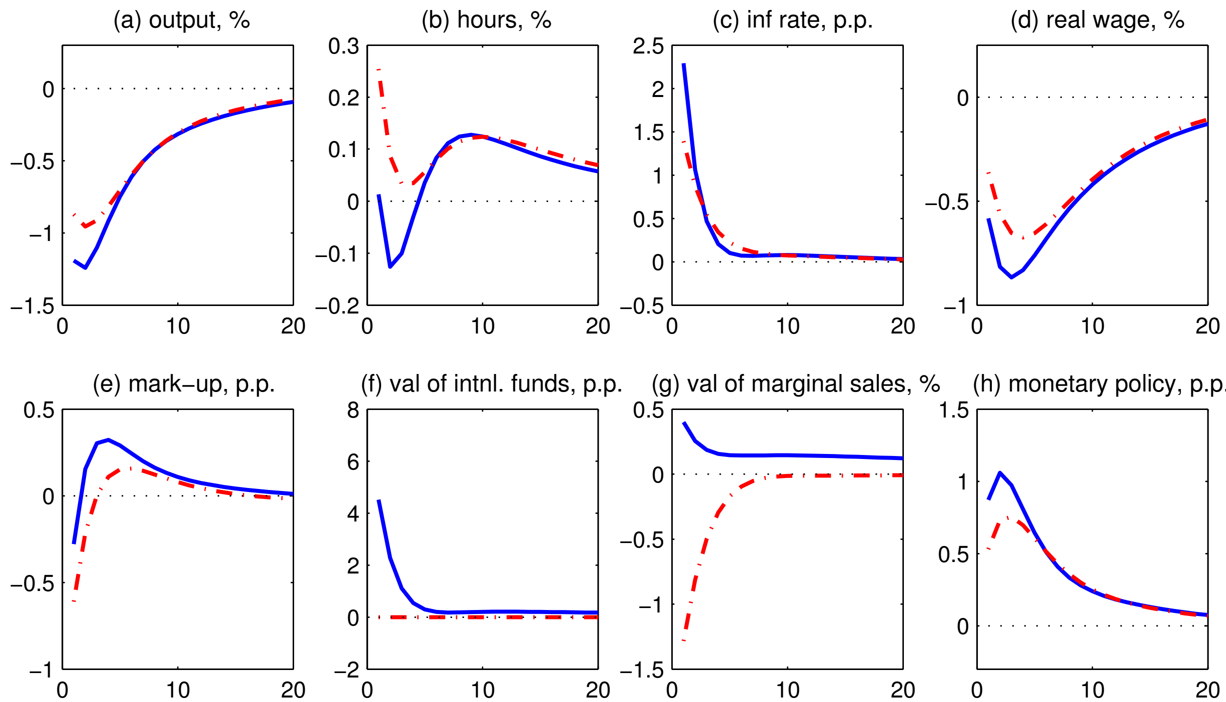

Figure 2: Impact of Demand Shock: With (solid) and Without (solid-dot) Financial Friction

beginning of the period deteriorates the firms' expected internal cashflows and elevates the probability of costly external finance event substantially, which then leads to a jump in the shadow value of internal funds as much as 400 basis points from its normal level, shown in panel (f). In response, the firms try to protect themselves against the tail event by choosing higher margins than the level otherwise optimal without liquidity problem as shown in panel (e).

As we emphasized earlier, a severe financial market friction may put the value of internal cashflows and the value of marginal sales in lockstep. Panel (f) and (g) show this: the financial market friction creates a direct link between the two valuations that does not exist for a frictionless economy. In fact, the value of marginal sales without the financial market friction moves in the opposite direction to that with the financial friction. Today's increase in price erodes the customer capital, not only for today but for days to come, hence the drop in the value of marginal sales. The same thing happens with the financial market friction. However, the substantial increase in the value of internal funds under the financial friction overturns the tendency of the value of marginal sales to drop.

Finally, as shown by the last term of the Phillips curve (22), the benefits of future customer

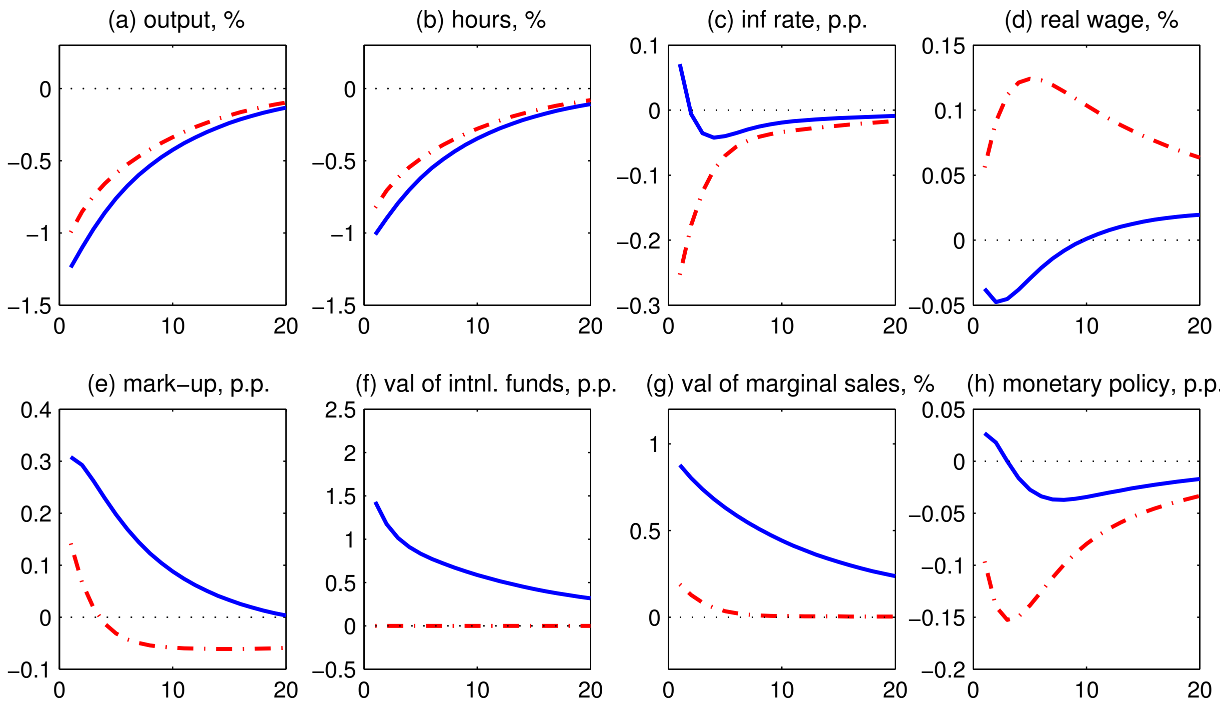

Figure 3: Impact of Demand Shock: With (solid) and Without (solid-dot) Financial Friction

base is heavily discounted when today's liquidity condition is expected to be much worse than the conditions in the future. As a result, the firms's pricing decision is overly driven by today's profit, rather than by its implication for future profits, a form of shortermism that is optimal from our theoretical perspective, but nevertheless might be charaterized as myopia. This is the reason why the inflation response exhibits an excess sensitivity to the technology shock.

Figure 3 shows the case of demand shock. Here the shock is affecting the marginal utility of consumption (see (4)), replicating so called *autonomous* spending cut. We find the same message in this figure. With the financial market friction, the firms will choose higher levels of prices that may be suboptimal from the perspective of firms with no liquidity problem. However, the message is delivered in a rather dramatic way. The financial market friction in this paper, in particular with our crisis calibration, delivers a small, but positive response in inflation in response to a negative demand shock.

Regardless of financial friction, the negative shock leads to a jump in mark-up. The counter-cyclical mark-up in a demand driven cycle is one motivation behind the deep habit models. What is surprising in the current context is the degree in which the countercyclicality of mark-up is

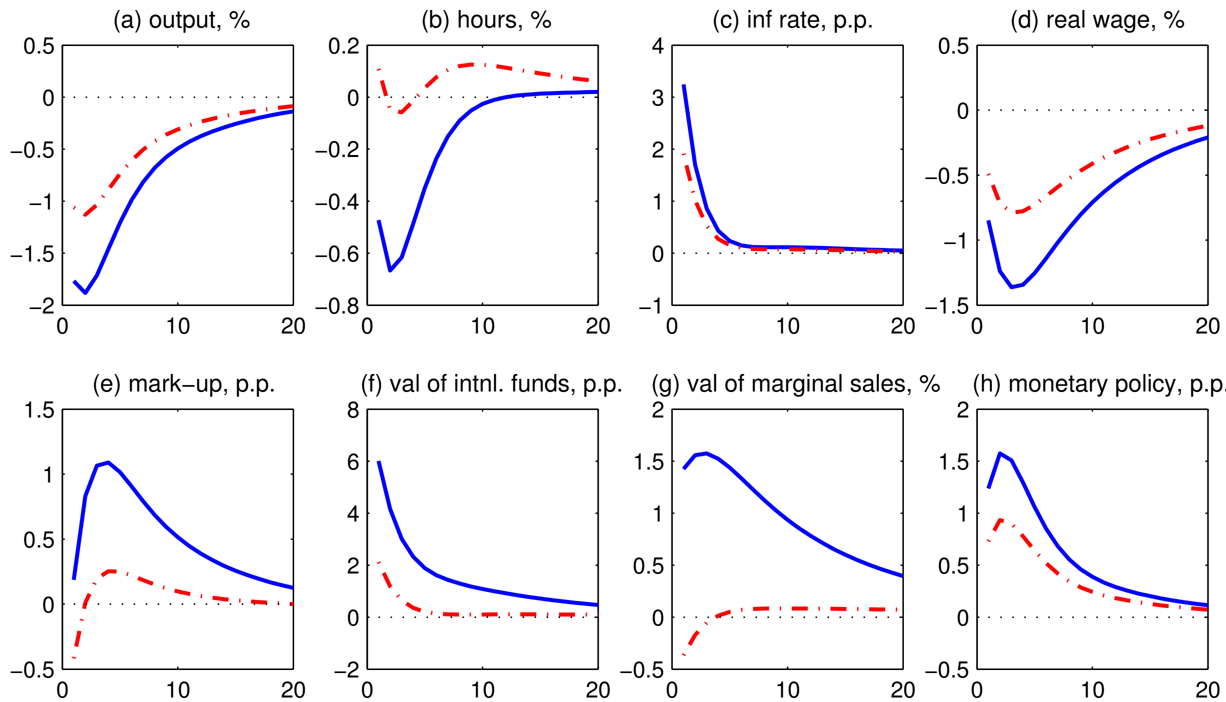

Figure 4: Impact of Technology Shock with Higher External Cost: With (solid) and Without (solid dot) Financial Shock

strengthened by the financial friction. In panel (e), one can see that the model with financial friction exhibits two time greater increase in mark-up during the downturn brought by the demand shock. Panel (f) and (g) show that the driving force behing the countercyclical mark-up variation is the sudden deterioration of liquidity condition to a degree in which the firms actually opt to increase prices facing weak demands to increase short-term profitability.

6.3 Impact of Financial Shock

Another way of characterizing a period of financial turmoil is to view such a period as a time when the cost of external funds is temporarily elevated from its normal level. We have emphasized that what matters for the implication of liquidity condition for pricing decision is not the absolute value of external financing cost per se, but the prospect that the financing condition will be improved in the future. If our reasoning is valid, we expect that the differential effects on mark-up/pricing of supply and demand shocks between the frictionless model and the model with the friction will be magnified with the temporary increase in the cost of external financing.

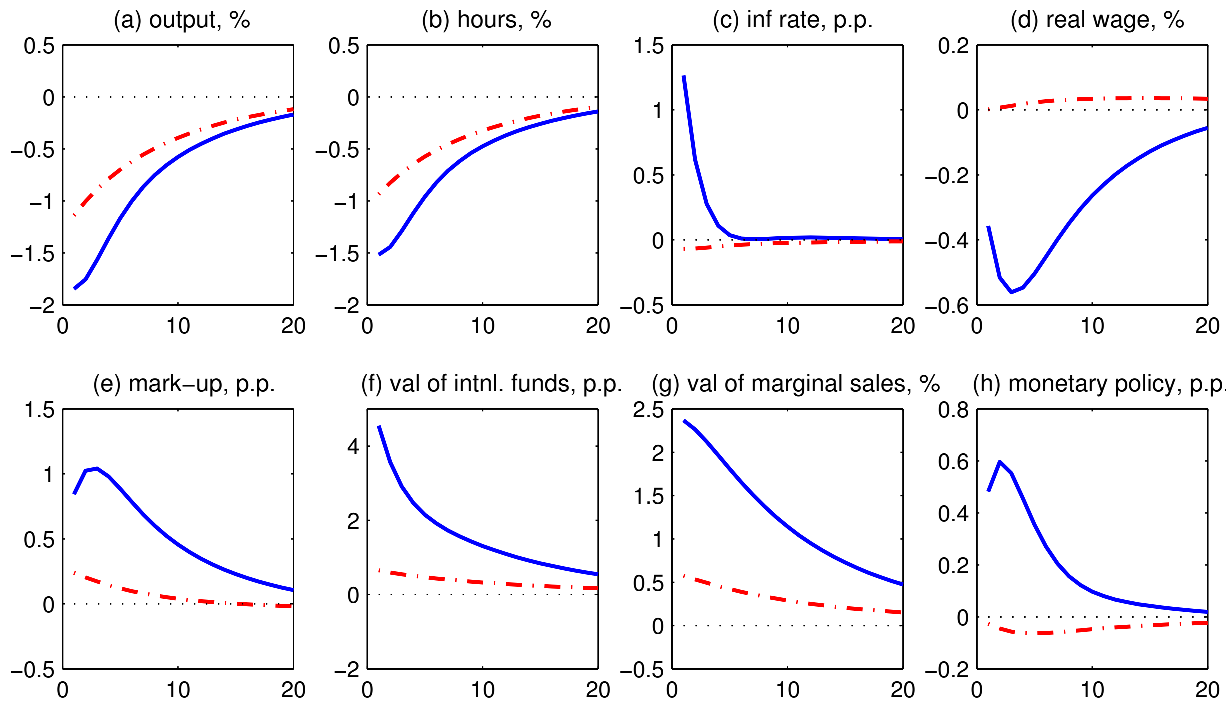

Figure 5: Impact of Demand Shock with Higher External Cost: With (solid) and Without (solid dot) Financial Shock

To explore this possibility, we assume that the equity issuance cost parameter follows an AR(1) process,

$$\varphi_t = \bar{\varphi} f_t, \ \ \log f_t = \rho_f \log f_{t-1} + \epsilon_{t,f}$$

We consider a shock $\epsilon_{t,f}$ that increases the level of dilution cost 25 percent from its normal level immediately, converging to the normal level thereafter. We consider the effects of supply and demand shocks we analyzed in the earlier section in this environment. Note that with the shock, the level of dilution cost is increased from 0.3 to 0.375, a much lower level than 0.5, the case in which we considered φ as a 'parameter' in the ealier section.

Figure 4 displays the responses of the model economy to one standard deviation technology shock: solid blue line is the case with the technology shock when there is a simultaneous shock to the cost of external finance; solid-dot red line is the responses to the technology shock without the fiancial shock. Figure 6.3 shows the results of the same exercise, but with the demand shock (the size of financial shock is identical to the one in figure 4).One can think of the vertical differences between the solid blue and solid-dot red lines in these figures as the additional impact created by the shock to the financing cost.[12]

As we conjectured, one can see that the economy is showing a hyper-sensitivity to both technology and demand shocks when the cost of external financing is temporarily elevated. For instance, in panel (a) and (b) of 4, one can see eailiy that the additional effect created by the temporarily increase in financing cost is tremendous: output drop is nearly doubled while the drop in hours is almost 10 times greater. In panel (e), the mark-up response is not positive on the impact of the shock, and strongly countercyclical even for the technology shock. Panel (f) shows that the increase in the shadow value of internal funds is two times greater than the case without the fianancial shock. Similar patterns can be found in the case of the demand shock, figure 6.3. Note that the substantial part of the increase in the shadow value of internal funds is endogenous in nature: As the economy deteriorates more than in the case without the financial shock, the probability of external financing gets even higher, which then increases the value of internal funds further. Such within-period financial multiplier is playing an important role in the greater propagation of the shocks in figure 4 and 6.3.

It is useful to compare the responses of the economy when the cost of external finance is permanently elevated to 0.5 (the solid blue lines in figure 2) and thos when the external financing cost is temporarily elevated up to 0.375 (the solid blue lines in figure 4). In terms of maximum dilution effect, the blue lines in 2 is much more harsher financial environment since its dilution cost is always equal to 0.5. However, the economic impact of the same sized technology shock is disproportionately greater for the case with the temporarily higher dilution cost. It is precisely in this sense that the prospect of improved financial condition makes matters worse since it maximizes economic agents' incentive to wait or postpone investment in market shares.

6.4 Role of Zero Lower Bound

We close our simulation exercises by analyzing the role of financial market friction on pricing under the environment of binding zero lower bound (ZLB for shorthand reference). To create a binding ZLB situation, we implement so called "paradox of thrift" scenario in which the time

[12]Since the normal level of dilution cost is 0.3 in this experiment, there exists a qualitative and quantitative difference between the solid blue lines in figure 2 and the solid-dot red lines in figure 4.

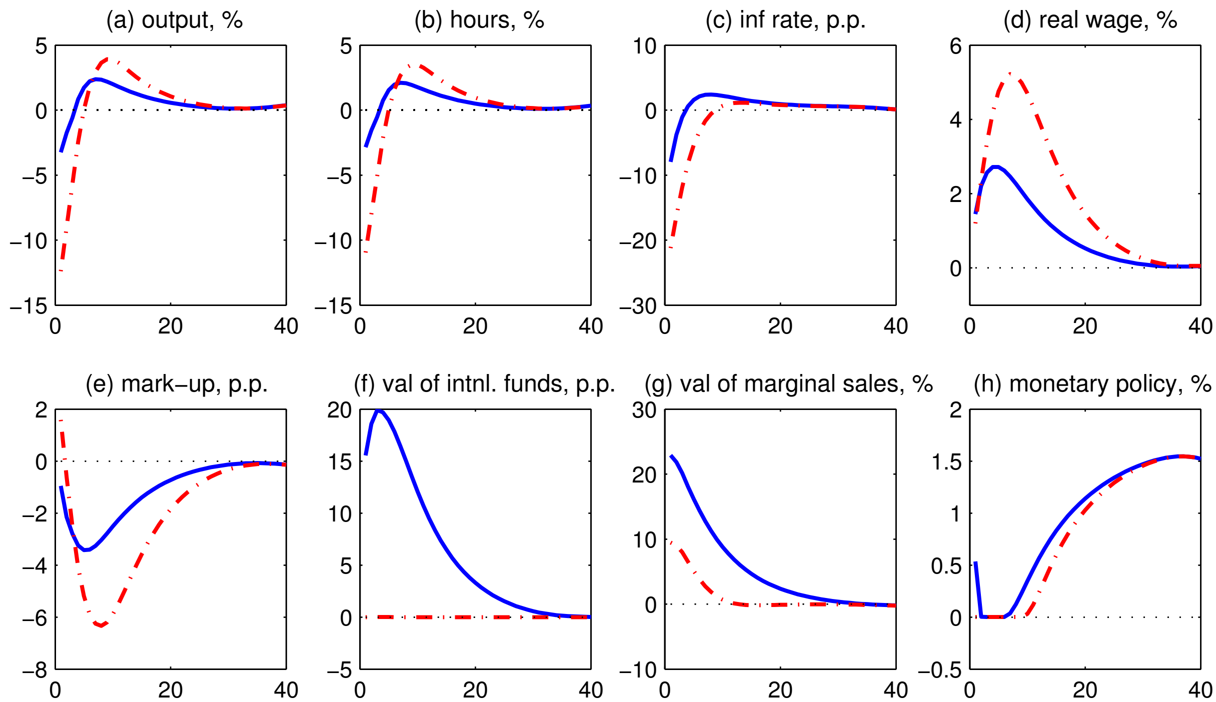

Figure 6: Impact of Discount Rate Shock: With (solid) and Without (solid-dot) Financial Friction

discounting factor of the agents is elevated for a certain number of periods exogenously before it comes down to a normal level. In particular, we assume the following shock process,

$$\beta_t = \bar{\beta} v_t, \quad \log v_t = \rho_v \log v_{t-1} + \epsilon_{t,v},$$

and set $\epsilon_{t,v} = 0.009$ for $t = 1, \ldots, 4$ and $\epsilon_{t,v} = 0.0$ for $t = 5, \ldots, \infty$. The consecutive shocks make the discounting rate shock linearly go up to 1.016 ("hyper-patience") at the 4th quarter and comes to down to the normal level thereafter.

Figure 6.3 displays the impact of such shocks for the baseline calibration. The figure shows very well how the binding ZLB could destroy our normal understanding of the economy. For the mechanism described in details earlir, the firms in the model economy with the financial friction are reluctant to cut their prices out of the concern for liquidity condition today. However, the firms in the frictionless economy take more aggressive stance: the prices are cut by 20 percent (a.r.) on the impact. Under the binding ZLB environment, which you can see in panel (h), this is translated into a massive increase in real interest rate, which then leads to a plunge in economic activity on the order of maginitude greater than 10 percent both in terms of output and hours. This suggests that once we are under the binding ZLB, a truly destabilizing force could be the aggressive price cuts by financially *stronger* firms attempting to drive out the competitors from the markets, simply put, the "bloodbath of pricing" and the "bloodbath on margins", to re-quote Mr. Marchionne.

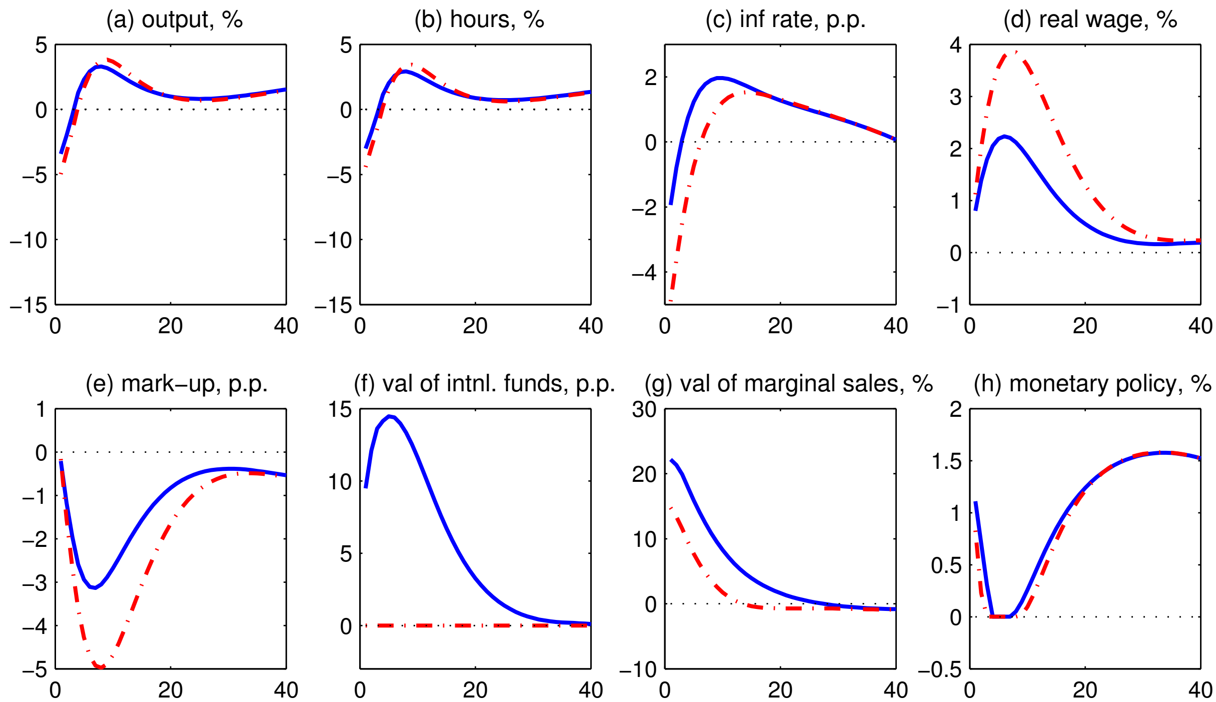

Figure 7: Impact of Discount Rate Shock with Substantially Greater Nominal Rigidity: With (solid) and Without (solid-dot) Financial Friction

In figure 7, we slightly tweak the experiment such that the economy gets the identical sequence of discounting rate shocks, but in an environment with 5 times greater nominal rigidity in terms of (nominal price and wage adjustment costs). The greater nominal rigidity makes it difficult for the firms to aggressively cut their nominal prices, and as a result, the deflationary force is much weaker than in our baseline calibration. This prevents the real interest rate from shooting up under the binding ZLB environment, and as a result, the recession is much milder. This means that in contrast to our intuition that a greater price flexibility leads to a better allocation of resources, a lack of flexibility can be a boon for the economy once you are under the binding ZLB.

7 Conclusion

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8 Tables

Table 2: Summary Statistics, Full and Matched PPI Sample

		Full PPI	Matched PPI Sample
Monthly Inflation			
	Mean	0.191%	0.185%
	Std. Dev.	0.183%	0.236%
	Median	0.205%	0.201%
Monthly Standard Deviation			
	Mean	4.495%	4.153%
	Std. Dev.	0.432%	1.284%
	Median	0.432%	1.284%
Monthly Inflation, Weighted			
	Mean	0.234%	0.218%
	Std. Dev.	0.728%	1.061%
	Median	0.728%	1.061%
Monthly Frequency of Price Changes			
	Mean	13.80%	17.12%
	Std. Dev.	1.08%	1.57%
	Median	13.88%	17.28%
Number of Firms			
	Mean	23167	772
	Std. Dev.	1429	95
	Median	23043	767

Table 3: Summary Statistics, COMPUSTAT and Matched Sample

		Full Sample	Matched Sample
Liquidity Ratio			
	Mean	0.193	0.147
	Std. Dev.	0.199	0.145
	Median	0.116	0.095
SGAX Ratio			
	Mean	0.175	0.065
	Std. Dev.	1.982	0.055
	Median	0.088	0.055
Interest Expense Ratio			
	Mean	0.026	0.004
	Std. Dev.	1.059	0.006
	Median	0.007	0.003
Sales			
	Mean	267.289	1514.051
	Std. Dev.	1615.47	5175.523
	Median	18.053	295.126
Total Assets			
	Mean	1227.422	6322.156
	Std. Dev.	6681.622	20856.896
	Median	84.053	1139.255
Total Cash			
	Mean	108.423	729.871
	Std. Dev.	620.438	2844.365
	Median	10.133	109.559
Number of Firms			
	Mean	4988	772
	Std. Dev.	2044	95
	Median	5655	767

9 Figures

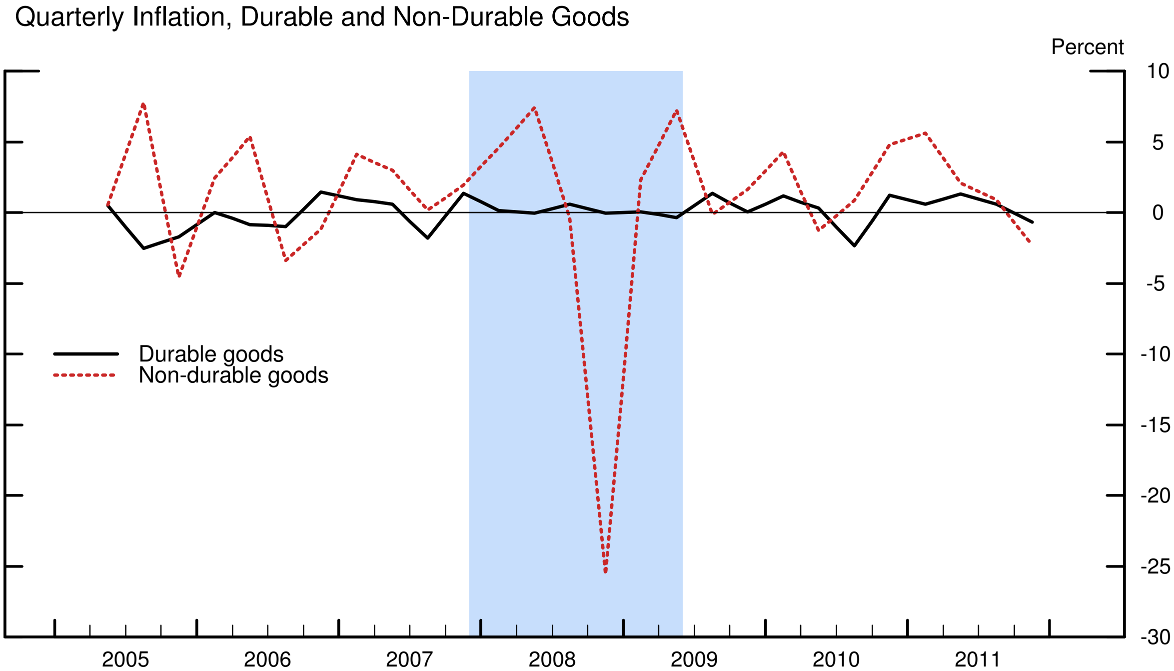
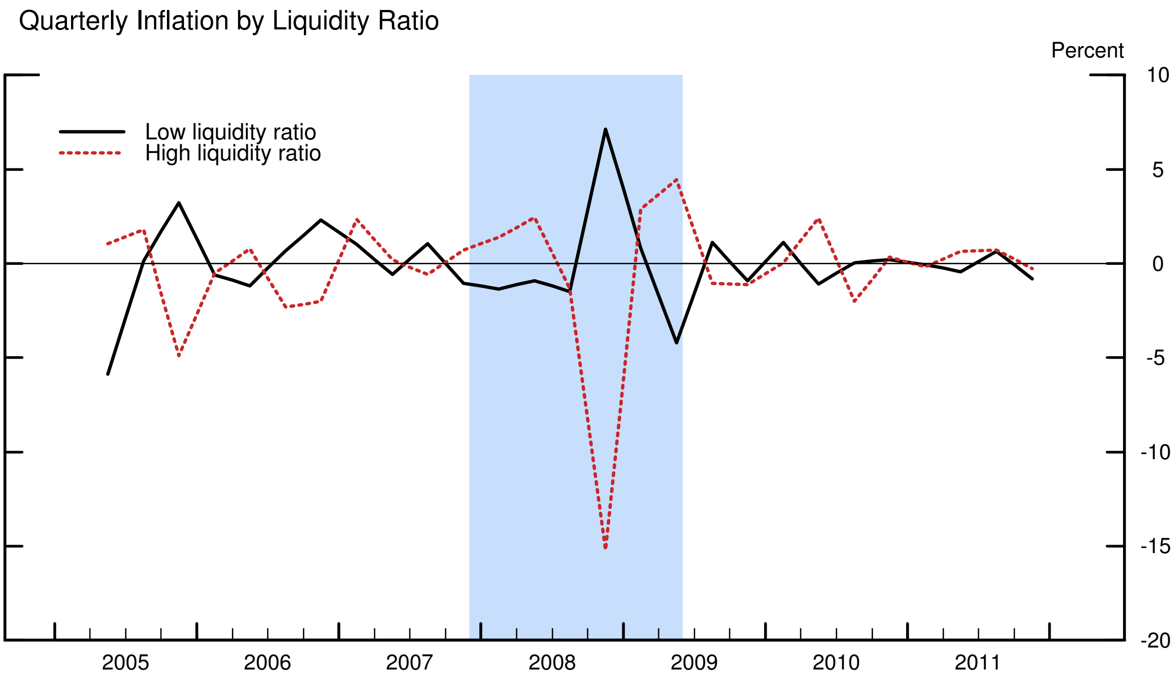


Figure 8: Quarterly Inflation Rates, Durable and Non-Durable Goods



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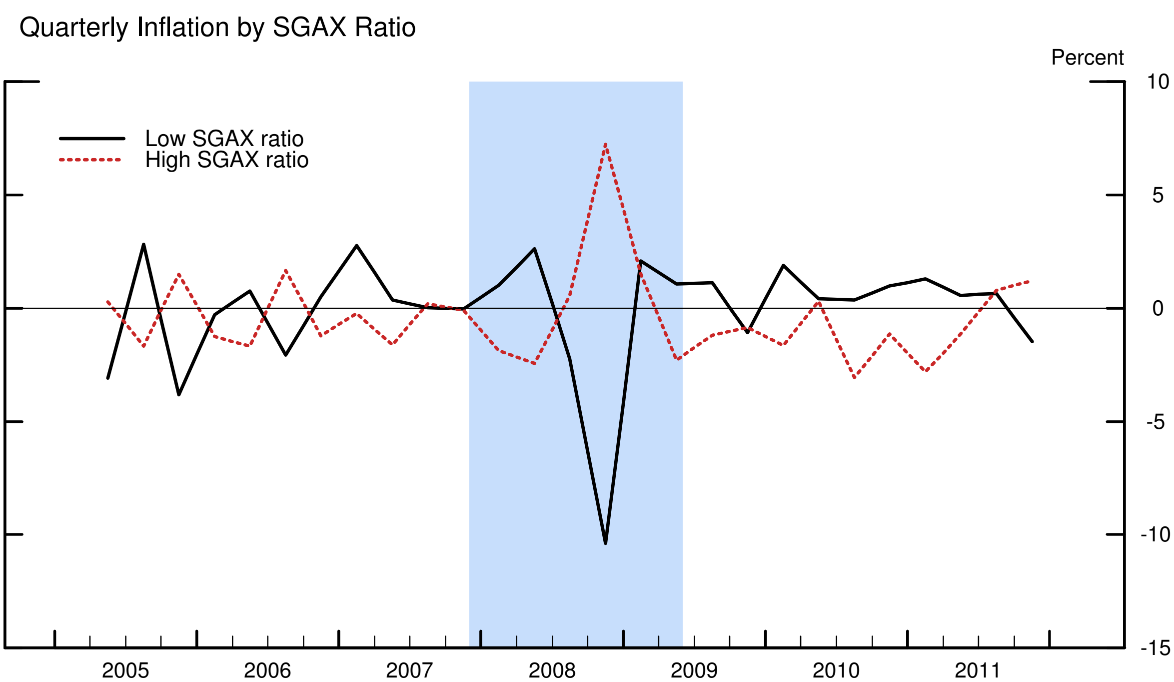

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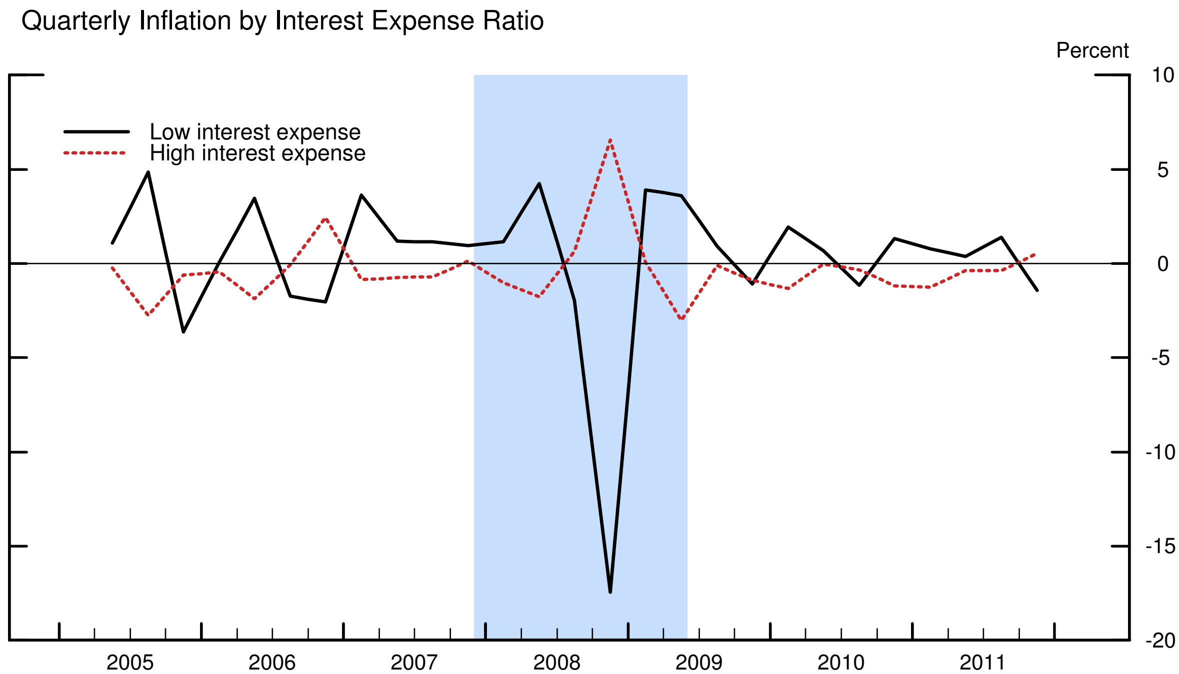

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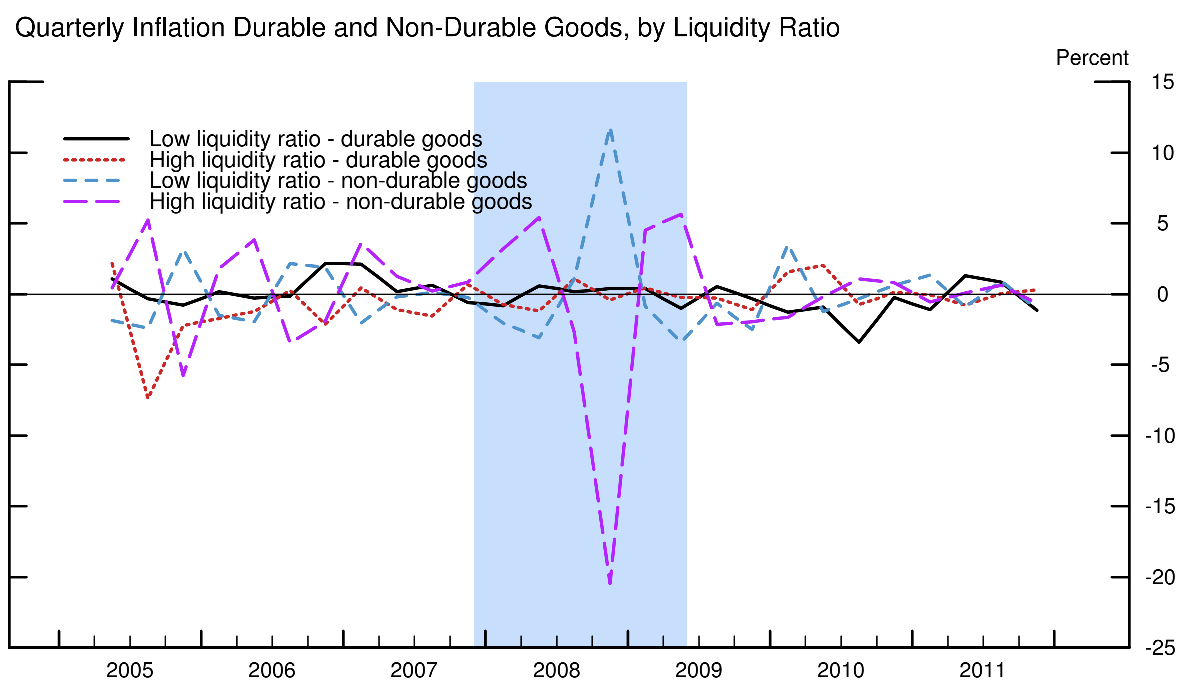

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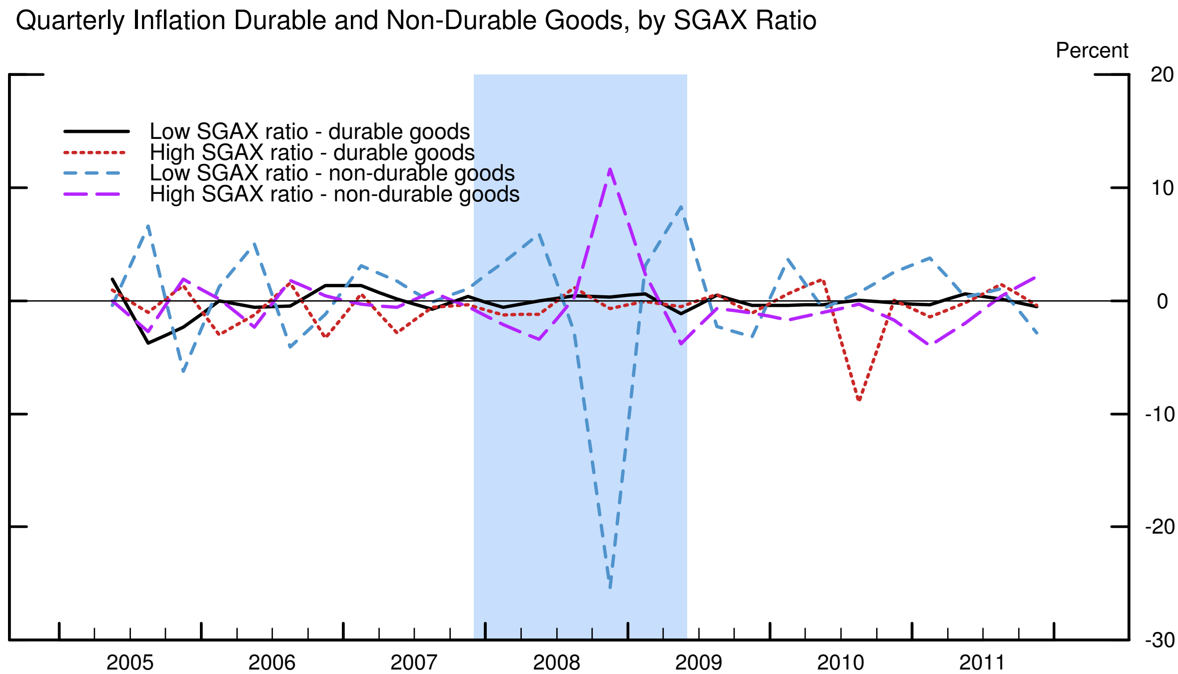

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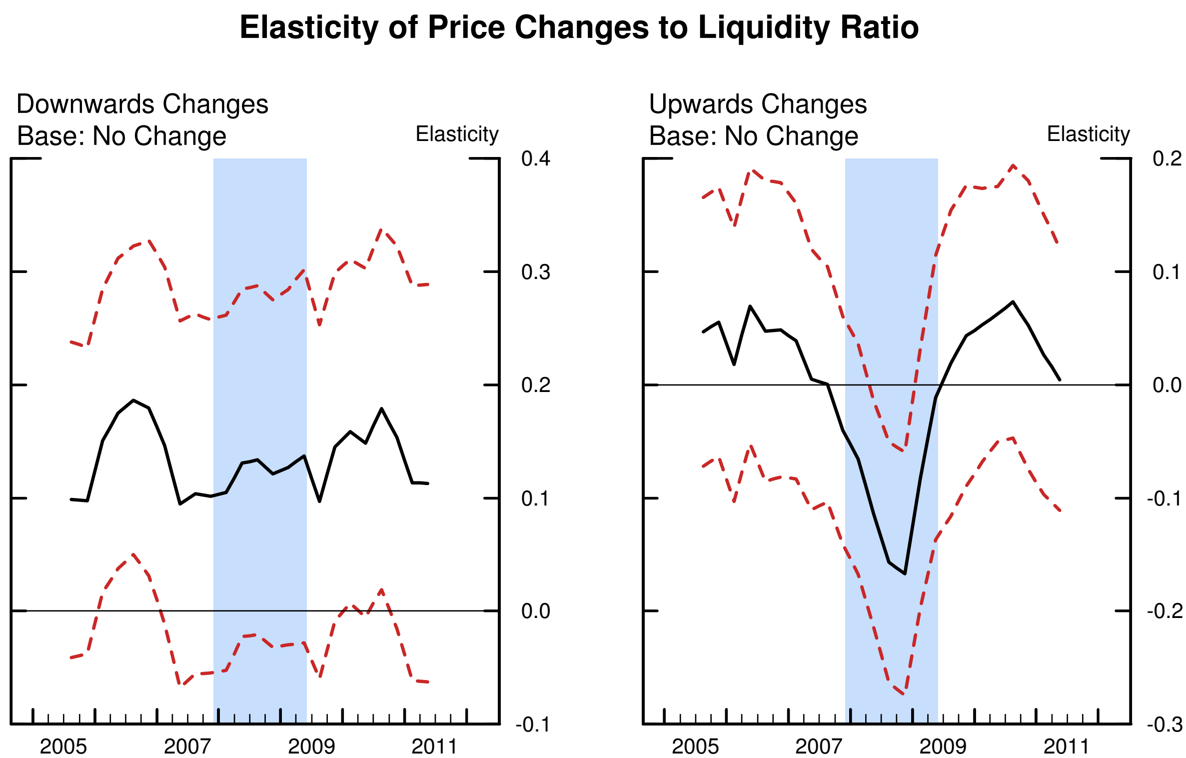

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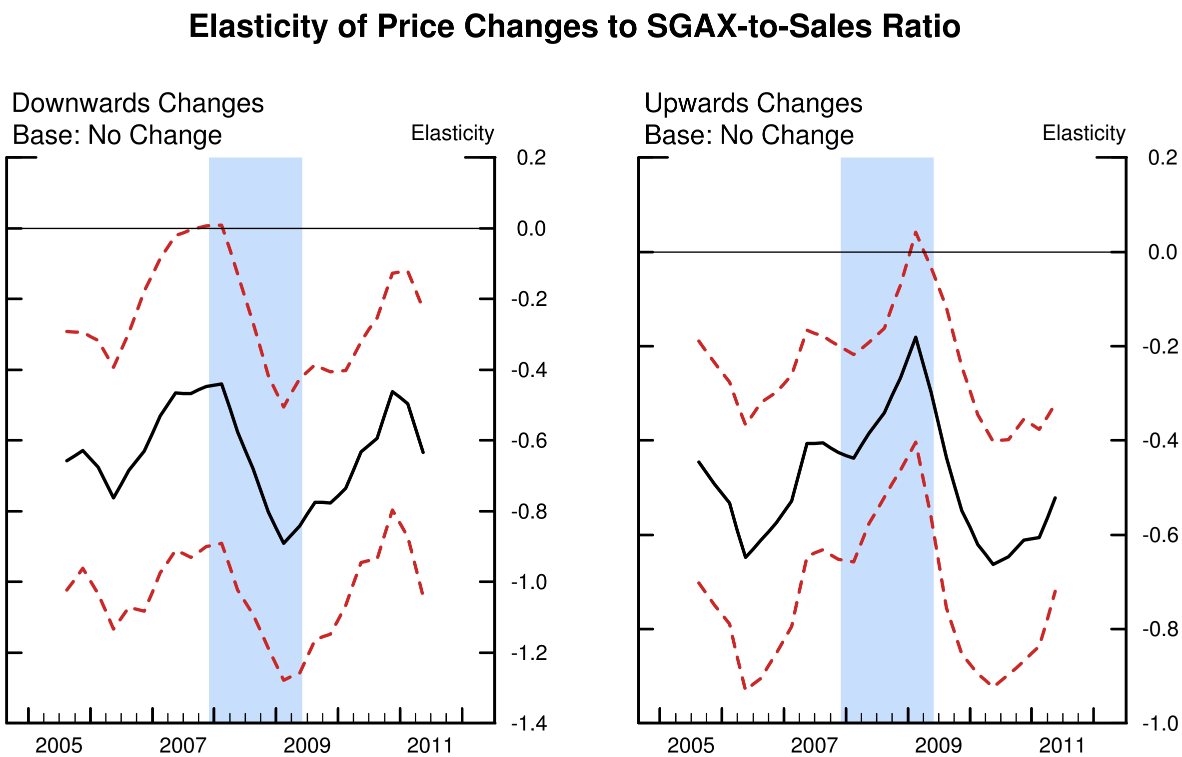
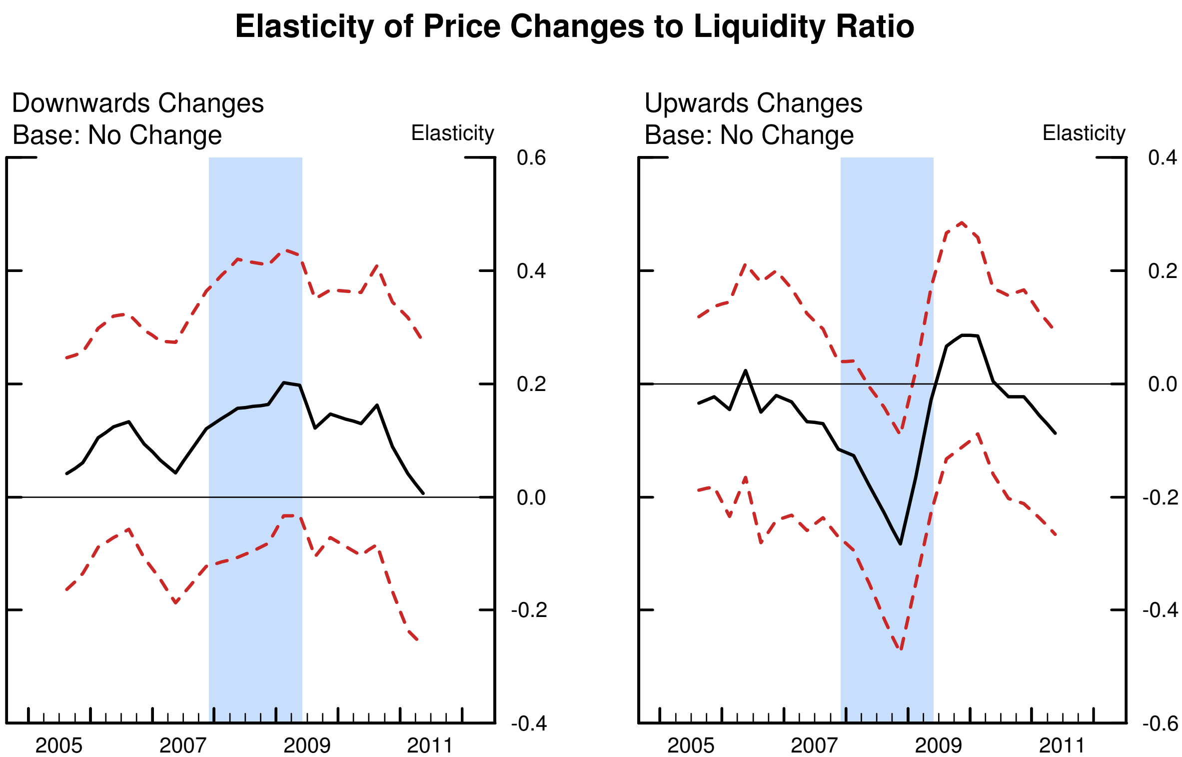


Elasticity of Price Changes to SGAX-to-Sales Ratio
Downwards Changes
Base: No Change
Elasticity
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
2005
2007
2009
2011
Upwards Changes
Base: No Change
Elasticity
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
2005
2007
2009
2011

Figure 15:



Elasticity of Price Changes to Liquidity Ratio
Downwards Changes
Base: No Change
Elasticity
0.6
0.4
0.2
0.0
-0.2
-0.4
2005
2007
2009
2011
Upwards Changes
Base: No Change
Elasticity
0.4
0.2
0.0
-0.2
-0.4
-0.6
2005
2007
2009
2011

Figure 16:

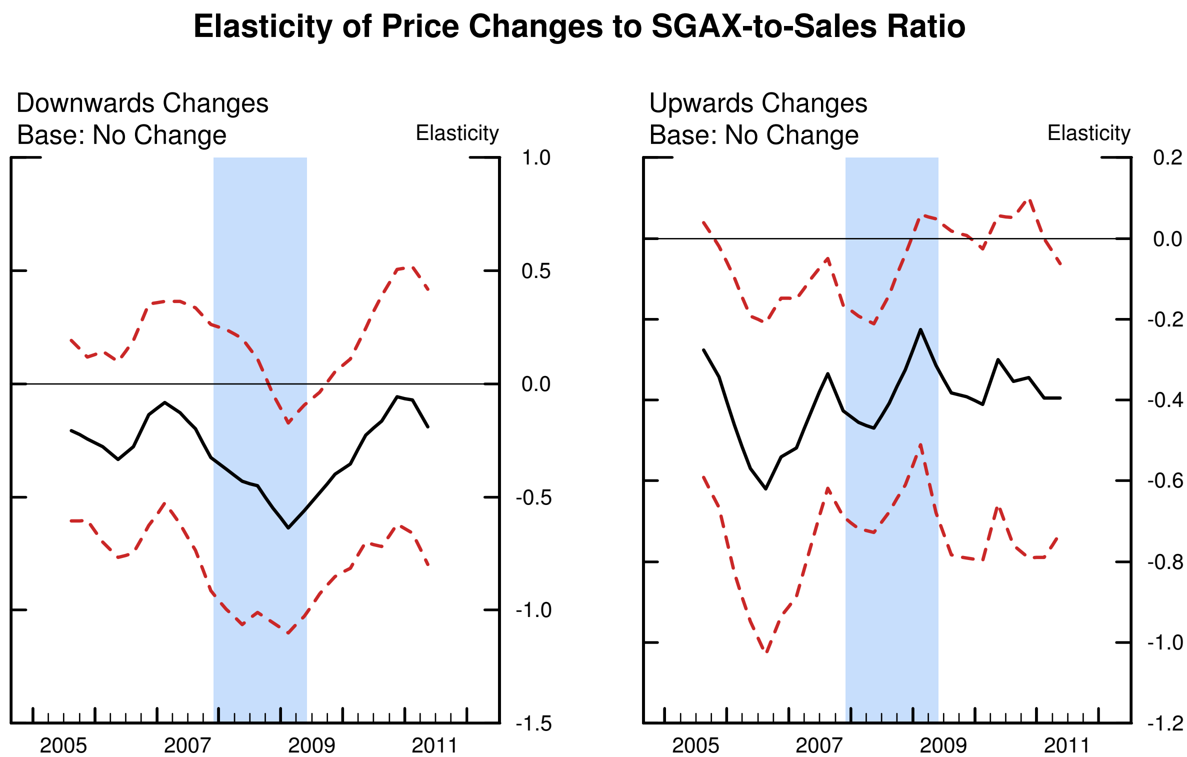
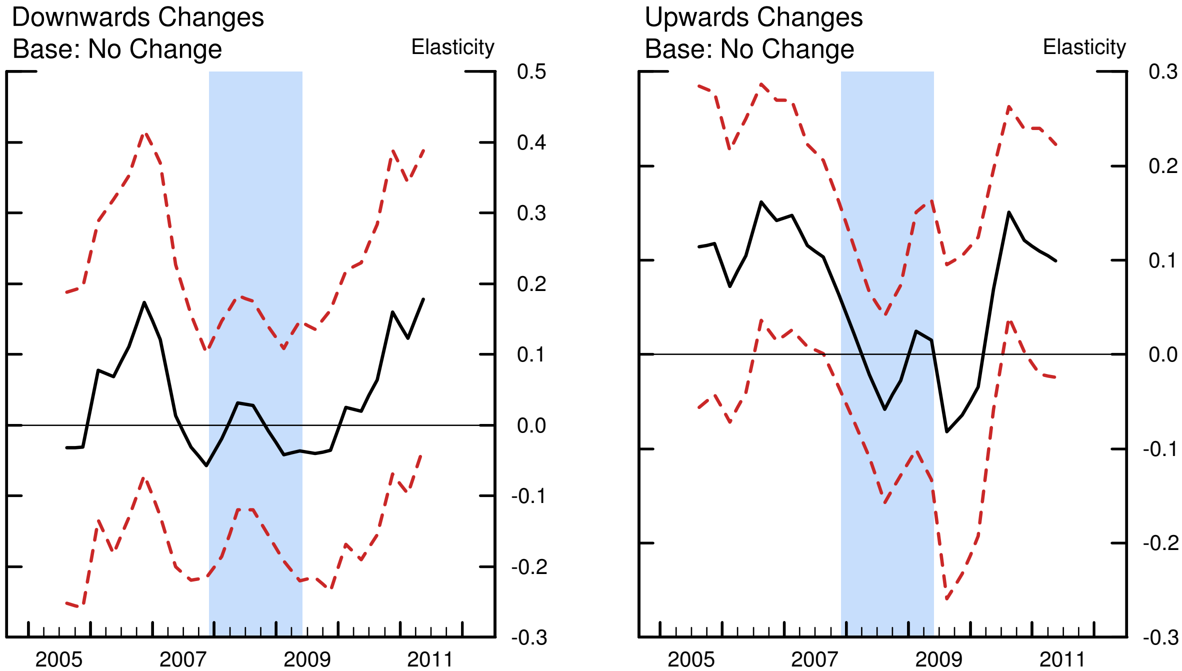

Elasticity of Price Changes to SGAX-to-Sales Ratio
Downwards Changes
Base: No Change
Elasticity
1.0
0.5
0.0
-0.5
-1.0
-1.5
2005
2007
2009
2011
Upwards Changes
Base: No Change
Elasticity
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
2005
2007
2009
2011

Figure 17:

Elasticity of Price Changes to Liquidity Ratio



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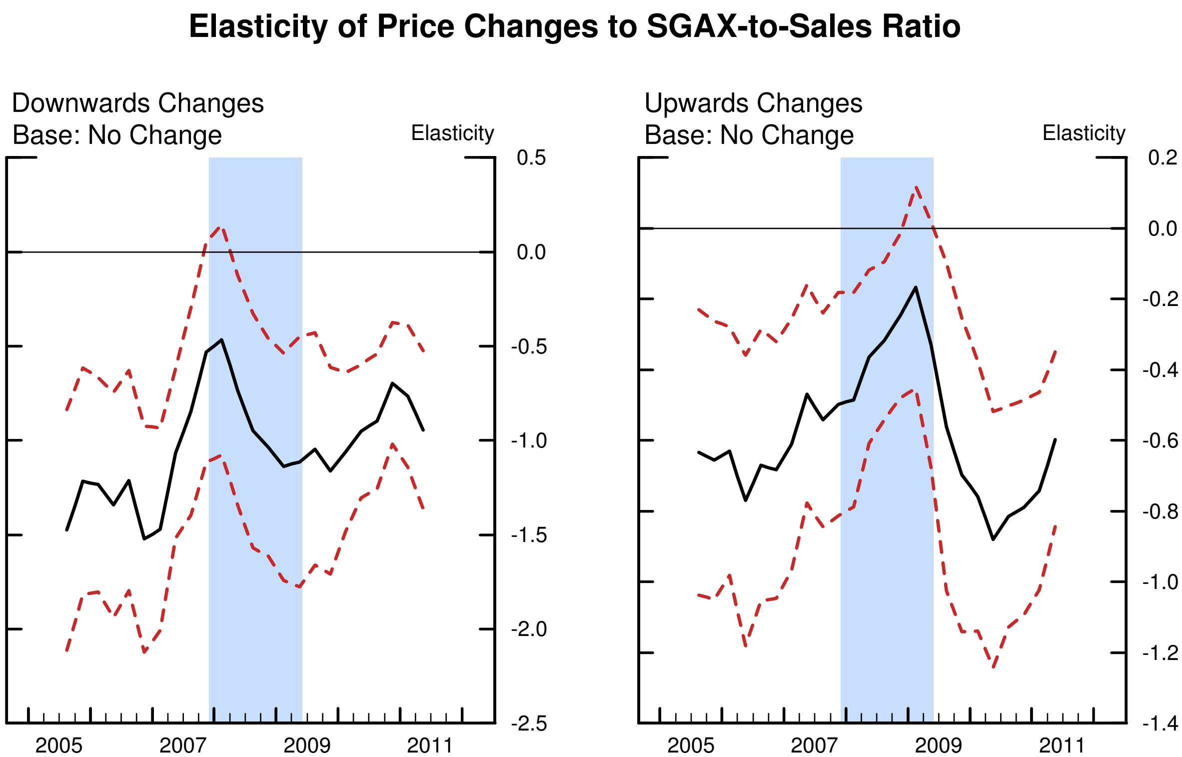

Elasticity of Price Changes to SGAX-to-Sales Ratio
Downwards Changes
Base: No Change
Elasticity
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
2005
2007
2009
2011
Upwards Changes
Base: No Change
Elasticity
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
2005
2007
2009
2011

Figure 19:

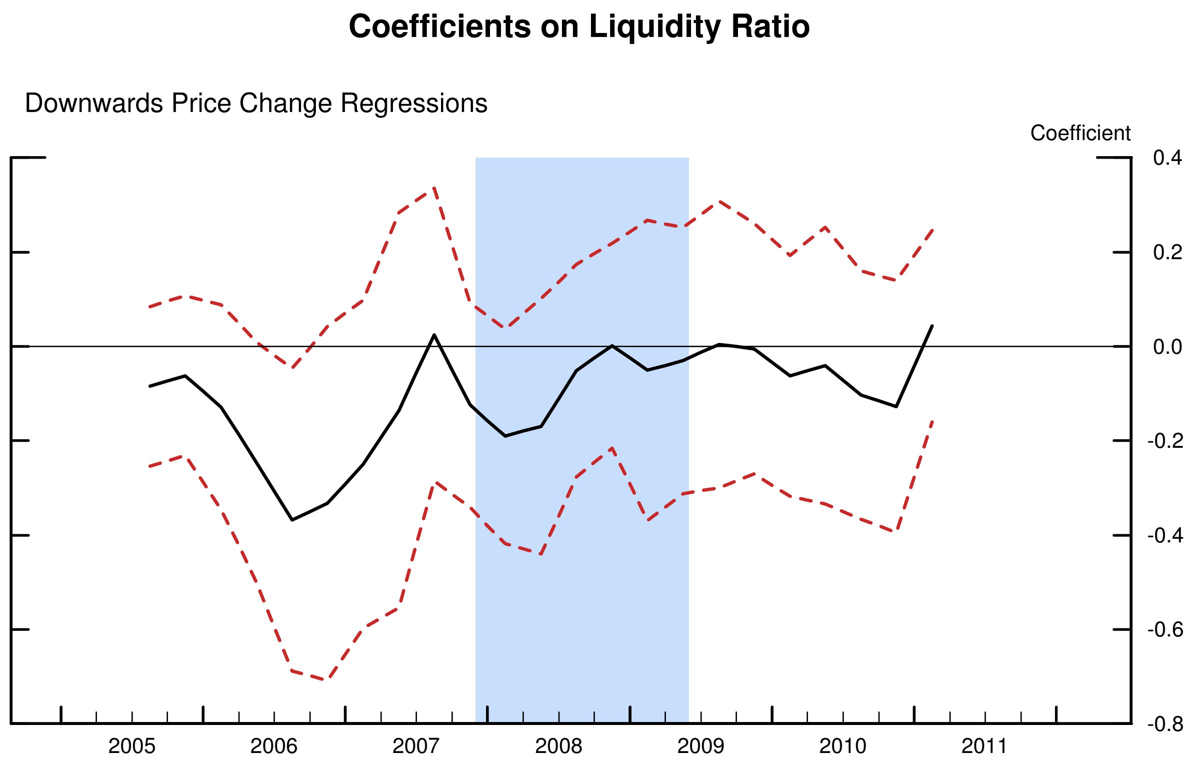
Coefficients on Liquidity Ratio
Downwards Price Change Regressions
Coefficient
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
2005
2006
2007
2008
2009
2010
2011

Figure 20:

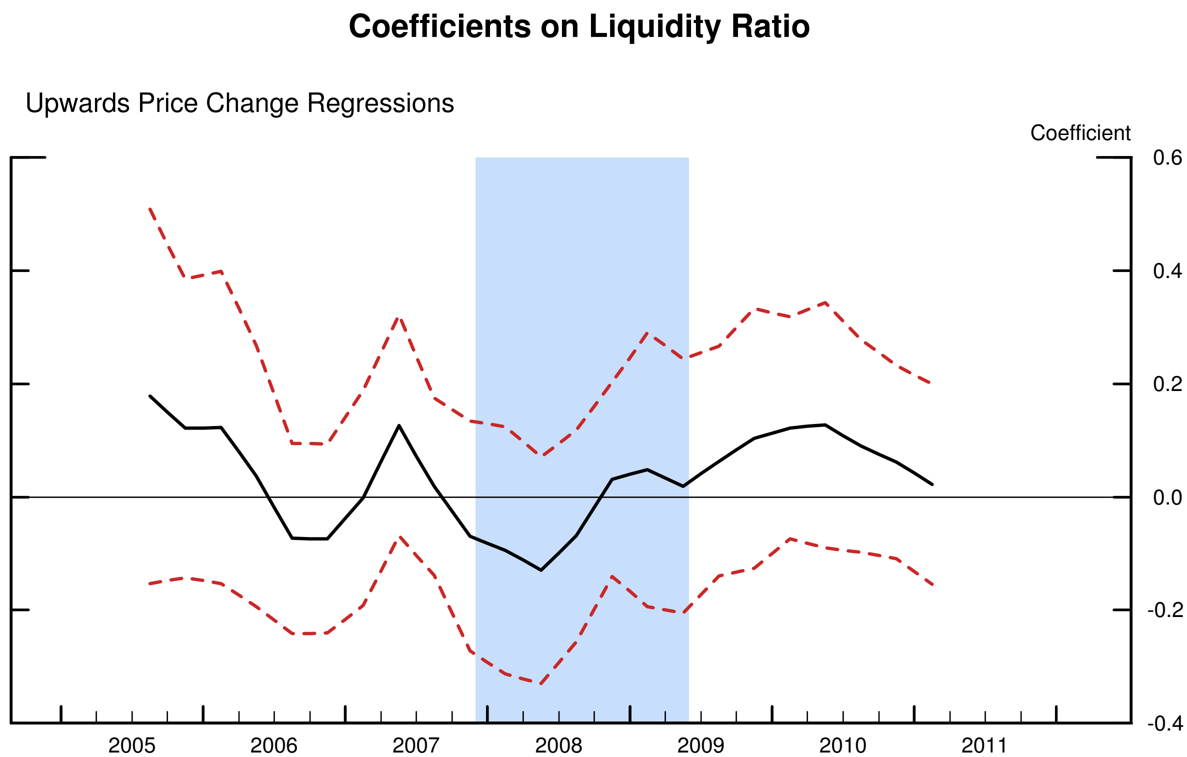
Coefficients on Liquidity Ratio
Upwards Price Change Regressions
Coefficient
0.6
0.4
0.2
0.0
-0.2
-0.4
2005
2006
2007
2008
2009
2010
2011

Figure 21:

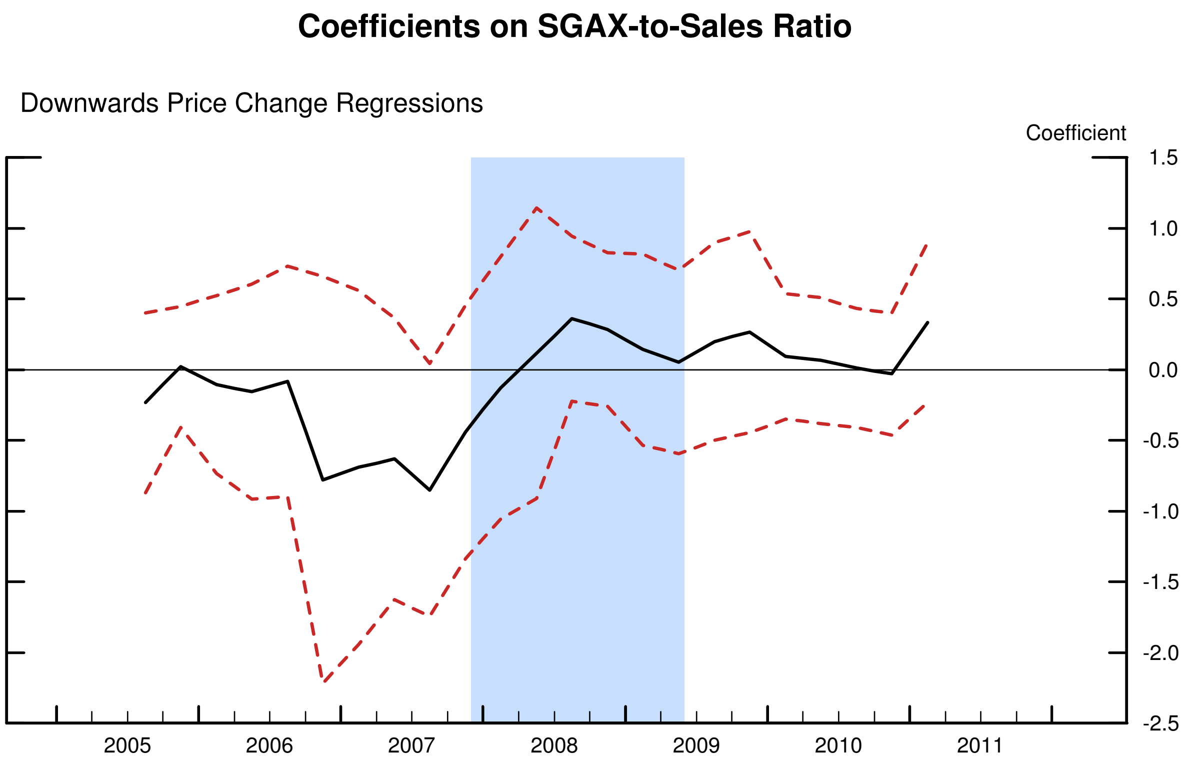
Coefficients on SGAX-to-Sales Ratio
Downwards Price Change Regressions
Coefficient
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
2005
2006
2007
2008
2009
2010
2011

Figure 22:

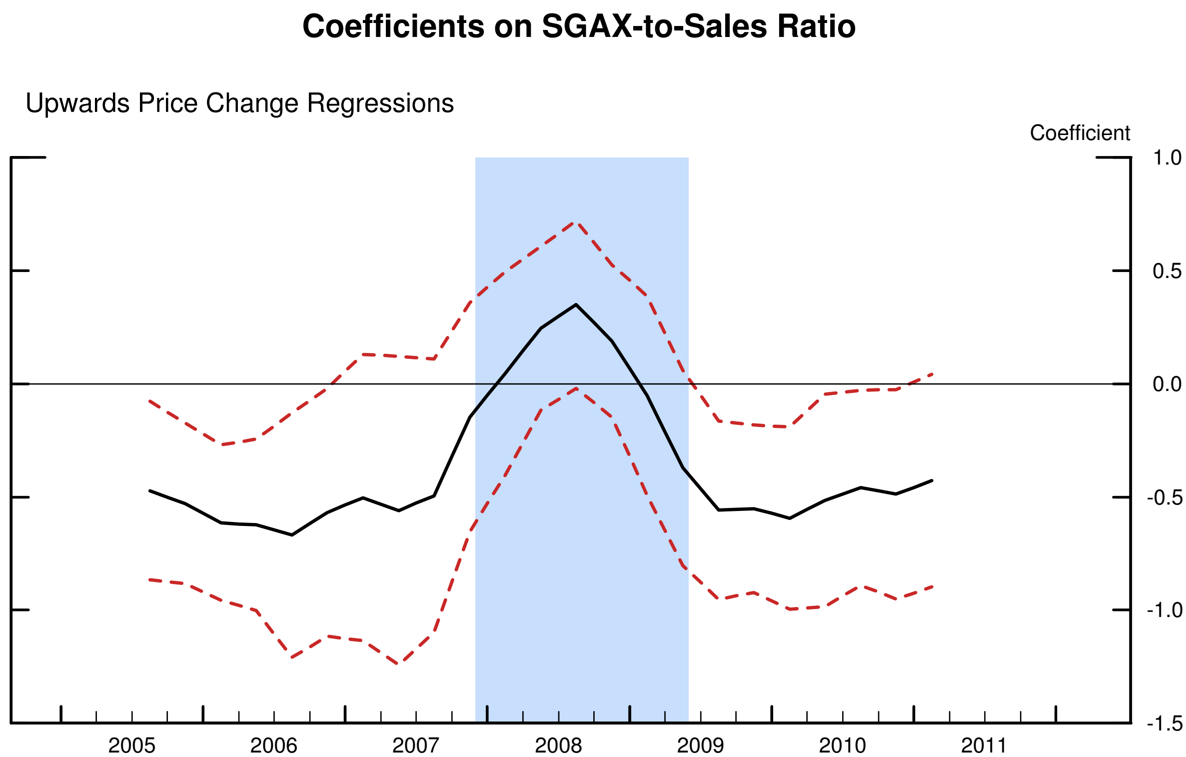
Coefficients on SGAX-to-Sales Ratio
Upwards Price Change Regressions
Coefficient
1.0
0.5
0.0
-0.5
-1.0
-1.5
2005
2006
2007
2008
2009
2010
2011

Figure 23:

Appendices

A Steady State (Not for Publication)

The Phillips curve in the steady state yields

$$\nu = \eta^{-1}\left[1 + \frac{\varphi}{1-\varphi}[1-\Phi(z)]\right]$$

The FOC with respect to s_{it} in the steady state yields

$$\lambda = \frac{\beta\theta(1-\eta)}{1-\rho\beta}\nu.$$

From the FOC with respect to c_{it} in the steady state, we have

$$\nu = 1 + \frac{\varphi}{1-\varphi}[1-\Phi(z)] - \frac{1}{\mu}\left[1 + \frac{\varphi}{1-\varphi}[1-\Phi(z-\sigma)]\right] + (1-\rho)\lambda.$$

Combining the three relationships, we reach

$$\begin{aligned}\eta^{-1}\left[1 + \frac{\varphi}{1-\varphi}[1-\Phi(z)]\right] \quad &= \quad \frac{1-\rho\beta}{1-\rho\beta-\beta\theta(1-\eta)(1-\rho)} \\ &\quad \times\left\{1 + \frac{\varphi}{1-\varphi}[1-\Phi(z)] - \frac{1}{\mu}\left[1 + \frac{\varphi}{1-\varphi}[1-\Phi(z-\sigma)]\right]\right\}.\end{aligned} \tag{29}$$

The definition of the equity issuance threhold shock in the steady state implies that

$$z = \frac{1}{\sigma}\left[\log\left(\mu\frac{\exp(\sigma^2)h-\phi}{\exp(\sigma^2)h}\right) + 0.5\sigma^2\right]. \tag{30}$$

Solving this for μ, we obtain

$$\mu = \frac{\exp(\sigma z + 0.5\sigma^2)h}{\exp(\sigma^2)h - \phi}. \tag{31}$$

From the FOCs of the household in the steady state and $w = 1/\mu$, we have

$$\frac{1}{\mu} = \zeta\tilde{p}\frac{h^{\gamma_h}}{x^{-\gamma_x}} = \zeta h^{\gamma_h}c^{\gamma_x(1-\theta)+\theta} \tag{32}$$

where the second inequality uses $\tilde{p} = s^\theta = c^\theta$ and $x = c/s^\theta = c^{1-\theta}$ in the steady state. From the resource constraint, we obtain the steady state hours as $h = (c+\phi)/\exp(\sigma^2)$.[13] Substituting this in (29), (31), and (32), one can solve these three nonlinear equations for c, μ and z using a numerical root finder.

In contrast to Ravn, Schmitt-Grohe, and Uribe (2006) and other canonical New Keynesian models, the mark-up over marginal cost (μ) is not fully determined by the parameters of preference and technology: the equilibrium mark-up is a function of external financing premium (φ). The first panel of figure **??** describes the relationship between the external financing premium on the

[13] The aggregate resource constraint, $c = \mathbb{E}_t^a[1/a_{it}]h - \phi$ can be evaluated using the fact that $1/a_{it}$ follows a lognormal distribution, $-\log a_{it} \sim N(0.5\sigma^2, \sigma^2)$, and hence, $\mathbb{E}_t^a[1/a_{it}] = \exp(\sigma^2) > 1$, where the last inequality shows the effect of Jensen's inequality.

horizontal axis and the mark-up on the vertical axis.[14] As can be seen, the equilibrium mark-up is an *increasing* function of external financing premium.

The second panel of the figure shows that the value of internal funds increases with the amount of external financing premium. This means that the greater the financing friction is facing the firm, the more sensitive to the current cash-flow is its pricing decision. Since the value of marginal sales is proportional to the shadow value of internal funds, i.e.,

$$\nu = \eta^{-1}\mathbb{E}^{a}[\zeta_i] = \eta^{-1}\left[1 + \frac{\varphi}{1-\varphi}[1-\Phi(z)]\right]$$

the positive relationship of the external financing premium with the value of internal funds also implies a positive relationship with the value marginal sales.ftbpFO5.7449in3.0796in0ptExternal Financing Cost, Equilibrium (Marginal) Mark-Up and Value of Internal Fundsssss.eps

The positive relationship between the external financing cost and the mark-up has an important implication. To the extent that the external financing cost is countercyclical, the positive relationship in the figure implies that the mark-up is highly countercyclical, adding another mechanism for countercyclical mark-up as in Chevalier and Scharfstein (1996b). We will analyze the short run dynamics of the model under a financial shock that raises the cost of external financing using a perturbation

B System of Equations

There are 18 endogenous variables:

$$X_t = [s_t, c_t, x_t, \tilde{p}_t, y_t, h_t, \pi_t, A_t, w_t, p_t^S, m_{t-1,t}, \tilde{d}_t, z_t, \bar{a}_t, \mu_t, \nu_t, \lambda_t, r_t].$$

[14]To show this, we allocate 5,001 points on the interval $[0, 0.5]$ on the horizontal axis, and numerically solve for equilirbrium margin for each point in the interval using (29) and (30).

Corresponding to these are the following 18 equations.

$$
\begin{aligned}
s_t &= \rho s_{t-1} + (1-\rho)c_t \\
x_t &= \frac{c_t}{s_{t-1}^{\theta}} \\
\tilde{p}_t &= s_{t-1}^{\theta} \\
y_t &= A_t^{\alpha} \exp(0.5\alpha(1+\alpha)\sigma^2) h_t^{\alpha} - \phi \\
c_t &= y_t - \frac{\gamma}{2}(\pi_t - \bar{\pi})^2 c_t \\
\ln A_t &= \rho_A \ln A_{t-1} + \epsilon_{A,t} \\
\delta_t &= \rho_\delta \delta_{t-1} + \epsilon_{\delta,t} \\
\frac{w_t}{\tilde{p}_t} &= -\frac{U_h(x_t - \delta_t, h_t)}{U_x(x_t - \delta_t, h_t)} \\
1 &= \mathbb{E}_t[m_{t,t+1}(1+r_t)] \\
p_t^S &= \mathbb{E}_t[m_{t,t+1}(\tilde{d}_{t+1} + p_{t+1}^S)] \\
m_{t-1,t} &= \beta \frac{U_x(x_t - \delta_t, h_t)}{U_x(x_{t-1} - \delta_{t-1}, h_{t-1})} \frac{\tilde{p}_{t-1}}{\tilde{p}_t} \\
\tilde{d}_t &= \left\{1 + \frac{\varphi}{1-\varphi}[1-\Phi(z_t)]\right\} \left[1 - \frac{\gamma}{2}(\pi_t - \bar{\pi})^2\right] c_t \\
&\quad - \left\{1 + \frac{\varphi}{1-\varphi}[1-\Phi(z_t - \sigma)]\right\} (c_t + \phi)^{1/\alpha} \frac{w_t}{A_t} \\
z_t &= (\log \bar{a}_t + 0.5\sigma^2)/\sigma \\
\bar{a}_t &= \mu_t \frac{c_t}{\alpha(\phi + c_t)} \left[1 - \frac{\gamma}{2}(\pi_t - \bar{\pi})^2\right] \\
\mu_t &= \alpha \frac{A_t}{w_t}(c_t + \phi)^{(\alpha-1)/\alpha} \\
\nu_t &= -\left[1 + \frac{\varphi}{1-\varphi}[1-\Phi(z_t - \sigma)]\right] \frac{1}{\mu_t} + 1 + \frac{\varphi}{1-\varphi}[1-\Phi(z_t)] + (1-\rho)\lambda_t \\
\lambda_t &= \rho \mathbb{E}_t[m_{t,t+1}\lambda_{t+1}] + \theta(1-\eta)\mathbb{E}_t\left[m_{t,t+1}\nu_{t+1}\frac{c_{t+1}}{s_t}\right] \\
1 &= \frac{\eta \nu_t}{1 + \varphi/(1-\varphi)[1-\Phi(z_t)]} + \gamma \pi_t (\pi_t - \bar{\pi}) \\
&\quad - \gamma \mathbb{E}_t \left\{ m_{t,t+1} \left[\frac{1 + \varphi/(1-\varphi)[1-\Phi(z_{t+1})]}{1 + \varphi/(1-\varphi)[1-\Phi(z_t)]}\right] \pi_{t+1} (\pi_{t+1} - \bar{\pi}) \frac{c_{t+1}}{c_t} \right\} \\
r_t &= (1 + r_{t-1})^{\rho_r} \left[(1+\bar{r}) \left(\frac{y_t}{y_t^*}\right)^{\rho_y} \left(\frac{\pi_t}{\pi_t^*}\right)^{\rho_\pi}\right]^{1-\rho_r} - 1
\end{aligned}
$$

Note that this appendix is written assuming that the monetary authority is responding to output cap as well. If this is the case, one needs to update the natural output y_t^*, which is taken as exogenous by the agents in the model. To update y_t^* endogenously, the computational program must have the equations and variables corresponding to the flexible price system, where the Phillips curve is replaced by

$$\nu_t^* = \eta^{-1} \left[1 + \frac{\varphi}{1-\varphi}[1 - \Phi(z_t^*)]\right]$$

and the monetary policy is replaced by $\pi_t^* = 1$. Finally, the resource constraint is simplified into $c_t^* = y_t^* = A_t \exp(\sigma^2) h_t^* - \phi$. The only link between the two systems (sticky and flexible) is provided by the monetary policy under the nominal rigidity. This closes the model.