

Inflation Dynamics during the Financial Crisis*

Simon Gilchrist, Raphael Schoenle, Jae Sim, Egon Zakrajsek[†]

December 26, 2012

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: E31, E32, E44

Keywords: U.S. Producer Price Inflation, Customer Markets, Financial Frictions.

– PRELIMINARY AND INCOMPLETE –

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 (Bils (1989)). As discussed by Gottfries (1991); Bucht et al. (2002), and Chevalier and Scharfstein

*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.

[†]Gilchrist: Boston University (sgilchri@bu.edu). Schoenle: Brandeis University (schoenle@brandeis.edu). Sim: Federal Reserve Board (jae.w.sim@frb.gov). Zakrajsek: Federal Reserve Board (Egon.Zakrajsek@frb.gov).

(1996), 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 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. Our 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 with weak balance sheets became more likely to increase prices during the financial crisis, and, 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 deter-

¹Christiano et al. (2001) and Christiano et al. (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.

mination 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 of the response of prices to contractionary demand shocks. Moreover, in a calibration in which external finance is extremely costly, as was likely during the depth of the 2008 financial crisis, our model implies that inflation rises rather than falls in response to contractionary demand shocks. These results are consistent with the apparent lack of significant deflationary pressure during the recent recession. These findings also suggest that financial factors may help explain sluggish price responses more generally.

We also consider the model's implication for output and inflation at the zero lower bound (ZLB). In the model with financial frictions, the lack of deflationary pressure implies that the ZLB is both harder to achieve, and when achieved, the economy is likely to exit the zero lower bound sooner. Moreover, the sharp contractionary nature of a deflationary spiral at the zero lower bound is mitigated to a great degree by the presence of financial distortions. This suggests that in a customer markets model, financial frictions may paradoxically improve overall economic outcomes in an environment where the zero lower bound is likely to bind. This echoes recent findings of Denes et al. (2013); Eggertsson (2011) that certain forms of taxation may improve economic outcomes in situations where the zero lower bound is binding.

As in the recent work of Gourio and Rudanko (2011), in our model the customer base is a form of investment. The investment literature has long emphasized the notion that financial distortions may create a debt-overhang problem that leads firms to pass up otherwise positive net present value projects (Myers (1977)). The presence of financial distortions may similarly influence the incentive to invest into customers via price reductions. The empirical investment literature has thoroughly explored the extent to which the sensitivity of investment spending to financial conditions (Fazzari et al. (1988), Chirinko (1993) and Gilchrist and Himmelberg (1995)). Our model implies a similar sensitivity to price-setting – when cash flow is low or financial frictions are severe, firms will “disinvest” by maintaining high prices. Our model also echoes the theoretical insights of Chevalier and Scharfstein (1996) regarding the role of financial market friction on variations in the mark-up, but generalizes their results to a fully dynamic general equilibrium setting. Finally, our model can be viewed as a special application to New Keynesian pricing theory of liquidity-based asset pricing (LAPM, Holmstrom and Tirole (2001)).

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 level of the firm. 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 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 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

²The 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).

firm.

We emphasize that we focus on the PPI data as opposed to consumer price (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 $\pi_{j,k,t}$ is given by the weighted quarterly average price changes of goods in each firm, after filtering out quarterly two-digit NAICS, inflation rates $\pi_{k,t}$:

$$\pi_{j,k,t} = \frac{1}{n_j} \sum_{i=1}^{n_j} w_{i,j,k,t} (\Delta p_{i,j,k,t} - \pi_{k,t}) \quad (1)$$

where $\Delta p_{i,j,k,t}$ denotes quarterly log price changes for each good i in firm j and sector k for a specific quarter t , and n_j the number of goods in a firm.³ 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 but no filtering.

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 $w_{i,j,k,t}$ as follows:

$$w_{i,j,k,t} = \bar{w}_{i,j,k,t} \omega_{j',t} \quad (2)$$

where $\bar{w}_{i,j,k,t}$ denotes the item relative weight for good i in firm j in sector k according to the BLS

³Note that taking out “industry inflation” does not take into account the weight assigned to each industry for a firm if the firm operates across multiple industries. This is not a problem for our data. The reason is the the BLS defines firms as price-setting units in one production unit, which is usually unique to a NAICS code, especially at 2-digit level of filtering. We drop the handful of cases where a firm operates across multiple industries.

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 used in the analysis 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:

$$LIQ_{j,t} = \frac{\text{Cash and other Liquid Assets}_{j,t}}{\text{Total Assets}_{j,t}} \quad (3)$$

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.⁴

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,⁵ 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 an SGAX ratio relative to total sales. As an alternative normalization, we use total assets since they do not fluctuate as much.

⁴Other widely used indicators to measure the degree of financial frictions faced by firms include the dividend payout behavior (Carpenter et al. (1994)); firm size (Gertler and Gilchrist (1994) and Carpenter et al. (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)).

⁵See for example Gottfries (1991); Bucht et al. (2002), Chevalier and Scharfstein (1996), Klemperer (1987, 1995), Bils (1989), Bagwell (2004), and Gourio and Rudanko (2011)

2.3 Matched Sample

One contribution of this paper 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 described by Schoenle (2010). The algorithm works by running a fuzzy matching of the names of firms in the PPI and Compustat databases.⁶ 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.

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 2 summarizes these results. When we plot the series of aggregate monthly PPI inflation rates in Figure 7, 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

In this section, we establish three facts about price-setting in the aggregate economy, firm financial conditions, and investment into customers. First, we show that firms substantially increased their prices during 2008 Q3 if they were financially constrained, or invested into their customer base. If they were not constrained or not invested into their customers, they substantially decreased

⁶The 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.

their prices during that period. Second, while we confirm the conventional wisdom for example from Bils et al. (2012) that the 2008-2009 inflationary dynamics were mainly driven by non-durable goods, we show that the dynamics of non-durable good prices are in fact again determined by our firm variables. Third, we show that firms with low investment into their customer base generally change their prices relatively less frequently than firms with high investment into their customer base, consistent with Blinder et al. (1998). However, during the crisis, they become relatively less likely to adjust upwards and more likely to adjust downwards.

3.1 Inflation Dynamics

First, our results show a substantial impact of both financial conditions of firms and investment into customers on aggregate inflation dynamics. We find that firms with a high liquidity ratio lowered their prices by 15 percentage points in 2008 Q3 while those with a low liquidity ratio increased prices by 5 percentage points, relative to the sectoral means. Similarly, firms with high investment into their customer base increased their prices by 5 percentage points during that quarter, while those with low investment into their customer base lowered their prices by 10 percentage points. Thus, the differential inflation rate between firms with high and low liquidity (SGAX-to-sales) ratios is on the order of 20 (15) percentage points. If we believe that the financial crisis represents an exogenous shock to non-financial, good-producing firms in the PPI, then this strongly suggests a causal interpretation of these facts.⁷ We present these results graphically in Figure 8 for the liquidity ratio in panel 8(a), and for the SGAX-to-sales ratio in panel 8(b).

We arrive at the results in these figures in the following way: First, we compute firm-level inflation rates as in equation (1), which filters out two-digit NAICS, quarterly inflation. Then, we group firms as having a liquidity ratio (SGAX-to-sale) ratio below and above the median values of their distribution. We compute rolling medians and a lag of 3 months to allow prices to react to the relevant past information, and to strengthen the case for causality. We identify good (bad) financial condition firms as firms with a liquidity ratio above (below) the sample median in the prior quarter. Similarly, we identify firms with high (low) investment into their customer base as firms with an SGAX-to-sales ratio above (below) the sample median in the prior quarter. Fi-

⁷This should hold especially true for good-producing firms in 2008 Q3 because we condition on three-month lagged firm information.

nally, we compute aggregate inflation in each grouping as weighted quarterly means of firm-level inflation.⁸

We emphasize that the results in Figure 8 are difficult to justify in the standard price-adjustment paradigm emphasized in the New Keynesian literature and underlying neoclassical models that do not allow for an important role for financial conditions to influence price-setting. Generally, we would expect that firms hit by an adverse demand shock should lower their prices. This should hold especially for firms with low liquidity ratios since they are likely to experience particularly weak demand conditions. Such firms should reduce their prices by more than the high-liquidity ratio firms during the crisis. However, we observe the opposite reaction in the data.

3.2 Durable and Non-Durable Good Inflation

Second, we find that the deflationary dynamics in the 2008-2009 crisis commonly attributed to the dynamics of non-durable goods such as in Bils et al. (2012) appear to be largely due to the dynamics of firms with solid financial conditions and low investment into customers within the non-durable good sector.

While we verify in Figure 9 that the fall in producer prices during the crisis indeed took place in non-durables, our new empirical finding is that these dynamics of non-durable good prices are in fact driven by our firm variables. We show this in Figure 10 panel 10(a) for the case of the liquidity ratio and non-durable good producers: firms with a high liquidity ratio in the non-durable sector lowered their prices by 20 percentage points during the crisis, relative to sectoral means. At the same time, firms with a low liquidity ratio in the non-durable sector increased their prices by more than 10 percentage points. There is no substantial inflation differential for high and low liquidity ratio firms in the durable good sector, though the directions of change both have the right signs.

As shown in panel 10(b), we obtain the same patterns when we condition inflation dynamics on high and low investment into customer base. Firms with a high SGAX-to-sales ratio increased their prices by more than 10 percentage points. Firms with a low SGAX-to-sales ratio lowered their prices by more than 20 percentage points. Note that our results hold even after we have

⁸We use as weights average sales of each firm f relative to total average sales in grouping g :

$$w_{f,g} = \frac{\bar{S}_{f,g}}{\sum_f \bar{S}_{f,g}} \quad (4)$$

filtered out two-digit NAICS, quarterly inflation from good-level inflation before aggregating to firms and each category of liquidity and durability.

The fact that non-durable good inflation during the crisis appears to be driven by financial and customer-market concerns of firms may have important implications for modeling. Recent work by Barsky et al. (2007) has shown that relative stickiness in durable relative to non-durable sectors determines the real effects of monetary policy shocks. While we explore the general importance for the aggregate economy when financial frictions and investment into a customer base are important concerns for firms, further modeling is warranted, especially to explain the responsiveness of inflation to these concerns in non-durable goods but not such much in durable goods.

3.3 Frequency of Price Changes

Third, we find that firms with high investment into their customer base generally change their prices less frequently. This is true across all time periods as Figure 11 shows. Firms with little investment into their customer base change prices with a quarterly probability of 45% to 65%. Firms with high investment into their customers only change prices with a quarterly probability of 20% to 40%. At all points, the difference is between 20% and 40% points and statistically significantly different from 0. This finding of overall more sticky prices of firms that care a lot about maintaining a stable customer base is consistent with the results of Blinder et al. (1998) that firms are averse to “angering” their customers.

During the crisis, we observe a drop in the frequency of price changes by the firms with low investment into their customer base. It is not very pronounced at the aggregate. However, we observe an underlying composition effect for these firms: firms with low investment into their customer base become less likely to increase their prices during the 2008-2009 crisis, while they are more likely on average to adjust prices downwards. We do not observe any particular patterns for firms with high investment into customers.

4 Learning from Micro Regressions

In terms of modeling price adjustment, our findings provide direct evidence on the role of firm balance sheets and investment into customers for aggregate price dynamics. Clearly, standard

Calvo, Taylor or state-dependent models of pricing cannot account for divergent pricing behavior depending on these factors. The aggregate results presented so far suggest that our conventional modeling approaches should be augmented by the inclusion of financial frictions and investment into a customer base 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 relative importance of firm balance sheets and investment into customers for price adjustment, we now turn to microeconomic regression analysis to measure the extent to which these firm-level factors influence the probability and size of *individual* price changes.

4.1 Extensive Margin of Price Adjustment

When we estimate a multinomial logit model of price adjustment, we find that during the crisis both financial conditions of firms, and their investment into a customer base had an impact on the probability of adjusting price and the direction.

To arrive at this conclusion, we estimate a multinomial logit model of the form as in Bhattarai and Schoenle (2010):

$$Pr(Y_{i,j,t+1} = 1, 0, -1 | X_{i,j,t} = x) = \Phi(\beta_t X_{i,j,t}) \quad (5)$$

where $Y_{i,j,t+1}$ is an indicator variable for upwards, no, or downwards price changes of good i produced by firm j at time $t + 1$, with 0 as the base category. The explanatory variables $X_{i,j,t}$ are at the firm level and include the liquidity-to-sales ratio, the SGAX-to-sales ratio and sales growth at time t . We also include time and three-digit NAICS sector fixed effects. We estimate four-quarter rolling regressions, hence β_t is time-varying. We use the estimates to compute elasticities around the mean of the explanatory variables.

Figure 12 panel 12(a) presents our results for the liquidity-to-sales ratio. We find that firms with bad financial conditions became more likely to increase their prices, and firms with good financial conditions less likely to increase their prices during the financial crisis, relative to holding them constant. This can be seen from the large, statistically significant drop from a positive but small and insignificant elasticity on upwards price changes both before and after the crisis to a negative 0.16 elasticity during the 2008 financial crisis: given a one percentage point increase in

the liquidity-to-sales ratio, a firm became 0.16 percentage points less likely to increase its price relative to holding it constant. At the same time, we find that there is a positive but not always significant elasticity on downwards adjustment. This indicates that firms with better financial conditions face lower downwards price rigidity on the extensive margin.

Panel 12(b) presents our result for the SGAX-to-sales ratio. We observe two clear trends during the financial crisis: First, the elasticity of firms to adjust prices upwards spikes up during the crisis from negative values before and after, and we cannot exclude that it is statistically different from a small, positive value. This suggest that firms with a high investment into their customer base became relatively more likely to increase their prices to before and after the crisis.

Second, we find that downwards rigidity along the extensive margin significantly increased: firms with high investment into their customers became more reluctant to lower their prices while firms without regards for such investment increased their downwards price flexibility. This can be seen from the fact that during the crisis, the elasticity of downwards adjustment drops from -.4 to -.9, implying that a one percentage increase in the SGAX-to-sales ratio would lead to a 0.5 percentage point lower probability of downwards price changes.

4.2 Intensive Margin of Price Adjustment

When we estimate a model of conditional price changes, we find evidence that during the financial crisis firms with high investment into customers adjusted prices upwards by more, conditional on adjustment. We do not find any pronounced effects on downwards price changes, or for the importance of the liquidity ratio.

We arrive at these conclusions by estimating the following specification:

$$\Delta p_{i,j,t+1}^d = \beta_t X_{i,j,t} + \lambda_{i,j,t} + \epsilon_{i,j,t} \quad \text{where } d \in (-1, +1) \quad (6)$$

where $\Delta p_{i,j,t+1}^d$ denotes the log price change of good i of firm j in quarter $t + 1$ and explanatory variables $X_{i,j,t}$ are at the firm level and include the liquidity-to-sales ratio, the SGAX-to-sales ratio and sales growth at time t . We also include time and four-digit NAICS sector fixed effects, and $\lambda_{i,j,t}$ is a selection-correction term implemented as in Asplund et al. (2000). We estimate four-quarter rolling regressions, hence β_t is again time-varying.

Our results are shown in Figures 13. What we find is consistent with the aggregate evidence: firms that invest into their customer base may exploit it to generate revenue by charging higher prices and markups. The right half of Panel 13(b) shows a pronounced upwards spike during the financial crisis: the estimated coefficient on the SGAX-to-sales ratio switches sign and becomes positive, from values of -0.5 to +0.3. Thus, at the peak of the crisis, firms with a high investment into customers increase their prices by more, conditional on adjustment and controlling for other factors: a one percentage point change in the SGAX-to-sales ratio implied a 0.3 percentage point increase in upwards price changes, conditional on adjustment. The other panels show our estimates for downwards price changes, as well as the coefficients due to changes in the liquidity ratio. There are no clear trends for these adjustment decisions during the crisis.

5 Model

In this section, we construct a general equilibrium model in which monopolistically competitive firms set price in a customer-markets environment whereby current pricing decisions influence future market share. To motivate the competition for market share implied by customer-markets models, we specify preferences that allow the formation of a *customer base* such that “lower prices are a form of investment, an investment in market share” (Rotemberg and Woodford (1991)).⁹ To that end, we adapt the good-specific habit model developed by Ravn et al. (2006). We further assume nominal rigidities in the form of quadratic costs to changing prices, which, in standard New Keynesian models, is equivalent to a Calvo price-setting mechanism. To explore the role of financial frictions, we augment this framework with a stylized but tractable model of external finance. We begin by describing preferences and technology, and then describe financial policy and price-setting behavior.

5.1 Preferences and Technology

We assume that there exists a continuum of households, indexed by $j \in [0, 1]$. Each household consumes a variety of consumption goods, indexed by $i \in [0, 1]$. The preferences are defined for a

⁹Switching 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.

habit-adjusted consumption bundle, x_t^j and labor, h_t^j

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s U(x_{t+s}^j - \delta_{t+s}, h_{t+s}^j). \quad (7)$$

The consumption/habit aggregator is defined as

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

where δ_t is a demand shock that alters the marginal utility of consumption today, and hence the final demand. The habit stock is assumed to be external and hence taken as given by consumers. We assume that the habit evolves according to

$$s_{it} = \rho s_{it-1} + (1 - \rho) c_{it}. \quad (8)$$

where $1 - \rho$ denotes the depreciation rate for the current habit stock. The dual problem of cost minimization gives rise to a good-specific demand,

$$c_{it}^j = \left(\frac{p_{it}}{\tilde{p}_t} \right)^{-\eta} s_{it-1}^{\theta(1-\eta)} x_t^j \quad (9)$$

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

$$\tilde{p}_t \equiv \left[\int_0^1 (p_{it} s_{it-1}^\theta)^{1-\eta} di \right]^{1/(1-\eta)}. \quad (10)$$

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

$$y_{it} = \left(\frac{A_t}{a_{it}} h_{it} \right)^\alpha - \phi, \quad 0 < \alpha \leq 1 \quad (11)$$

where A_t is a TFP shock, which follows an AR(1) process, and a_{it} is an i.i.d. idiosyncratic shock, following a log-normal distribution, $\log a_{it} \sim N(-0.5\sigma^2, \sigma^2)$. As indicated by (11), we allow the

production technology to be either DRS or CRS. We assume that production is subject to fixed operating costs, denoted by ϕ , which makes it possible for firms to incur negative income.

5.2 Pricing Frictions and Financial Distortions

To allow for nominal rigidities, we assume that the firms face a quadratic cost to 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)). Staggered pricing models such as Calvo (1983) would not change the main conclusions. Convex adjustment costs are adopted for the sake of algebraic simplicity.

To introduce financial frictions in a simple tractable manner we assume that firms must commit to pricing and hence output decisions based on all aggregate information available within the period but prior to the realization of their firm-specific idiosyncratic shock to productivity. Based on this aggregate information, firms post prices, take orders from customers and plan production based on expected marginal cost. Firms then realize actual marginal cost and hire labor to meet demand. Ex post, profits may be too low to cover the total cost of production in which case firms must raise external finance. Without loss of generality, we focus on equity finance.¹⁰ We assume that ex-post equity finance involves a constant per-unit dilution cost $\varphi \in (0, 1)$.

5.3 Profit Maximization Problem

The firm problem is to maximize the present value of dividend flows, $\mathbb{E}_t[\sum_{s=0}^{\infty} m_{t,t+s} d_{it+s}]$ where d_{it} denotes (real) dividend payouts when positive and equity issuance when negative. 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,

$$0 = p_{it}c_{it} - w_t h_{it} - \frac{\gamma}{2} \left(\pi_t \frac{p_{it}}{p_{it-1}} - \bar{\pi} \right)^2 c_t - d_{it} + \varphi \min\{0, d_{it}\}. \quad (12)$$

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

$$\left(\frac{A_t}{a_{it}} h_{it} \right)^\alpha - \phi \geq c_{it}. \quad (13)$$

¹⁰As shown by Gomes (2001) and Stein (2003), other forms of costly external financing can be replicated by properly parameterized equity dilution costs.

The Lagrangean of the problem can then be expressed as

$$\begin{aligned} \mathcal{L} = & \mathbb{E}_0 \sum_{t=0}^{\infty} m_{0,t} \left\{ d_{it} + \kappa_{it} \left[\left(\frac{A_t}{a_{it}} h_{it} \right)^{\alpha} - \phi - c_{it} \right] \right. \\ & + \xi_{it} [p_{it} c_{it} - w_t h_{it} - \frac{\gamma}{2} \left(\pi_t \frac{p_{it}}{p_{it-1}} - \bar{\pi} \right)^2 c_t - d_{it} + \phi \min\{0, d_{it}\}] \\ & \left. + \nu_{it} \left[\left(\frac{p_{it}}{\bar{p}_t} \right)^{-\eta} s_{it-1}^{\theta(1-\eta)} x_t - c_{it} \right] + \lambda_{it} [\rho s_{it-1} + (1-\rho)c_{it} - s_{it}] \right\} \end{aligned} \quad (14)$$

where κ_{it} , ξ_{it} , ν_{it} and λ_{it} are the Lagrangean multipliers associated with (13), (12), (9) and (8).

The efficiency conditions are summarized by FOCs¹¹:

$$d_{it} : \xi_{it} = \begin{cases} 1 & \text{if } d_{it} \geq 0 \\ 1/(1-\phi) & \text{if } d_{it} < 0 \end{cases} \quad (15)$$

$$h_{it} : \kappa_{it} = \xi_{it} a_{it} \frac{w_t}{\alpha A_t} (c_{it} + \phi)^{\frac{1-\alpha}{\alpha}} \quad (16)$$

$$c_{it} : \mathbb{E}_t^a[\nu_{it}] = -\mathbb{E}_t^a[\kappa_{it}] + \mathbb{E}_t^a[\xi_{it} p_{it}] + (1-\rho)\lambda_{it} \quad (17)$$

$$\begin{aligned} s_{it} : \lambda_{it} = & \rho \mathbb{E}_t \{ m_{t,t+1} \lambda_{it+1} \} \\ & + \theta(1-\eta) \mathbb{E}_t \left\{ m_{t,t+1} \mathbb{E}_{t+1}^a \left[\nu_{it+1} \frac{c_{it+1}}{s_{it}} \right] \right\} \end{aligned} \quad (18)$$

$$\begin{aligned} p_{it} : 0 = & \mathbb{E}_t^a[\xi_{it}] c_{it} - \eta \frac{\mathbb{E}_t^a[\nu_{it}]}{p_{it}} c_{it} - \gamma \frac{\pi_t}{p_{it-1}} \mathbb{E}_t[\xi_{it}] \left(\pi_t \frac{p_{it}}{p_{it-1}} - \bar{\pi} \right) c_t \\ & + \gamma \mathbb{E}_t \left[m_{t,t+1} \mathbb{E}_{t+1}^a[\xi_{it}] \pi_{t+1} \frac{p_{it+1}}{p_{it}^2} \left(\pi_{t+1} \frac{p_{it+1}}{p_{it}} - \bar{\pi} \right) c_{t+1} \right] \end{aligned} \quad (19)$$

The last three FOCs denote decisions made prior to the realization of the idiosyncratic cost shock. These first-order conditions include the expected value of internal funds $\mathbb{E}_t^a[\xi_{it}] \equiv \int_0^\infty \xi_{it} dF(a)$ where the information set of the expectations operator includes all aggregate information up to time t except the realization of the idiosyncratic shock. In contrast, the realized values ξ_{it} and a_{it} enter the efficiency conditions (15) and (16) without the expectation operator since equity issuance and labor hiring decisions are made after the realization of the idiosyncratic shock.¹²

With risk-neutrality and i.i.d. idiosyncratic shocks, the timing convention adopted above implies that ex ante firms are identical. Hence we focus on a symmetric equilibrium whereby all mo-

¹¹Note that in (16), 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.

¹²A similar timing convention has been used by Kiley and Sim (2012) in the context of financial intermediation.

nopolistically 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 $\mathbb{E}_t^a[\tilde{\xi}_{it}]c_{it}$ yields the following Philips curve:

$$1 = \gamma\pi_t(\pi_t - \bar{\pi}) - \gamma\mathbb{E}_t \left[m_{t,t+1} \frac{\mathbb{E}_{t+1}^a[\tilde{\xi}_{it+1}]}{\mathbb{E}_t^a[\tilde{\xi}_{it}]} \pi_{t+1} (\pi_{t+1} - \bar{\pi}) \frac{c_{t+1}}{c_t} \right] + \eta \frac{\mathbb{E}_t^a[v_{it}]}{\mathbb{E}_t^a[\tilde{\xi}_{it}]} \quad (20)$$

Financial distortions modify the Phillips curve through the term, $\mathbb{E}_t^a[\tilde{\xi}_{it}]$.

To analyze how the financial market friction interacts with pricing/mark-up decisions, we now consider the value of internal funds. Define the equity issuance trigger a_t^E as the idiosyncratic productivity level that satisfies the flow of funds constraint when dividends are exactly zero:

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

The FOC for d_{it} can be expressed as

$$\xi(a_{it}) = \begin{cases} 1 & \text{if } a_{it} \leq a_t^E \\ 1/(1 - \phi) & \text{if } a_{it} > a_t^E \end{cases} \quad (21)$$

Let z_t^E denote the standardized value of a_t^E , i.e., $z_t^E = \sigma^{-1}(\log a_t^E + 0.5\sigma^2)$. From (21), the expected shadow value of internal funds is

$$\begin{aligned} \mathbb{E}_t^a[\xi_{it}] &= \Phi(z_t^E) + \frac{1}{1 - \phi} [1 - \Phi(z_t^E)] \\ &= 1 + \frac{\phi}{1 - \phi} [1 - \Phi(z_t^E)] \geq 1 \end{aligned}$$

where $\Phi(\cdot)$ denotes the cdf of the standard normal distribution.

The expected shadow value is strictly greater than unity as long as equity issuance is costly ($\phi > 0$) and future costs are uncertain ($\sigma > 0$). This makes the firms de facto risk averse in their pricing decision: setting the price too low and taking an imprudently large number of orders exposes the firm to the risk of incurring negative operating income, which must be financed

through costly equity issuance. When the expected mark-up, $c_t/(w_t h_t) = c_t A_t/[w_t(c_t + \phi)^{1/\alpha}]$ rises, the probability of external financing $1 - \Phi(z_t^E)$ falls, and as a result, the shadow value of internal funds also falls. Furthermore, under reasonable parameter values, and, holding wages fixed, a contraction in demand that causes a reduction in c_t implies an increase in the expected cost of external finance since, with lower production, fixed costs now account for a greater share of total costs.

We now consider how the value of internal funds affects the value of marginal sales. In the FOC for c_{it} (17), we can see that the value of marginal sales is composed of two elements, the current profit and the value of the customer base: From (17), after imposing the symmetric equilibrium condition, we have

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

To see that the first component is the value of marginal profit, we can substitute (16) in the second term of the above to obtain

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

where $\mu(A_t, c_t, w_t) \equiv \alpha(A_t/w_t)(c_t + \phi)^{\frac{\alpha-1}{\alpha}}$ denotes the aggregate (marginal) mark-up. Without the financial market friction, the value of marginal profit is $1 - 1/\mu(A_t, c_t, w_t)$. The financial friction tilts the way the firm assess the marginal revenue and cost in an important way through the terms $\mathbb{E}_t^a[\zeta_{it}]$ and $\mathbb{E}_t^a[\zeta_{it} a_{it}]$. Using the property of lognormal distributions (see Johnson et al. (1994)), the interaction term can be expressed as

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

Note that $\mathbb{E}_t^a[\zeta_{it} a_{it}] \geq \mathbb{E}_t^a[\zeta_{it}] \geq 1$. The financial friction raises both the value of marginal revenue and the value of marginal cost, but the effect on marginal cost dominates so that a reduction in technology or an increase in demand makes the firm more conservative in its pricing decision to

avoid negative profits. To streamline notations, we define the financially-adjusted mark-up

$$\tilde{\mu}(A_t, c_t, w_t) \equiv \frac{\mathbb{E}_t^a[\zeta_{it}]}{\mathbb{E}_t^a[\zeta_{it}a_{it}]} \mu(A_t, c_t, w_t) \leq \mu(A_t, c_t, w_t) \quad (22)$$

To derive a closed-form solution for the value of the 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 marginal value of an increase in the customer base satisfies:

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

where $\tilde{\beta}_{t,s} \equiv m_{s,s+1} g_{s+1} \cdot \prod_{j=1}^{s-t} [\rho + \theta(1 - \eta)(1 - \rho)g_{t+j}] m_{t+j-1,t+j}$ denotes a growth-adjusted discount factor. The marginal value of the customer base is the expected present value of future marginal profits. Substituting the expression for the value of the customer base into (17), and using the financially-adjusted mark-up yields a closed form solution for the value of marginal sales:

$$\mathbb{E}_t^a[v_{it}] = \mathbb{E}_t^a[\zeta_{it}] \left[\frac{\tilde{\mu}_t - 1}{\tilde{\mu}_t} \right] + (1 - \rho)\theta(1 - \eta) \mathbb{E}_t \left[\sum_{s=t}^{\infty} \tilde{\beta}_{t,s} \mathbb{E}_{s+1}^a[\zeta_{is+1}] \left[\frac{\tilde{\mu}_{s+1} - 1}{\tilde{\mu}_{s+1}} \right] \right]. \quad (23)$$

The liquidity conditions of the firm measured by the sequence of $\mathbb{E}_s^a[\zeta_{is}]$, $s = t, \dots, \infty$ determines the weight that the firm places on current versus future profits when setting the expected price path. If today's liquidity premium is higher than future liquidity premia, the firm places more weight on current profits relative to future profits. In the simulations shown below, today's liquidity premium sufficiently outweighs tomorrow's concern so that the first term on the right side of (23) dominates, and the value of marginal sales moves up and down in tandem with the value of internal funds.

Dividing (23) through by $\mathbb{E}_t^a[\zeta_{it}]$ and substituting this in (20), we obtain our final expression for the Phillips curve,

$$\begin{aligned} 1 = & \gamma \pi_{it} (\pi_{it} - \bar{\pi}) - \gamma \mathbb{E}_t \left[m_{t,t+1} \frac{\mathbb{E}_{t+1}^a[\zeta_{it+1}]}{\mathbb{E}_t^a[\zeta_{it}]} \pi_{it+1} (\pi_{it+1} - \bar{\pi}) \frac{c_{it+1}}{c_{it}} \right] \\ & + \eta \left[\frac{\tilde{\mu}_t - 1}{\tilde{\mu}_t} \right] + \eta(1 - \rho)\theta(1 - \eta) \mathbb{E}_t \left[\sum_{s=t}^{\infty} \tilde{\beta}_{t,s} \frac{\mathbb{E}_{s+1}^a[\zeta_{is+1}]}{\mathbb{E}_t^a[\zeta_{it}]} \left[\frac{\tilde{\mu}_{s+1} - 1}{\tilde{\mu}_{s+1}} \right] \right]. \end{aligned} \quad (24)$$

The left side measures the current marginal benefit of increasing price: holding demand quantity

constant, the firm earns one additional unit of revenue. The right side measures the cost of doing so. The first line measures the current versus future marginal adjustment costs owing to nominal price rigidity. The second line shows the effect of price changes on the current and future marginal cost and hence markups. If the customer base ($\rho = 0$) is irrelevant and only the current markup matters, and when $\gamma > 0$ one can solve this equation forward to obtain the familiar New Keynesian Philips curve that determines current inflation as a present value of future marginal costs. The last term ($\rho > 0$) measures the effect of current price on the future customer base. By raising price today, the firm reduces the expected customer base which also reduces future marginal costs.

In the absence of sticky prices ($\gamma = 0$) and a customer base ($\rho = 0$), the markup is a constant – the financial distortion is irrelevant for the pricing decision. This is distinct from a cost-channel of monetary policy that emphasizes that firms must increase their current markup to cover the expected financing costs of labor inputs.

Both sticky prices and the customer base imply that the firm is forward looking which creates a role for financial distortions that influence how the firm discounts profits today versus in the future. Importantly, even in the absence of sticky prices, firms vary the markup to tradeoff current versus future marginal profits through the decision to invest in a customer base. Financial frictions alter this tradeoff so that when the current value of liquidity is high relative to the future ($\mathbb{E}_{s+1}^a[\zeta_{is+1}]/\mathbb{E}_t^a[\zeta_{it}] < 1$), firms discount the future more and hence value the future investment gains less. As a result, they are more likely to set a high price today for $s = t, \dots, \infty$ which increases the counter-cyclical of markups.

5.4 The Rest of the Model Economy

The household budget constraint is given by

$$b_{t+1}^j + \int_0^1 p_{it} c_{it}^j di + \int_0^1 p_{it}^S s_{F,it+1}^j di = w_t h_t^j + (1 + r_{t-1}) b_t^j + \int_0^1 [\max\{d_{it}, 0\} + p_{it-1,t}^S] s_{F,it}^j di$$

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 terms are related via the 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 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 (9), one can rewrite the budget constraint as

$$b_{t+1}^j + \tilde{p}_t x_t^j + \int_0^1 p_{it}^S s_{F,it+1}^j di = w_t h_t^j + (1 + r_{t-1}) b_t^j + \int_0^1 [\max\{d_{it}, 0\} + (1 - \varphi) \min\{d_{it}, 0\} + p_{it}^S] s_{F,it}^j di. \quad (25)$$

The above expression makes it clear that 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, there is no direct wealth effect associated with 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 (7) subject to (25) yields

$$x_t^j : \Lambda_t^j \tilde{p}_t = U_x(x_t^j - \delta_t, h_t^j) \quad (26)$$

$$h_t^j : \Lambda_t^j w_t = -U_h(x_t^j - \delta_t, h_t^j) \quad (27)$$

$$b_{t+1}^j : \Lambda_t^j = \beta \mathbb{E}_t[\Lambda_{t+1}^j (1 + r_t)] \quad (28)$$

$$s_{F,it+1}^j : \Lambda_t^j = \beta \mathbb{E}_t \left[\Lambda_{t+1}^j \left(\frac{\tilde{d}_{t+1} + p_{t+1}^S}{p_t^S} \right) \right] \quad (29)$$

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 (26), we have $\Lambda_t^j = U_x(x_t^j, h_t^j) / \tilde{p}_t$. In the 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

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

(26) and (27) together imply the following efficiency condition.¹³

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

¹³In actual implementation of the model, we also assume an adjustment cost for the nominal wage by introducing market power associated with 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.

5.5 Monetary Policy

To close the model, we assume that the monetary authority sets the nominal interest rate using a Taylor-type rule that responds to the inflation and output gaps, i.e.,

$$r_t = \max \left\{ 0, (1 + r_{t-1})^{\rho_r} \left[(1 + \bar{r}) \left(\frac{\pi_t}{\pi^*} \right)^{\rho_\pi} \left(\frac{y_t}{y_t^*} \right)^{\rho_y} \right]^{1-\rho_r} - 1 \right\}. \quad (30)$$

This equation also allows for policy inertia, $\rho_r \in (0, 1)$. In our baseline specification we set $\rho_y = 0$ so that only inflation enters the Taylor rule. We then explore the effects of allowing $\rho_y > 0$. We also 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.¹⁴

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 parameter 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 the habit stock is depreciated in a quarter. The CRRA parameter is then set equal to one given that the deep habit specification provides a strong motive to smooth consumption. 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 a number of elements that generate persistent dynamics of the endogenous quantities.

The elasticity of substitution is a key parameter in the customer-markets model: the greater the market power the firm has, the greater incentive to invest in customer capital. Broda and Wein-

¹⁴For this type of analysis, we use deterministic simulation routine of Adjemian et al. (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.

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

stein (2006) provides a set of point estimates for the elasticity of substitution for the U.S. economy. The estimates hover around 2.1~4.8, 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 a 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 et al. (2010) also provide a point estimate of 2.48 using their structural estimation method.

Another important parameter is the fixed operating 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. Decreasing returns to scale enhances the link between the financial market friction and the pricing decision. We choose $\alpha = 0.8$. While this degree of returns to scale parameter is not unusual in empirical investment literature based on Compustat data (for instance, see Hennessy and Whited (2007)), model's dynamics are not substantially 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.

To calibrate 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 at 0.90. However, in our crisis experiment in which we consider an extreme degree of financial market frictions, we use $\varphi = 0.50$ as well. We discuss the influence of these choices on model outcomes below. The volatility of the 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 $\mathbb{E}^a[\xi_i] = 1.17$.

For the parameters related to 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 et al. (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. In experiments where monetary policy responds to the output gap we set $\rho_y = 0.5$.

6.2 Crisis and Inflation

Our main goal in developing the model is to gain insight as to why the massive slack in productive capacity observed in the last recession did not lead to a sizable drop in inflation rate, let alone an outright deflationary spiral that was of much concern to both academics and policy makers. To study the dynamics of inflation and other endogenous variables in a financial crisis, we conduct two types of experiments. In this subsection, we consider an extreme calibration in which raising external finance is not impossible, but is tremendously costly, and the firms in the model finance themselves nearly entirely through internal cash flows. 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 bankruptcy in 2008, where virtually no firms could contemplate raising outside

equities to finance operating cost and investment. With this calibration, we study the impact of conventional supply and demand shocks on the pricing decisions of the firms.

Figure 1: Impact of Supply Shock: With (solid) and Without (solid-dot) Financial Friction

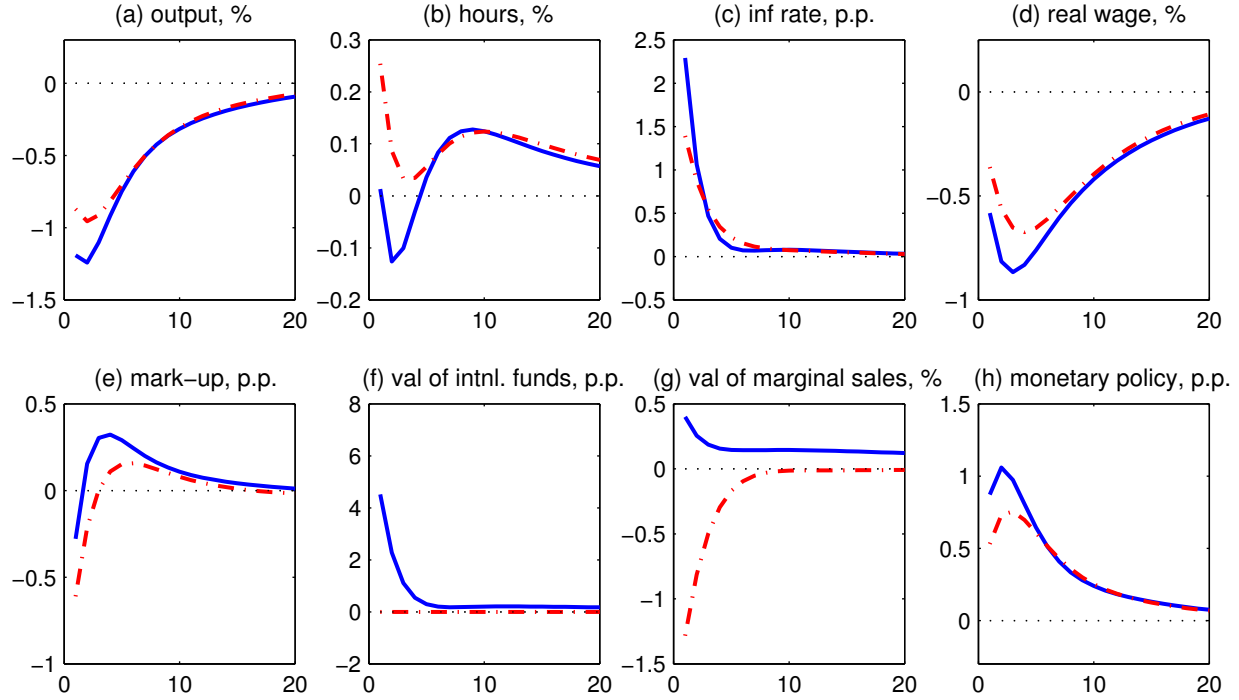


Figure 14 shows the impact of one standard deviation technology shock both for the economy with the financial friction (solid blue) and for the economy without the financial friction (solid dot red). The negative technology shock leads a sizable drop in economic activity shown in panel (a) and a short 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 implies a mild amplification in output, consistent with a financial accelerator mechanism at play.

Although the output differential owing to the financial friction is modest, Figure 14 highlights that the differential responses of inflation rate is quite substantial – the inflation response is 40 percent greater with the financial friction. Panel (e)~(f) of the figure provide an explanation for the differential responses in inflation. In our environment, the news of negative technology shock becomes known before pricing decisions are made. Under the financial market friction, the news about the bad technology shock at the beginning of the period reduces the firms' expected internal cashflows and raises the probability that firms require costly external finance, which then leads to

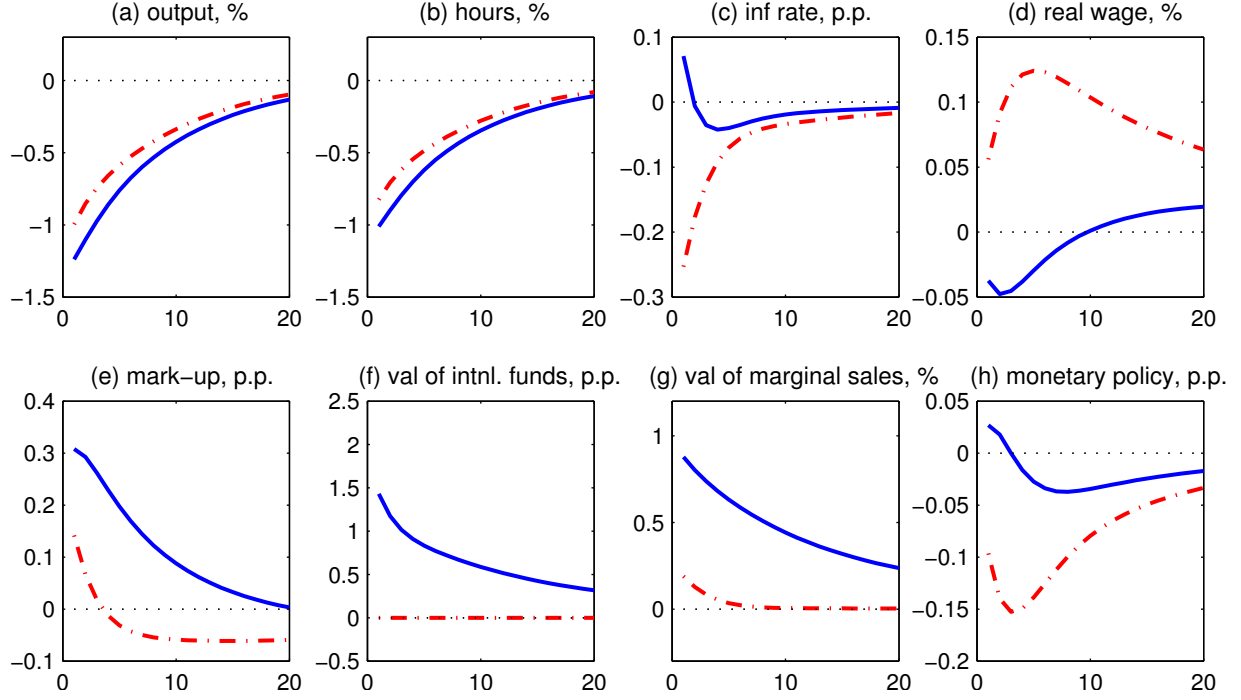
a 400 basis point increase in the shadow value of internal funds, shown in panel (f). In response, the firms seek to protect themselves against the idiosyncratic tail event that ex-post cash flows are negative and hence require external funds by choosing higher markups relative to the case where external finance is costless as shown in panel (e).

As discussed above, a severe financial market friction causes the value of internal cashflows and the value of marginal sales to move in tandem. Panel (f) and (g) displays this result: 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 base both today and in the future. In the absence of financial frictions, firms are more concerned about the future customer base relative to current profits and the marginal value of sales falls. In contrast, in the model with financial frictions, the substantial increase in the value of internal funds causes the marginal value of sales to rise. Finally, as shown by the last term of the Phillips curve (24), the benefits of future customer base is heavily discounted when liquidity conditions today are expected to be much worse than in the future. As a result, concern for current relative to future profits dominate the firms's pricing decision, a form of short-termism that is optimal from the firm's perspective, but that results in a significant rise in inflation which is suboptimal from the perspective of a purely monopolistic firm that internalizes the effect of all pricing decisions on demand.

Figure 2 shows the case of demand shock which directly affects the marginal utility of consumption (see (7)), replicating a so called *autonomous* spending cut. The contractionary demand shock implies a very similar output path across the model with versus without the financial friction but markedly divergent inflation paths. With no financial friction, prices fall substantially, leading to a persistent reduction in inflation. With the financial market friction, firms choose higher rather than lower prices to ensure against the need to issue external funds to meet liquidity requirements. As a result, the inflation rate exhibits a modest increase rather than a substantial decrease.

In both models, the negative demand shock leads to a sharp increase in the mark-up. The countercyclical mark-up in a demand-driven cycle arises naturally in the deep habit models. Our results highlight that this countercyclicalitity is substantially strengthened by the financial friction.

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



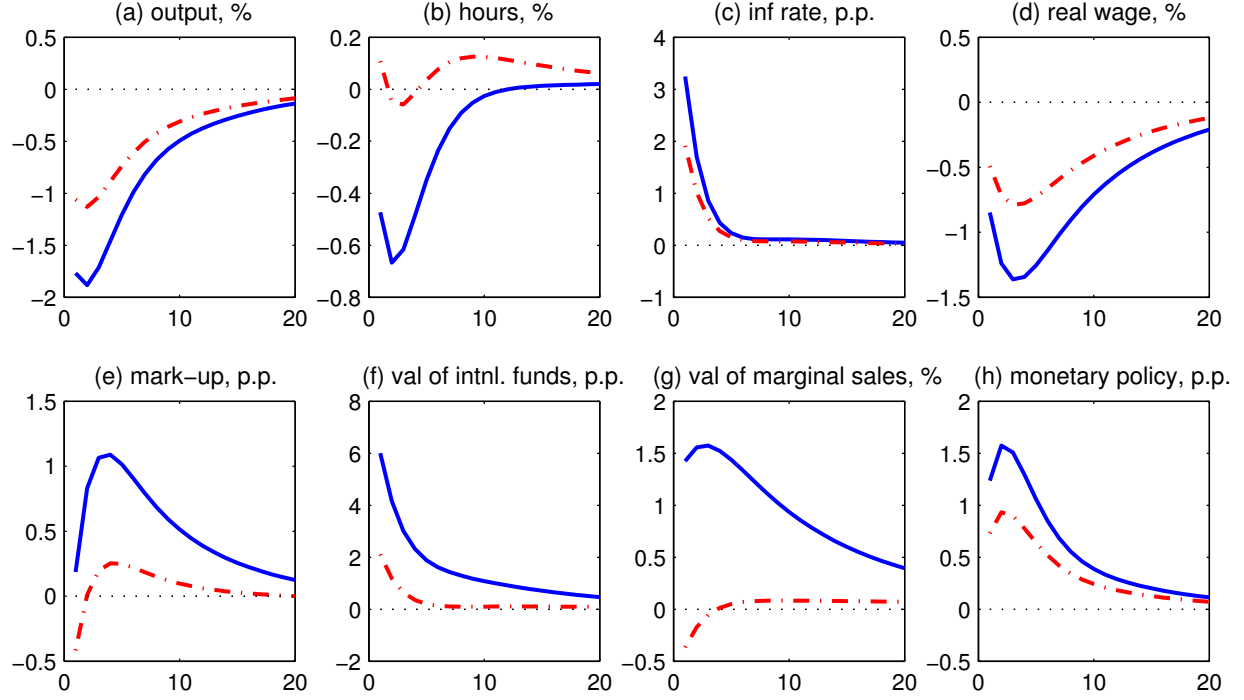
According to panel (e), the model with financial friction exhibits an increase in the markup that is two time greater than the increase that would occur in the absence of financial distortions. Panel (f) and (g) show that the driving force behind the countercyclical mark-up is the sudden deterioration of liquidity conditions which causes firms to increase prices to maintain short term profit rates in the face of weak demand.

6.3 Impact of Financial Shock

An alternative way to characterize 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. The model mechanism implies that liquidity conditions matter for pricing decision not because of their absolute level but because of the prospect that financing conditions will improve in the future. This suggests that the differential effects on markups and pricing policy between the frictionless model and the model with the financial friction will be magnified with a temporary increase in the cost of external financing.

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

Figure 3: Impact of Technology Shock with Higher External Cost: With (solid) and Without (solid dot) Financial Shock



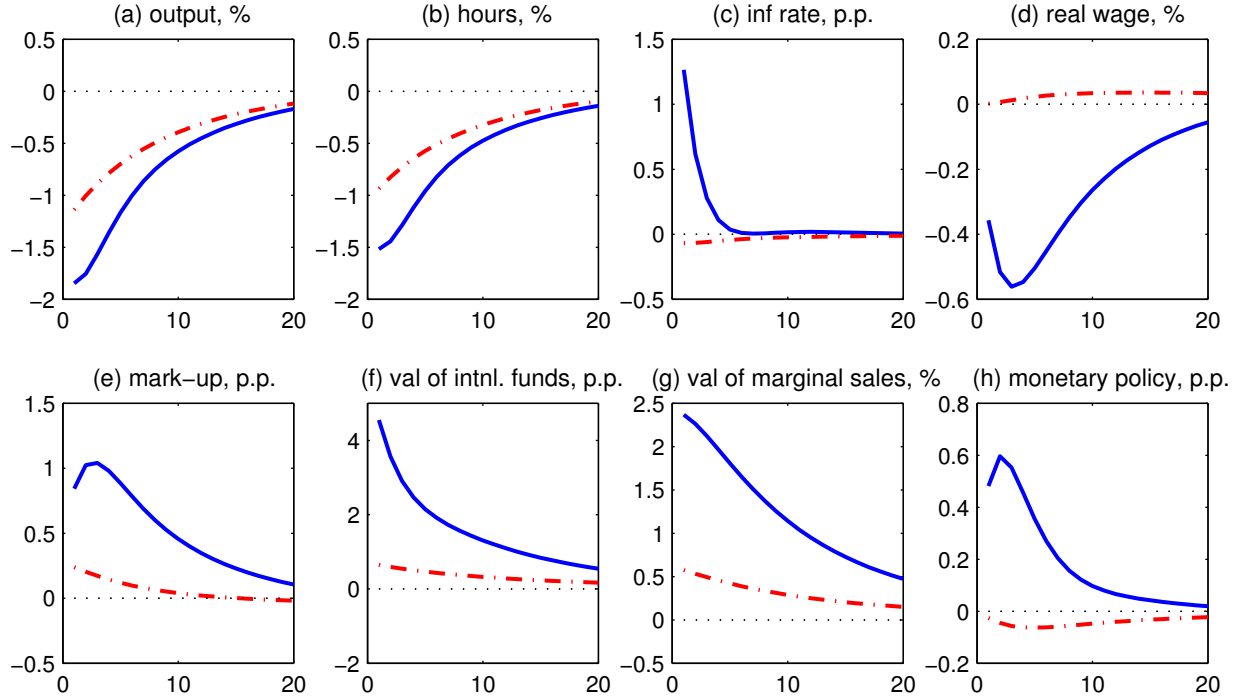
process,

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

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 reconsider 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 level chosen for φ as a 'parameter' in the earlier section.

Figure 3 displays the responses of the model economy to a one standard deviation technology shock: the 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 financial shock. Figure 4 shows the results of the same exercise, but with the demand shock (the size of financial shock is identical to the one in Figure 3). The vertical differences between the solid blue and solid-dot red lines in these figures then measures the additional impact created by

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



the shock to the financing cost.¹⁵

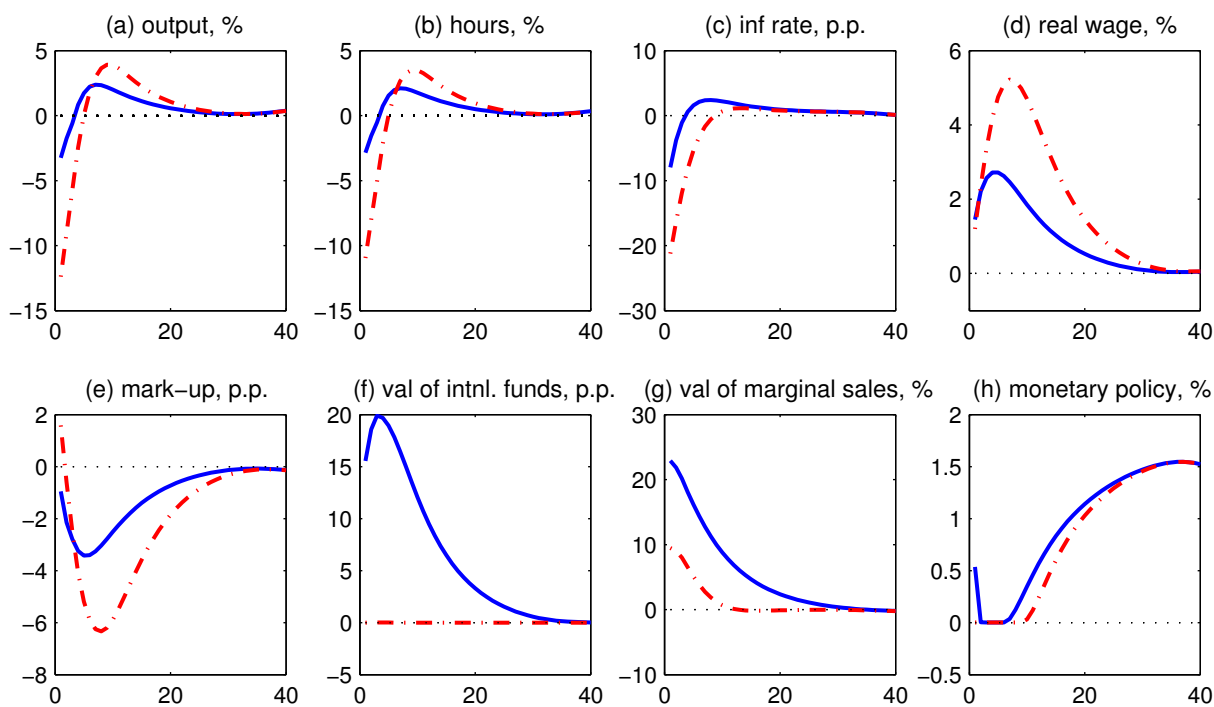
As we conjectured, the economy exhibits extreme sensitivity to both technology and demand shocks when the cost of external financing is temporarily elevated. For instance, in panel (a) and (b) of 3, the additional effect created by the temporarily increase in financing cost is tremendous: the output 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 is strongly countercyclical even in response to a technology shock. Panel (f) shows that the increase in the shadow value of internal funds is two times larger than the case without the financial shock.

Similar patterns can be found in the case of the demand shock, Figure 4. Note that a 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. This within-period financial multiplier plays an important role in the greater propagation of the shocks in Figure 3 and 4.

¹⁵Since 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 14 and the solid-dot red lines in Figure 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 14) and the situation when the external financing cost is temporarily elevated up 0.375 (the solid blue lines in Figure 3). The blue lines in 14 represents a much harsher financial environment since the 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.

Figure 5: Impact of Discount Rate Shock: With (solid) and Without (solid-dot) Financial Friction



6.4 Role of Zero Lower Bound

We close our simulation exercises by analyzing the role of the financial markets friction on pricing under the environment of a 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 discounting factor of the agents is elevated exogenously for a certain number of periods before it

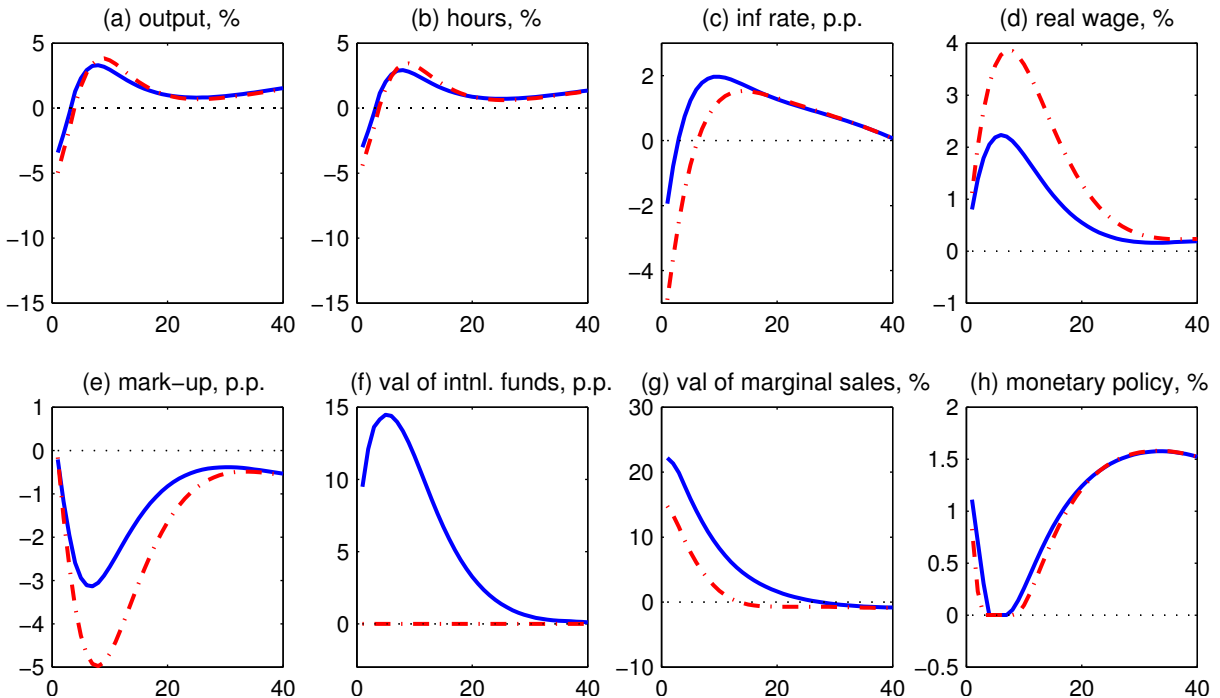
returns to a normal level. In particular, we assume the following shock process,

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

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

Figure 5 displays the impact of such shocks for the baseline calibration. The figure shows how the economic impact of the binding ZLB is altered by the presence of financial distortions. The firms in the model economy with the financial friction are reluctant to cut their prices in order to maintain liquidity. However, the firms in the frictionless economy take a more aggressive stance: the prices are cut by 20 percent (a.r.) on the impact. Under the binding ZLB environment, in panel (h), this translates into a massive increase in the real interest rate, which then leads to a 10 percentage point drop in both output and hours. This suggests that once the ZLB is binding, the incentives of firms to cut price to maintain market share – a highly destabilizing force – are substantially counteracted by firms that need to maintain high cash flows due to financial frictions.

Figure 6: Impact of Discount Rate Shock with Substantially Greater Nominal Rigidity: With (solid) and Without (solid-dot) Financial Friction



In Figure 6, we alter this experiment so that the economy experiences 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. In the model without financial frictions, 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 the baseline calibration. This is consistent with the findings of Christiano et al. (2011) and Bhattarai et al. (2012) who document that increased price flexibility can exacerbate deflationary spirals and destabilize output. In contrast, in the model with financial frictions, it makes little difference whether firms face mild or severe nominal rigidities.

7 Conclusion

In this paper, we have investigated 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.

First, we use confidential, individual producer prices from the Bureau of Labor Statistics and Compustat to 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. Similarly, firms with high investment into their customer base increased their prices during the financial crisis while firms with low investment into customers lowered their prices. Regression analysis shows that both the firm liquidity ratio and investment into customers matter for pricing decisions.

Second, 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 implies a substantial attenuation of price dynamics relative to the baseline model without financial distortions in response to contractionary demand shocks. This implies that in the context of the zero lower bound, financial frictions can paradoxically improve overall economic outcomes.

References

- Adjemian, S., H. Bastani, M. Juillard, F. Mihoubi, G. Perendia, M. Ratto, and S. Villemot (2011, April). Dynare: Reference manual, version 4. Dynare Working Papers 1, CEPREMAP.
- Asplund, M., R. Eriksson, and R. Friberg (2000, March). Price adjustments by a gasoline retail chain. *The Scandinavian Journal of Economics* 102(1), 101–121.
- Bagwell, K. (2004, November). Countercyclical pricing in customer markets. *Economica* 71(284), 519–542.
- Barsky, R. B., C. L. House, and M. S. Kimball (2007, June). Sticky-price models and durable goods. *American Economic Review* 97(3), 984–998.
- Barth, M. J. and V. A. Ramey (2002, August). The cost channel of monetary transmission. In *NBER Macroeconomics Annual 2001, Volume 16*, NBER Chapters, pp. 199–256. National Bureau of Economic Research, Inc.
- Bhattarai, S., G. Eggertsson, and R. Schoenle (2012). Is increased price flexibility stabilizing? redux. Staff Reports 540, Federal Reserve Bank of New York.
- Bhattarai, S. and R. Schoenle (2010, July). Multiproduct firms and price-setting: Theory and evidence from u.s. producer prices. Working Papers 1245, Princeton University, Department of Economics, Center for Economic Policy Studies.
- Bils, M. (1989, November). Pricing in a customer market. *The Quarterly Journal of Economics* 104(4), 699–718.
- Bils, M. and P. J. Klenow (2004, October). Some evidence on the importance of sticky prices. *Journal of Political Economy* 112(5), 947–985.
- Bils, M., P. J. Klenow, and B. A. Malin (2012, August). Testing for keynesian labor demand. In *NBER Macroeconomics Annual 2012, Volume 27*, NBER Chapters. National Bureau of Economic Research, Inc.
- Blinder, A. S., E. R. D. Canetti, D. E. Lebow, and J. B. Rudd (1998). *Asking About Prices: A New Approach to Understanding Price Stickiness*. Russell Sage Foundation, New York.
- Broda, C. and D. E. Weinstein (2006, May). Globalization and the gains from variety. *The Quarterly Journal of Economics* 121(2), 541–585.
- Bucht, C., N. Gottfries, and M. Lundin (2002, February). Why don't prices fall in a recession? financial constraints, investment, and customer relations. Working Paper Series 2002:3, Uppsala University, Department of Economics.
- Calvo, G. A. (1983, September). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics* 12(3), 383–398.
- Carpenter, R. E., S. M. Fazzari, and B. C. Petersen (1994). Inventory investment, internal-finance fluctuation, and the business cycle. *Brookings Papers on Economic Activity* 25(2), 75–138.
- Carpenter, R. E., S. M. Fazzari, and B. C. Petersen (1998, November). Financing constraints and inventory investment: A comparative study with high-frequency panel data. *The Review of Economics and Statistics* 80(4), 513–519.

- Chevalier, J. A. and D. S. Scharfstein (1996, September). Capital-market imperfections and countercyclical markups: Theory and evidence. *American Economic Review* 86(4), 703–25.
- Chirinko, R. S. (1993). Business fixed investment spending: Modeling strategies, empirical results, and policy implications. *Journal of Economic Literature* 31(4), pp. 1875–1911.
- Christiano, L., M. Eichenbaum, and S. Rebelo (2011). When is the government spending multiplier large? *Journal of Political Economy* 119(1), 78 – 121.
- Christiano, L. J., M. Eichenbaum, and C. Evans (2001). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Proceedings* (Jun).
- Christiano, L. J., C. Gust, and J. Roldos (2004, November). Monetary policy in a financial crisis. *Journal of Economic Theory* 119(1), 64–103.
- Cooley, T. F. and V. Quadrini (2001). Financial markets and firm dynamics. *The American Economic Review* 91(5), pp. 1286–1310.
- Denes, M., G. B. Eggertsson, and S. Gilbukh (2013). Deficits, public debt dynamics, and tax and spending multipliers. *Economic Journal*, forthcoming.
- Eggertsson, G. B. (2011, July). What fiscal policy is effective at zero interest rates? In *NBER Macroeconomics Annual 2010, Volume 25*, NBER Chapters, pp. 59–112. National Bureau of Economic Research, Inc.
- Fazzari, S., R. G. Hubbard, and B. C. Petersen (1988, December). Financing constraints and corporate investment. NBER Working Papers 2387, National Bureau of Economic Research, Inc.
- Gertler, M. and S. Gilchrist (1994, May). Monetary policy, business cycles, and the behavior of small manufacturing firms. *The Quarterly Journal of Economics* 109(2), 309–40.
- Gilchrist, S. and C. P. Himmelberg (1995, December). Evidence on the role of cash flow for investment. *Journal of Monetary Economics* 36(3), 541–572.
- Goldberg, P. K. and R. Hellerstein (2009). How rigid are producer prices? Staff Reports 407, Federal Reserve Bank of New York.
- Gomes, J. F. (2001). Financing investment. *The American Economic Review* 91(5), pp. 1263–1285.
- Gopinath, G. and O. Itskhoki (2011, March). In search of real rigidities. In *NBER Macroeconomics Annual 2010, Volume 25*, NBER Chapters, pp. 261–309. National Bureau of Economic Research, Inc.
- Gottfries, N. (1991, August). Customer markets, credit market imperfections and real price rigidity. *Economica* 58(231), 317–23.
- Gourio, F. and L. Rudanko (2011, July). Customer capital. Working Paper 17191, National Bureau of Economic Research.
- Hennessy, C. A. and T. M. Whited (2007). How costly is external financing? evidence from a structural estimation. *The Journal of Finance* 62(4), pp. 1705–1745.
- Holmstrom, B. and J. Tirole (2001). Lapm: A liquidity-based asset pricing model. *The Journal of Finance* 56(5), pp. 1837–1867.

- Johnson, N. L., S. Kotz, and N. Balakrishnan (1994). *Continuous Univariate Distributions* (2nd ed.), Volume 1. Wiley.
- Kiley, M. T. and J. W. Sim (2012). Intermediary leverage, macroeconomic dynamics and macroprudential policy. mimeo, Board of Governors of the Federal Reserve System.
- Klemperer, P. (1987, May). Markets with consumer switching costs. *The Quarterly Journal of Economics* 102(2), 375–94.
- Klemperer, P. (1995, October). Competition when consumers have switching costs: An overview with applications to industrial organization, macroeconomics, and international trade. *Review of Economic Studies* 62(4), 515–39.
- Myers, S. C. (1977, November). Determinants of corporate borrowing. *Journal of Financial Economics* 5(2), 147–175.
- Nakamura, E. and J. Steinsson (2008, November). Five Facts about Prices: A Reevaluation of Menu Cost Models. *Quarterly Journal of Economics* 123(4), 1415–1464.
- Nilsen, J. H. (2002, February). Trade credit and the bank lending channel. *Journal of Money, Credit and Banking* 34(1), 226–53.
- Petersen, M. A. and R. G. Rajan (1994, March). The benefits of lending relationships: Evidence from small business data. *Journal of Finance* 49(1), 3–37.
- Rajan, R. G. and L. Zingales (1998, June). Financial dependence and growth. *American Economic Review* 88(3), 559–86.
- Ravn, M., S. Schmitt-Grohe, and M. Uribe (2006, 01). Deep habits. *Review of Economic Studies* 73(1), 195–218.
- Ravn, M. O., S. Schmitt-Grohe, M. Uribe, and L. Uuskula (2010, June). Deep habits and the dynamic effects of monetary policy shocks. *Journal of the Japanese and International Economies* 24(2), 236–258.
- Rotemberg, J. J. (1982). Monopolistic price adjustment and aggregate output. *The Review of Economic Studies* 49(4), pp. 517–531.
- Rotemberg, J. J. and M. Woodford (1991, July). Markups and the business cycle. In *NBER Macroeconomics Annual 1991, Volume 6*, NBER Chapters, pp. 63–140. National Bureau of Economic Research, Inc.
- Schoenle, R. S. (2010, January). International Menu Costs and Price Dynamics. Working paper, Princeton.
- Stein, J. C. (2003). Agency, information and corporate investment. In G. Constantinides, M. Harris, and R. M. Stulz (Eds.), *Handbook of the Economics of Finance*, Volume 1 of *Handbook of the Economics of Finance*, Chapter 2, pp. 111–165. Elsevier.
- Stigler, G. J. and J. K. Kindahl (1970). *The Behavior of Industrial Prices*. Columbia University Press, New York, N.Y.

8 Tables and Figures

Table 2: Summary Statistics, PPI and Matched 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%
Monthly Frequency of Price Changes, Weighted	Mean	41.28%	52.39%
	Std. Dev.	5.19%	11.17%
	Median	42.48%	52.11%
Number of Firms	Mean	23167	772
	Std. Dev.	1429	95
	Median	23043	767

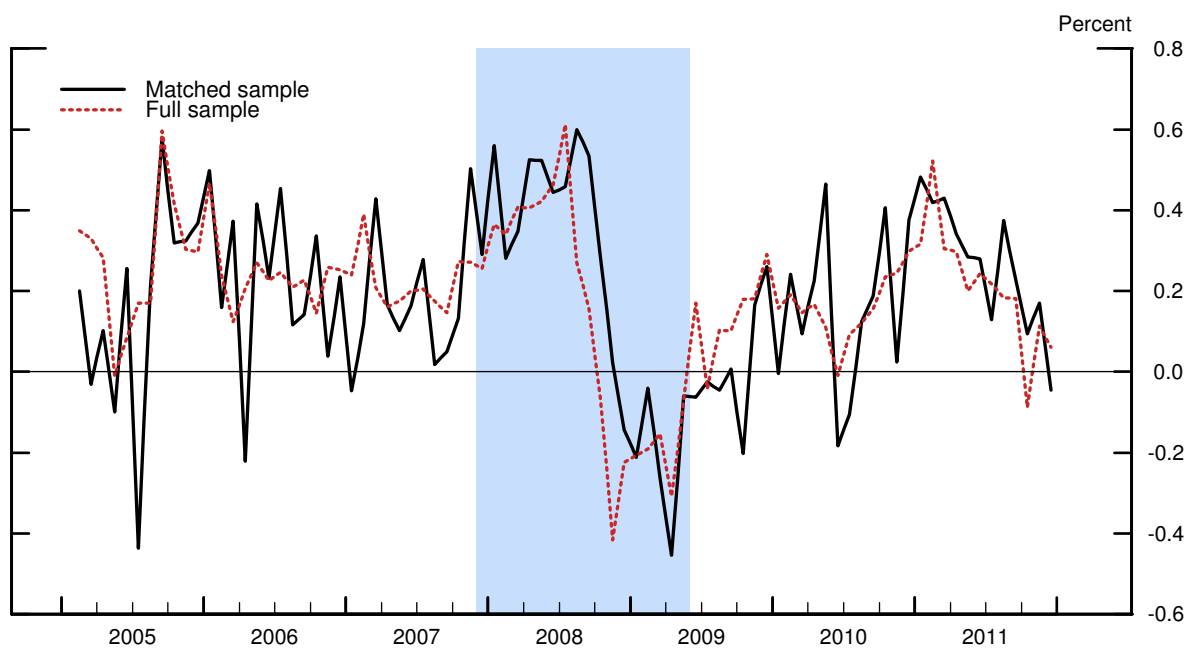
NOTE: We compute the above statistics using the micro price data underlying the PPI (full sample) and our sample matched to Compustat. The time period is from June 2005 through October 2011. First, we compute monthly inflation rates and the frequency of price changes at the level of the firm as the (weighted) means of log price changes and the price change indicators using within-firm importance weights. Second, we take (sales-weighted) means in each monthly cross section of firms. Finally, we report means, medians and standard deviations of these means, as well as of the average monthly number of firms in the data.

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

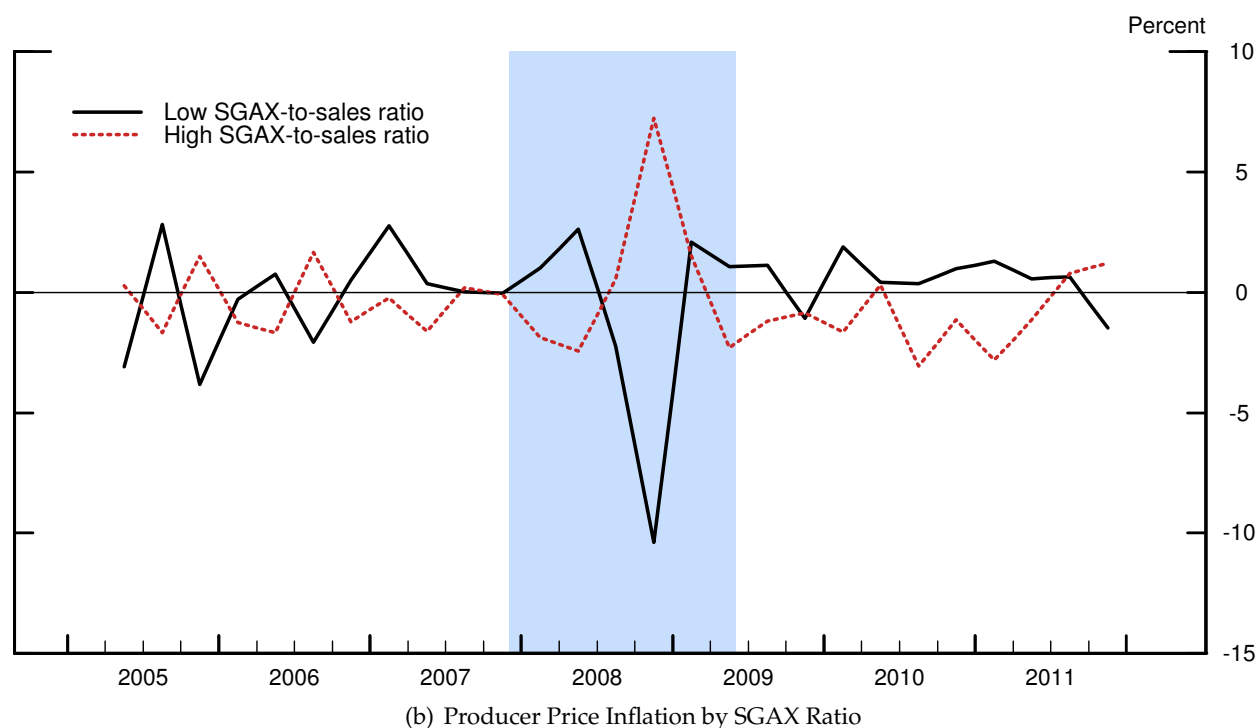
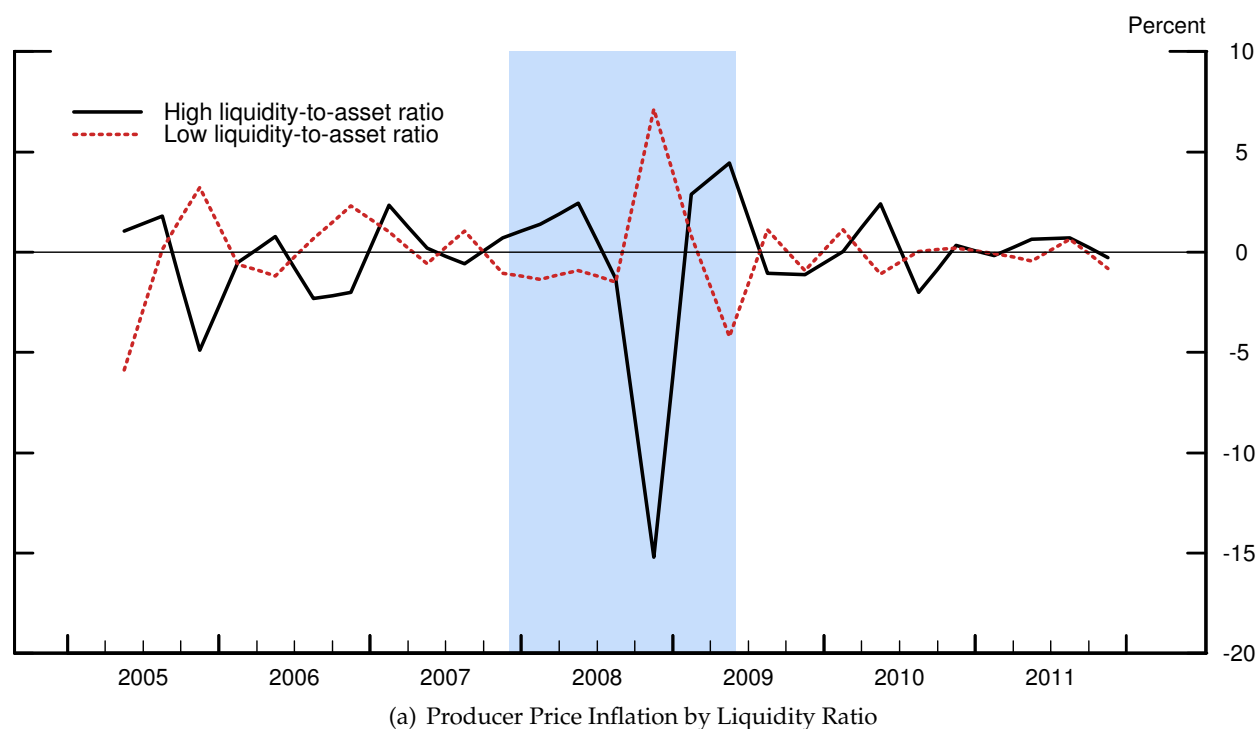
NOTE: We compute the above statistics using the full Compustat database for 2005 through 2011 and our matched sample. First, we compute at the firm level and quarterly frequency the ratio of cash and other liquid assets to total assets, the ratio of sales and administrative expenses to total assets, and the ratio of interest expenses to total assets. Second, we compute time-series averages for each firm of these ratios, total sales, total assets, and cash and other liquid assets. Finally, we report means, medians and standard deviations of these means, as well as of the average monthly number of firms in the data.

Figure 7: Monthly Producer Price Inflation Rates, Full and Matched PPI Sample



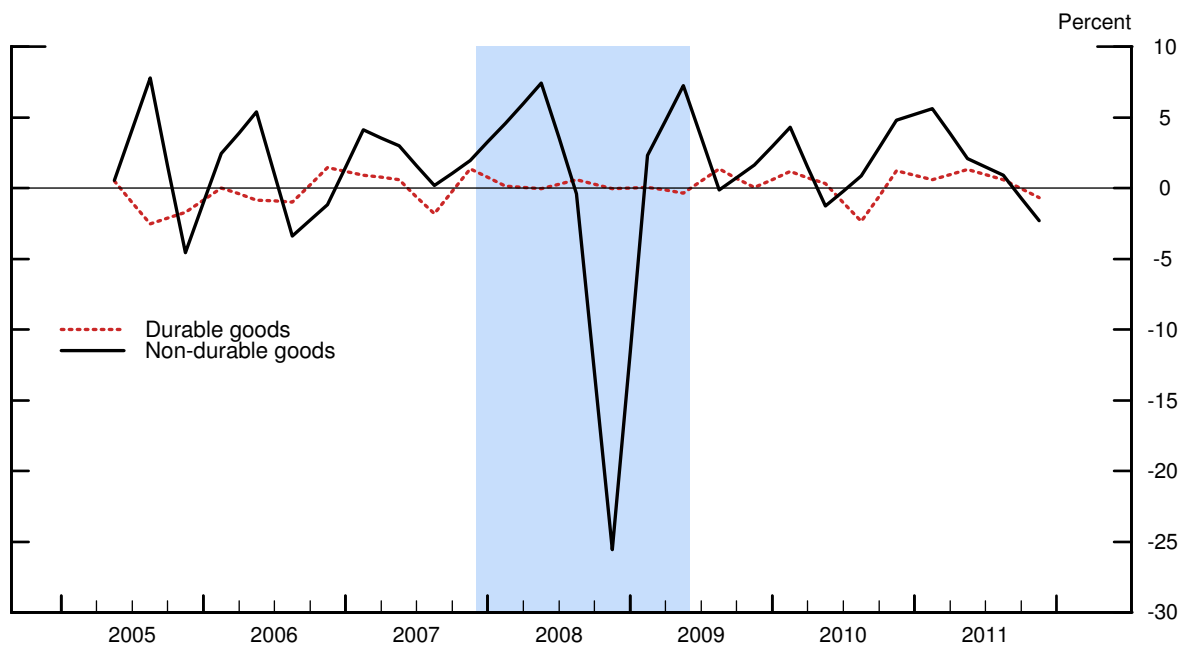
NOTE: The figure shows monthly inflation rates for the full PPI sample (red dotted line) and our matched sample (black solid line). To construct the series, we first average monthly log price changes within firms in each sample, then across firms.

Figure 8: Quarterly Producer Price Inflation by Selected Characteristics, Relative to Industry



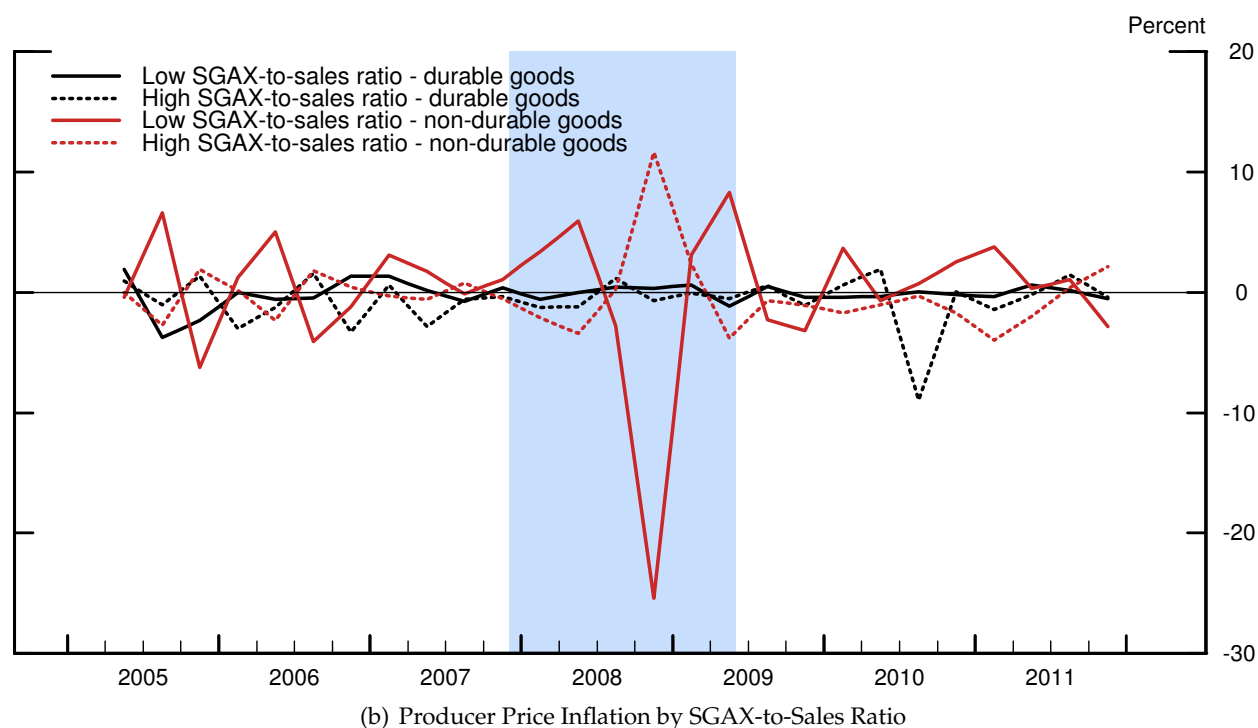
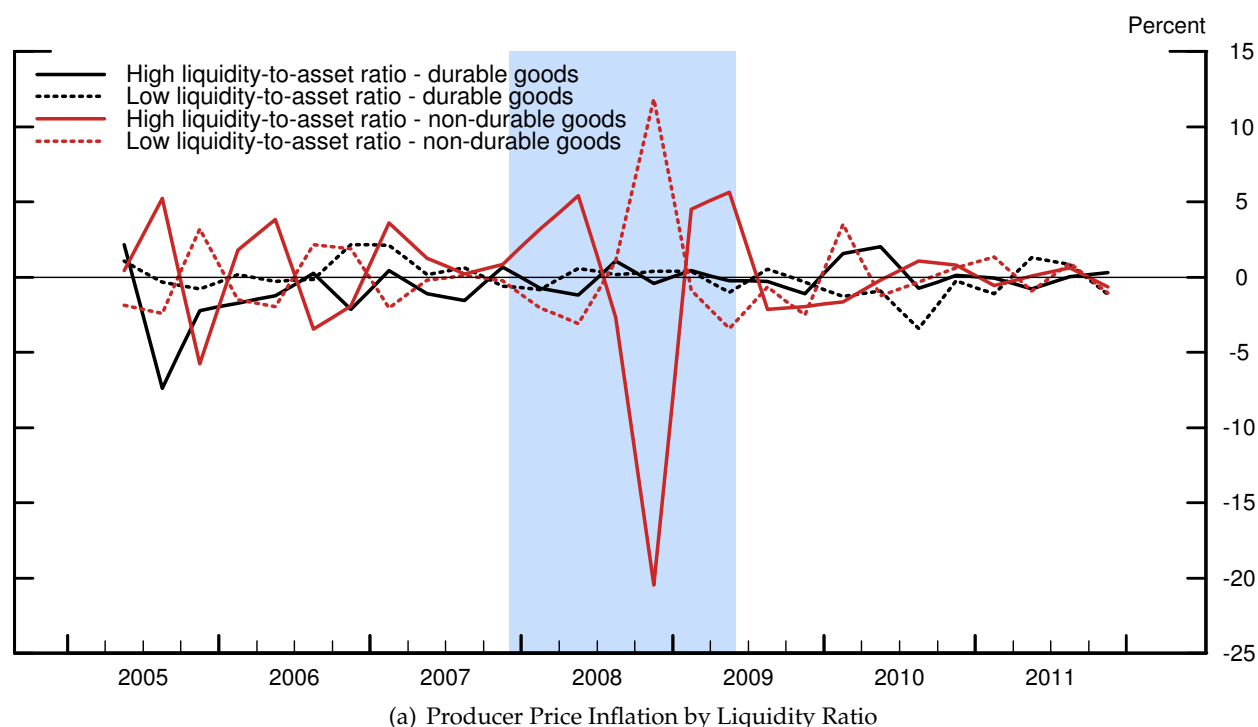
NOTE: Using the PPI micro data, we first filter out two-digit NAICS quarterly inflation rates from good-level log price changes. Second, we compute quarterly inflation rates at the level of the firm by calculating the weighted means of filtered log price changes using within-firm importance weights given by the BLS. Third, we group firms as having a liquidity ratio (SGAX-to-sale) ratio below and above the median values of their distribution. We compute rolling medians and condition on a lag of 3 months. Third, we take sales-weighted means in each quarterly cross section of firms.

Figure 9: Producer Price Inflation by Sector



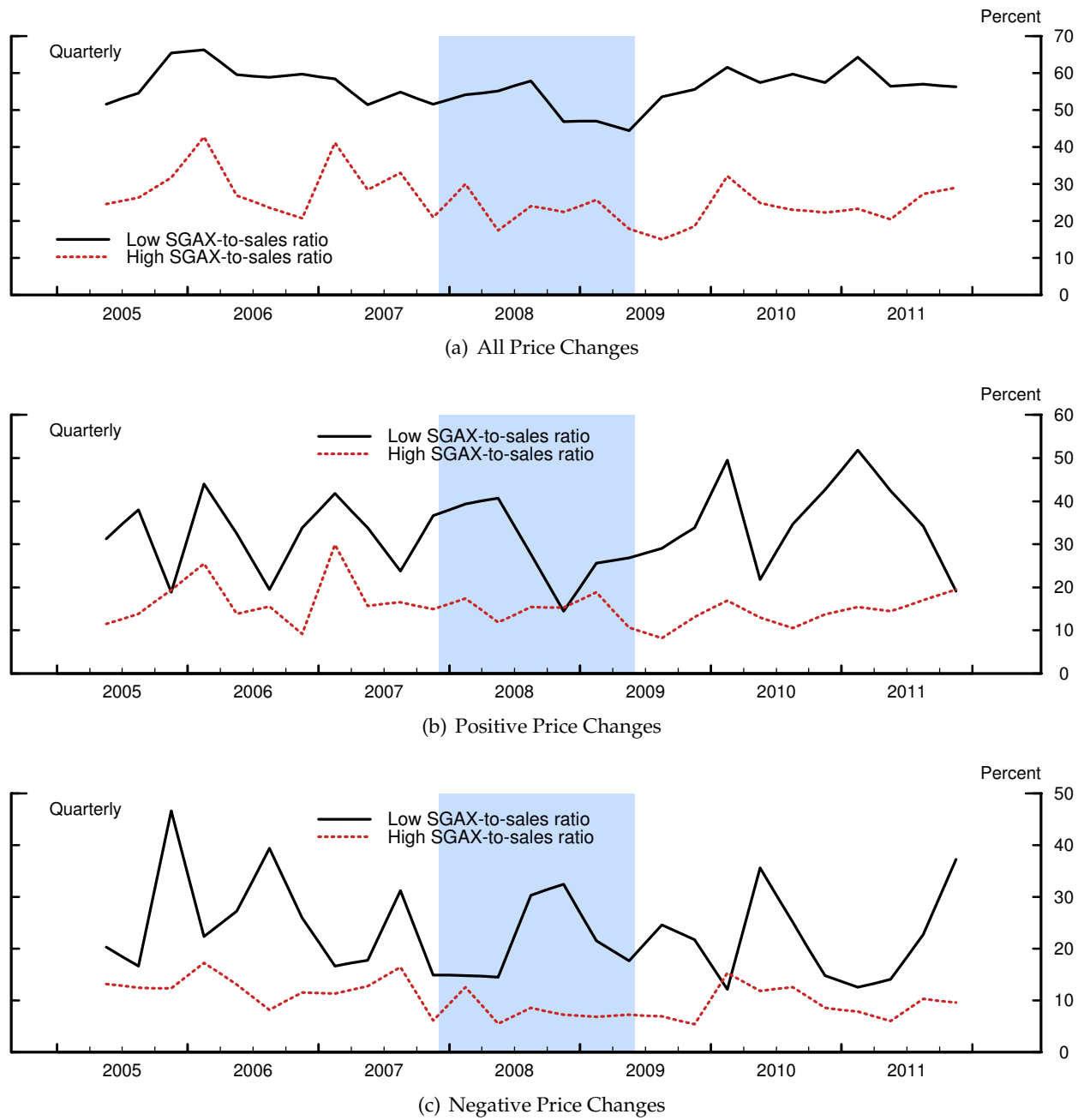
NOTE: Using the PPI micro data, we compute (non-)durable quarterly inflation rates in three steps. First, we compute quarterly inflation rates at the level of the firm by calculating the weighted means of unfiltered log price changes using within-firm importance weights given by the BLS. Second, we group firms according to their industry codes as belonging to either the durable or non-durable good producing sectors. Finally, we take sales-weighted means in each sector and quarterly cross section of firms.

Figure 10: Producer Price Inflation by Selected Characteristics and Sector, Relative to Industry



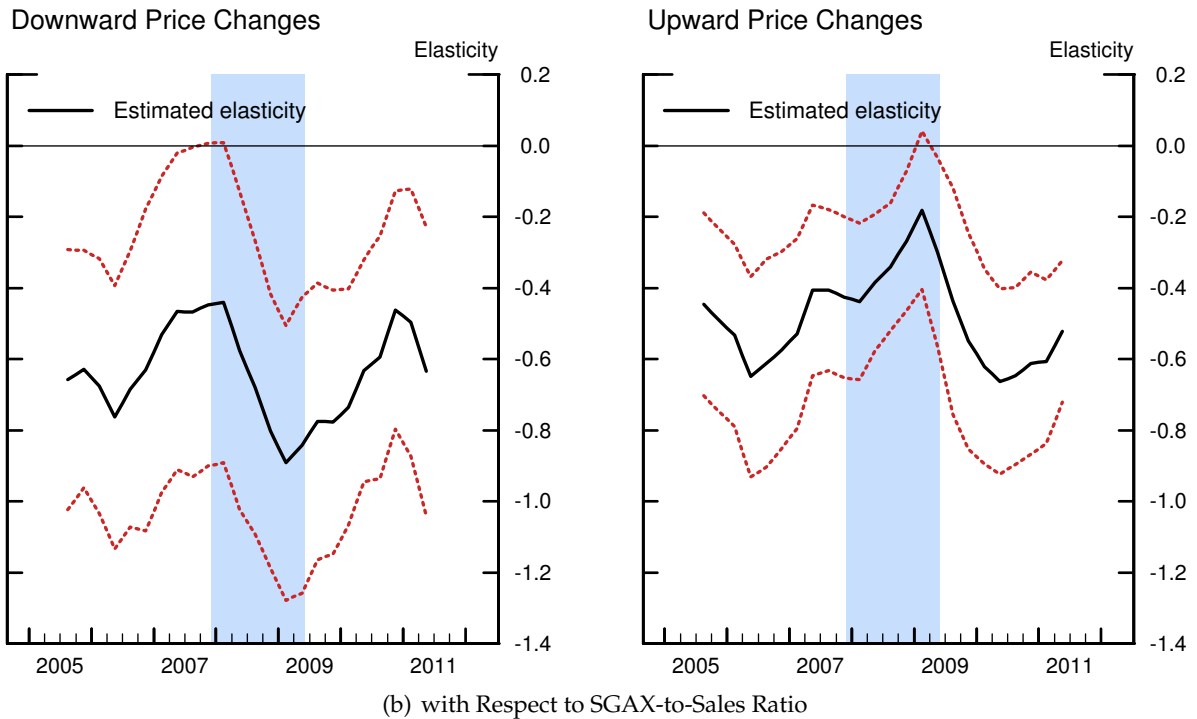
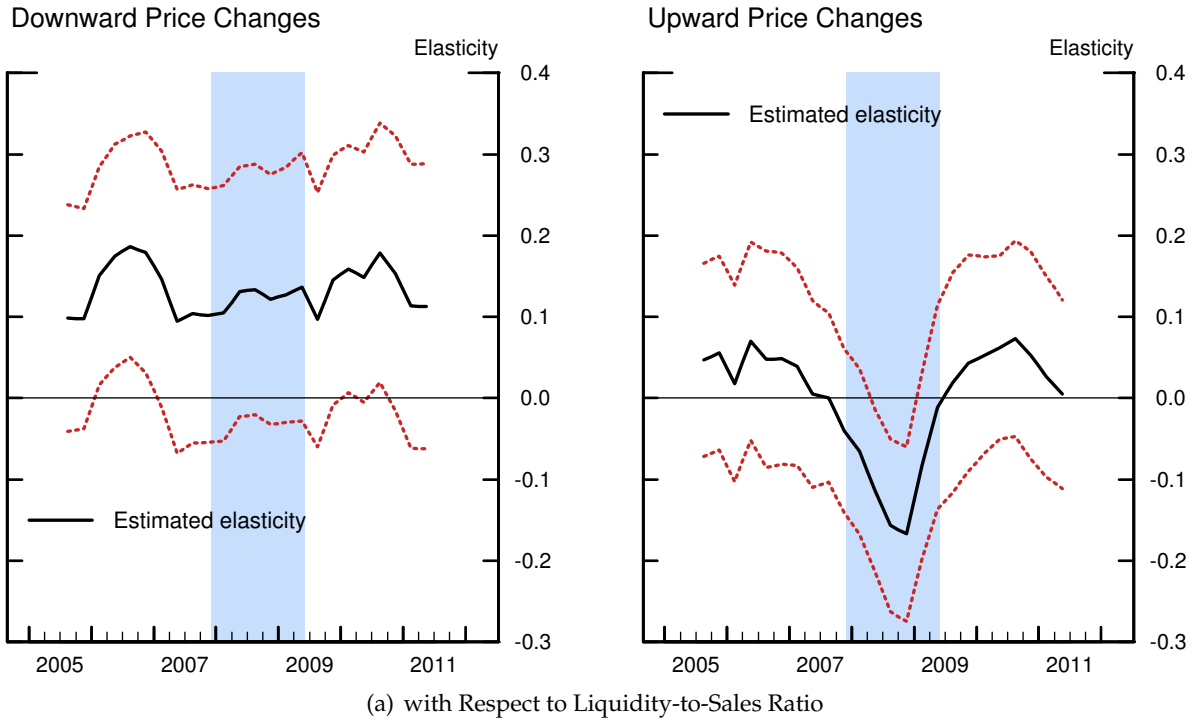
NOTE: First, we filter out two-digit NAICS quarterly inflation rates from PPI good-level log price changes. Second, we compute quarterly inflation rates at the level of the firm by calculating the weighted means of filtered log price changes using within-firm importance weights given by the BLS. Third, we group firms as having a liquidity ratio (SGAX-to-sale) ratio below and above the median values of their distribution and according to their industry codes as belonging to either the durable or non-durable good producing sectors. We compute rolling medians and condition on a lag of 3 months. Third, we take sales-weighted means in each of the four quarterly cross sections of firms.

Figure 11: Quarterly Frequency of Price Changes



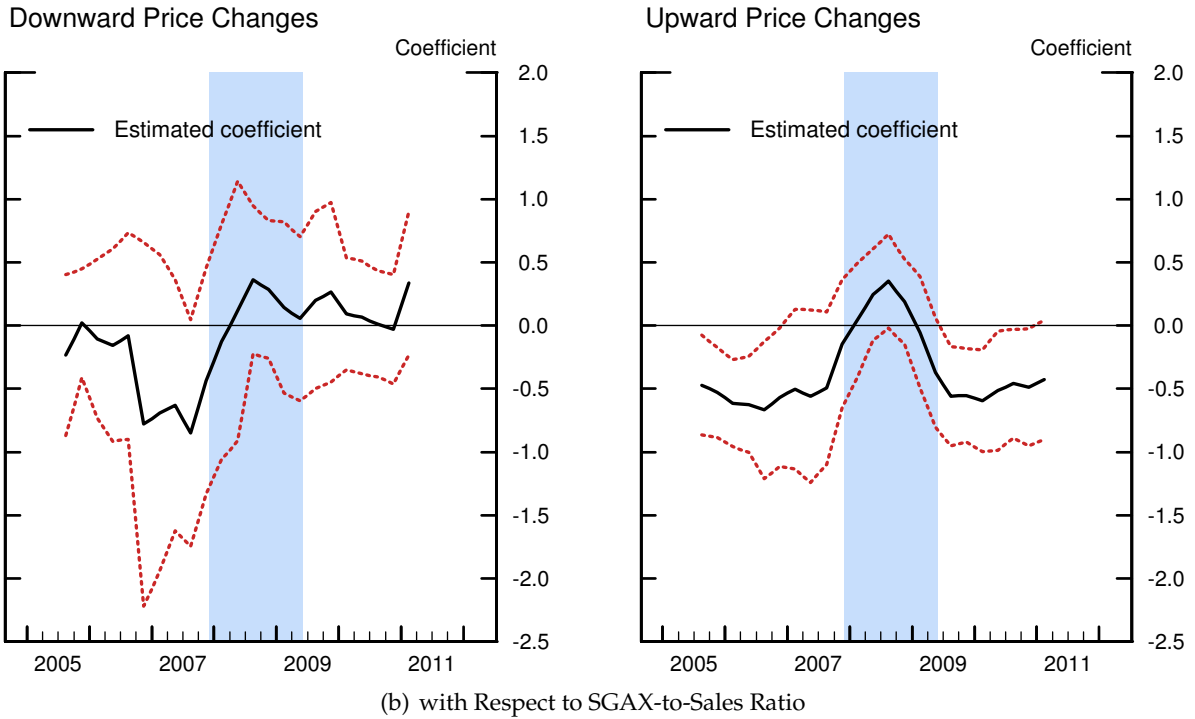
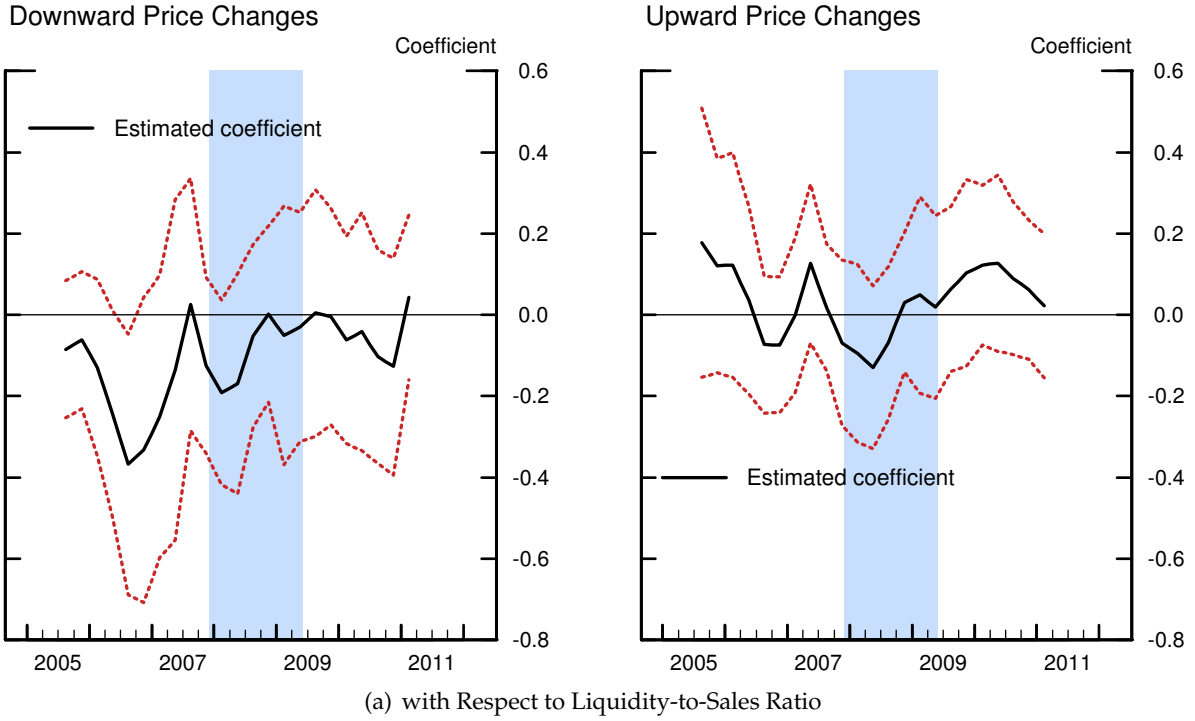
NOTE: First, we compute quarterly frequencies of price changes at the level of the firm by calculating the weighted means of a good-level indicator variable for quarterly log price changes using within-firm importance weights given by the BLS. Second, we group firms as having an SGAX-to-sale ratio below and above the median values of its distribution. We compute rolling medians and condition on a lag of 3 months. Third, we take sales-weighted means in each of the four quarterly cross sections of firms.

Figure 12: Elasticity of Price Changes with Respect to Selected Firm Characteristics



NOTE: We obtain elasticities of the decision to adjust prices upwards and downwards – relative to a base of no adjustment – by estimating the following multinomial logit model: $Pr(Y_{i,j,t+1} = 1, 0, -1 | X_{i,j,t} = x) = \Phi(\beta_t X_{i,j,t})$ where $Y_{i,j,t+1}$ is an indicator variable for upwards, or downwards PPI log price changes of good i produced by firm j at time $t + 1$. The explanatory variables $X_{i,j,t}$ are lagged 3 months at the firm level and include the liquidity-to-sales ratio, the SGAX-to-sales ratio and sales growth. We also include time and three-digit NAICS sector fixed effects. We estimate four-quarter rolling regressions and calculate quarterly elasticities around the mean.

Figure 13: Coefficients of Price Changes with Respect to Selected Firm Characteristics



NOTE: We obtain the plotted coefficients from estimating the following specification: $\Delta p_{i,j,t+1}^d = \beta_t X_{i,j,t} + \lambda_{i,j,t} + \epsilon_{i,j,t}$ where $\Delta p_{i,j,t+1}^d$ is the PPI good-level quarterly conditional upwards ($d = +1$)/downwards ($d = -1$) log price change of good i produced by firm j at time t . The explanatory variables $X_{i,j,t}$ are lagged 3 months at the firm level and include the liquidity-to-sales ratio, the SGAX-to-sales ratio and sales growth. We also include time and three-digit NAICS sector fixed effects, and $\lambda_{i,j,t}$ is a selection-correction term implemented as in Asplund et al. (2000). We estimate four-quarter rolling regressions.

Appendices

A Steady State (Not for Publication)

The Phillips curve in the steady state yields

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

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

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

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

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

Combining the three relationships, we reach

$$\begin{aligned} \eta^{-1} \left[1 + \frac{\varphi}{1-\varphi} [1 - \Phi(z)] \right] &= \frac{1-\rho\beta}{1-\rho\beta-\beta\theta(1-\eta)(1-\rho)} \\ &\times \left\{ 1 + \frac{\varphi}{1-\varphi} [1 - \Phi(z)] - \frac{1}{\mu} \left[1 + \frac{\varphi}{1-\varphi} [1 - \Phi(z - \sigma)] \right] \right\}. \end{aligned} \quad (31)$$

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

$$z = \frac{1}{\sigma} \left[\log \left(\mu \frac{\exp(\sigma^2)h - \phi}{\exp(\sigma^2)h} \right) + 0.5\sigma^2 \right]. \quad (32)$$

Solving this for μ , we obtain

$$\mu = \frac{\exp(\sigma z + 0.5\sigma^2)h}{\exp(\sigma^2)h - \phi}. \quad (33)$$

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

$$\frac{1}{\mu} = \zeta \tilde{p} \frac{h^{\gamma_h}}{x^{-\gamma_x}} = \zeta h^{\gamma_h} c^{\gamma_x(1-\theta)+\theta} \quad (34)$$

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 $h = (c + \phi) / \exp(\sigma^2)$.¹⁶ Substituting this in (31), (33), and (34), one can solve these three nonlinear equations for c , μ and z using a numerical root finder.

In contrast to Ravn et al. (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 ??

¹⁶The 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.

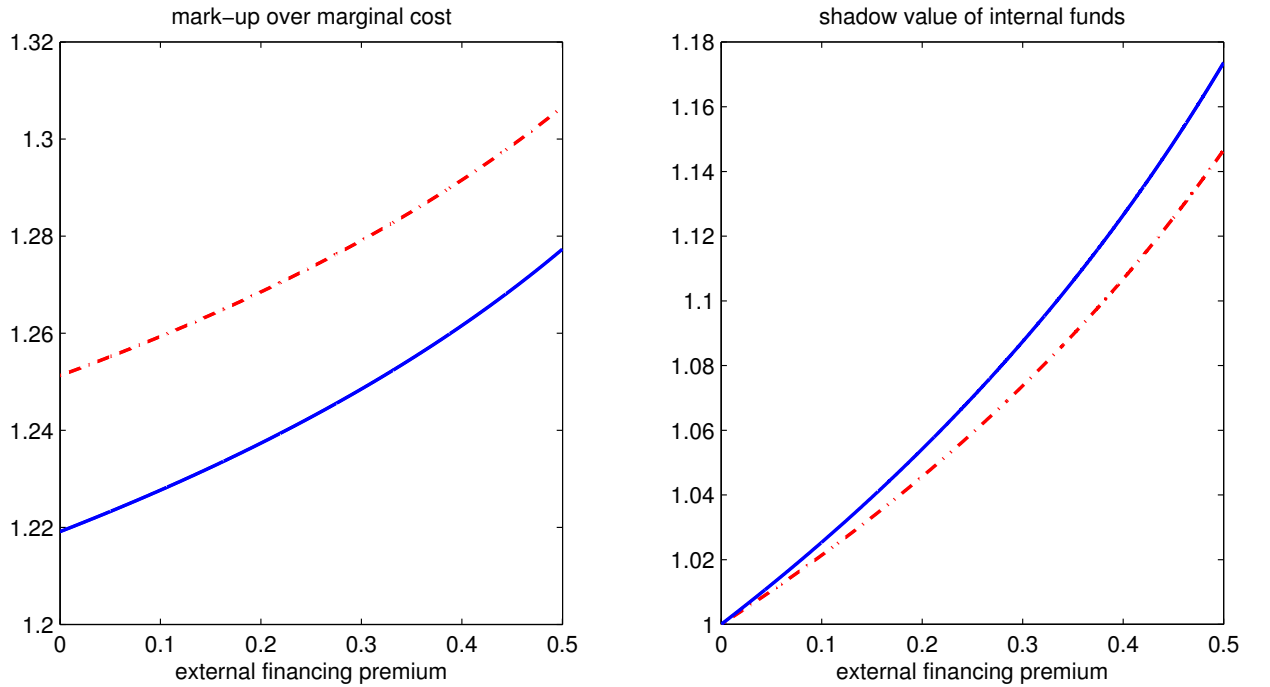
describes the relationship between the external financing premium on the horizontal axis and the mark-up on the vertical axis.¹⁷ As can be seen, the equilibrium mark-up is an *increasing* function of external financing premium.

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.,

$$v = \eta^{-1} \mathbb{E}^a[\tilde{\zeta}_i] = \eta^{-1} \left[1 + \frac{\varphi}{1 - \varphi} [1 - \Phi(z)] \right]$$

the positive relationship of the external financing premium with the value of internal funds also implies a positive relationship with the value marginal sales.

Figure 14: External Financing Cost, Equilibrium (Marginal) Mark-Up and Value of Internal Funds



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 ?. We will analyze the short run dynamics of the model under a financial shock that raises the cost of external financing using a perturbation

¹⁷To show this, we allocate 5,001 points on the interval $[0, 0.5]$ on the horizontal axis, and numerically solve for the equilibrium margin for each point in the interval using (31) and (32).

B System of Equations

There are 18 endogenous variables:

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

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} \\ v_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} v_{t+1} \frac{c_{t+1}}{s_t} \right] \\ 1 &= \frac{\eta v_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 exoge-

nous 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

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

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.