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Professor Richard Stanton

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Abstract

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Are prices sticky? This simple question has been at the cornerstone of heated discussions in macroeconomics for several decades. Price rigidities can potentially be an amplifying force for business cycle fluctuations and are the leading explanation for the effectiveness of monetary policy to stimulate the real side of the economy. Large-scale micro pricing datasets unambiguously show that prices at the micro level indeed adjust infrequently. This finding has moved the discussion about the existence of price stickiness to the question of whether or not they matter for the real economy. In my dissertation, I first address this question using information in the stock market valuation of firms. I then use information on the price stickiness of individual firms to better understand firms' exposure to systematic risk and the cross section of stock returns.

In the first chapter of my dissertation which is co-authored with Yuriy Gorodnichenko, I investigate whether sticky prices are costly and burden firms. A central tenet of New Keynesian models is that firms face costs of price adjustments or other rigidities that hinder them from adjusting output prices once hit by nominal or real shocks. Models in the tradition of the New Monetarist search literature instead suggest that sticky prices are an equilibrium outcome. These models generate sticky prices at the micro level even though firms could adjust prices at each instant in time without any costs. Both classes of models have vastly different implications for policy and business cycles. The key insight of this chapter is that sticky price firms should have a larger responsiveness of profits, returns, and volatilities to nominal or real shocks compared to flexible price firms in New Keynesian models, while New Monetarist search models predict an equal reaction across firms with different price stickiness. I show that after monetary policy announcements, the conditional volatility of stock market returns rises more for firms with stickier prices than for firms with more flexible prices. This differential reaction is economically large as well as strikingly robust to a broad array of checks. These results suggest that menu costs – broadly defined to include physical costs of price adjustment, informational frictions, etc. – are an important factor for nominal price rigidity. I also show that my empirical results are qualitatively and, under plausible

calibrations, quantitatively consistent with New Keynesian macroeconomic models in which firms have heterogeneous price stickiness. Since the framework is valid for a wide variety of theoretical models and frictions preventing firms from price adjustment, I provide "model-free" evidence that sticky prices are indeed costly for firms. My findings provide support for workhorse models with sticky prices at policy institutions and imply that nominal rigidities are a central force for the real effects of monetary policy.

The second chapter examines the asset-pricing implications of nominal rigidities. I find that firms that adjust their product prices infrequently earn a cross-sectional return premium of more than 4% per year. Merging confidential product price data at the firm level with stock returns, I document that the premium for sticky-price firms is a robust feature of the data and is not driven by other firm and industry characteristics. The consumption-wealth ratio is a strong predictor of the return differential in the time series, and differential exposure to systematic risk fully explains the premium in the cross section. The sticky-price portfolio has a conditional market β of 1.3, which is 0.4 higher than the β of the flexible-price portfolio. The frequency of price adjustment is therefore a strong determinant of the cross section of stock returns. To rationalize these facts, I develop a multi-sector production-based asset-pricing model with sectors differing in their frequency of price adjustment. My results show that nominal rigidities are not only central in macroeconomics for business cycle fluctuations and the real effects of nominal shocks but are also a strong determinant of the cross section of stock returns. To the extent that firms equalize the costs and benefits of price adjustment the higher cost of capital for firms with stickier prices can provide a holistic measure for the cost of price adjustment.

My dissertation shows that price rigidities explain both business-cycle dynamics in aggregate quantities and cross-sectional variation in stock returns, and further bridge macroeconomics and finance.

To my grandma, Irma Wesch

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Chapter 1

Are Sticky Prices Costly?

1.1 Introduction

In principle, fixed costs of changing prices can be observed and measured. In practice, such costs take disparate forms in different firms, and we have no data on their magnitude. So the theory can be tested at best indirectly, at worst not at all. Alan Blinder (1991)

Are sticky prices costly? This simple question stirs an unusually heated debate in macroeconomics. While there seems to be a growing consensus that prices at the micro-level are fixed in the short run,[1] it is still unclear why firms have rigid prices. A central tenet of New Keynesian macroeconomics is that firms face fixed "menu" costs of nominal price adjustment which can rationalize why firms may forgo an increase in profits by keeping existing prices unchanged after real or nominal shocks. However, the observed price rigidity does not necessarily entail that nominal shocks have real effects or that the inability of firms to adjust prices burdens firms. For example, Head et al. (2012) present a theoretical model where sticky prices arise endogenously even if firms are free to change prices at any time without any cost. This alternative theory has vastly different implications for business cycles and policy. How can one distinguish between these opposing motives for price stickiness? The key insight of this paper is that in New Keynesian models, sticky prices are costly to firms, whereas in other models they are not. While the sources and types of "menu" costs are likely to vary tremendously across firms thus making the construction of an integral measure of the cost of sticky prices extremely challenging, looking at market valuations of firms can provide a natural metric to determine whether price stickiness is indeed costly. In this paper, we exploit stock market information to explore these costs and— to the extent that firms equalize costs and benefits of nominal price adjustment—quantify "menu" costs. The evidence we document is consistent with the New Keynesian interpretation of price stickiness.

Specifically, we merge confidential micro-level data underlying the producer price index (PPI) from the Bureau of Labor Statistics (BLS) with stock price data for individual firms

[1] Bils and Klenow (2004), Nakamura and Steinsson (2008).

from NYSE Trade and Quote (taq) and study how stock returns of firms with different frequencies of price adjustment respond to monetary shocks (identified as changes in futures on the fed funds rates, the main policy instrument of the Fed) in narrow time windows around press releases of the Federal Open Market Committee (FOMC). To guide our empirical analyses, we show in a basic New Keynesian model that firms with stickier prices should experience a greater increase in the volatility of returns than firms with more flexible prices after a nominal shock. Intuitively, firms with larger costs of price adjustment tolerate larger departures from the optimal reset price. Thus, the range in which the discounted present value of cash flows can fluctuate is wider. The menu cost in this theoretical exercise is generic and, hence, our framework covers a broad range of models with inflexible prices.

Consistent with this logic, we find that returns for firms with stickier prices exhibit greater volatility after monetary shocks than returns of firms with more flexible prices, with the magnitudes being broadly in line with the estimates one can obtain from a calibrated New Keynesian model with heterogeneous firms: a hypothetical monetary policy surprise of 25 basis points (bps) leads to an increase in squared returns of $8\%^2$ for the firms with stickiest prices. This sensitivity is reduced by a factor of three for firms with the most flexible prices in our sample. Our results are robust to a large battery of specification checks, subsample analyses, placebo tests, and alternative estimation methods.

Our work contributes to a large literature aimed at quantifying the costs of price adjustment. Zbaracki et al. (2004) and others measure menu costs directly by keeping records of costs associated with every stage of price adjustments at the firm level (data collection, information processing, meetings, physical costs). Anderson et al. (2012) have access to wholesale costs and retail price changes of a large retailer. Exploiting the uniform pricing rule employed by this retailer for identification, they show that the absence of menu costs would lead to 18% more price changes. This approach sheds light on the process of adjusting prices, but it is difficult to generalize these findings given the heterogeneity of adjustment costs across firms and industries. Our approach is readily applicable to any firm with publicly traded equity, independent of industry, country or location. A second strand (e.g., Blinder (1991)) elicits information about costs and mechanisms of price adjustment from survey responses of managers. This approach is remarkably useful in documenting reasons for rigid prices but, given the qualitative nature of survey answers, it cannot provide a magnitude of the costs associated with price adjustment. In contrast, our approach can provide a quantitative estimate of these costs. A third group of papers (e.g. Klenow and Willis (2007), Nakamura and Steinsson (2008)) integrates menu costs into fully fledged dynamic stochastic general equilibrium (DSGE) models. Menu costs are estimated or calibrated at values that match moments of aggregate (e.g. persistence of inflation) or micro-level (e.g. frequency of price changes) data. This approach is obviously most informative if the underlying model is correctly specified. Given the striking variety of macroeconomic models in the literature and limited ability to discriminate between models with available data, one may be concerned that the detailed structure of a given DSGE model can produce estimates that are sensitive to auxiliary assumptions necessary to make the model tractable or computable. In contrast, our approach does not have to specify a macroeconomic model and thus our estimates are robust to alternative assumptions about the structure of the economy.[2]

Our paper is also related to the literature investigating the effect of monetary shocks on asset prices. In a seminal study, Cook and Hahn (1989) use an event study framework to examine the effects of changes in the federal funds rate on bond rates using a daily event window. They show that changes in the federal funds target rate are associated with changes in interest rates in the same direction with larger effects at the short end of the yield curve. Bernanke and Kuttner (2005)—also using a daily event window—focus on unexpected changes in the federal funds target rate. They find that an unexpected interest rate cut of 25 basis points leads to an increase in the CRSP value weighted market index of about 1 percentage point. Gürkaynak et al. (2005) focus on intraday event windows and find effects of similar magnitudes for the S&P500. Weber (2014) uses non-parametric portfolio sorts and panel regressions to show that sticky price firms command a cross sectional return premium of up to 4% per year compared to flexible price firms. In addition, besides the impact on the level of returns, monetary policy surprises also lead to greater stock market volatility. For example, consistent with theoretical models predicting increased trading and volatility after important news announcements (e.g. Harris and Raviv (1993) and Varian (1989)), Bomfim (2003) finds that the conditional volatility of the S&P500 spikes after unexpected FOMC policy movements. Given that monetary policy announcements also appear to move many macroeconomic variables (see e.g. Faust et al. (2004b)), these shocks are, thus, a powerful source of variation in the data.

There are several limitations to our approach. First, we require information on returns with frequent trades to ensure that returns can be precisely calculated in narrow event windows. This constraint excludes illiquid stocks with infrequent trading. We focus on the constituents of the S&P500 which are all major US companies with high stock market capitalization.[3] Second, our methodology relies on unanticipated, presumably exogenous shocks that influence the stock market valuation of firms. A simple metric of this influence could be whether a given shock moves the aggregate stock market. While this may appear an innocuous constraint, most macroeconomic announcements other than the Fed's (e.g. the surprise component of announcements of GDP or unemployment figures by the Bureau of Economic Analysis (BEA) and BLS) fail to consistently move the stock market in the U.S. Third, our approach is built on "event" analysis and therefore excludes shocks that hit the economy continuously. Finally, we rely on the efficiency of financial markets.[4]

[2]Other recent contributions to this literature are Goldberg and Hellerstein (2011), Eichenbaum et al. (2011) Midrigan (2011), Eichenbaum et al. (2012), Bhattarai and Schoenle (2012), Vavra (2013), Berger and Vavra (2013). See Klenow and Malin (2010) and Nakamura and Steinsson (2013) for recent reviews of this literature.

[3]The intraday event window restricts our universe of companies to large firms as small stocks in the early part of our sample often experienced no trading activity for several hours even around macroeconomic news announcements contrary to the constituents of the S&P500. Given the high volume of trades for the latter firms, news are quickly incorporated into stock prices. For example, Zebedee et al. (2008) among others show that the effect of monetary policy surprises is impounded into prices of the S&P500 within minutes.

[4]Even though the information set required by stock market participants may appear large (frequencies of price adjustments, relative prices etc.), we document in Section 1.4 that the effects for conditional stock

The rest of the paper is structured as follows. The next section describes how our measure of price stickiness at the firm level is constructed. Section 1.3 lays out a static version of a New Keynesian model with sticky prices and provides guidance for our empirical specification. This section also discusses our high frequency identification strategy employing nominal shocks from fed funds futures and the construction of our variables and controls. Section 1.4 presents the estimates of the sensitivity of squared returns to nominal shocks as a function of price stickiness. Section 1.5 calibrates a dynamic version of a New Keynesian model to test whether our empirical estimates can be rationalized by a reasonably calibrated model. Section 1.6 concludes and discusses further applications of our novel methodology.

1.2 Measuring Price Stickiness

A key ingredient of our analysis is a measure of price stickiness at the firm level. We use the confidential microdata underlying the PPI of the BLS to calculate the frequency of price adjustment for *each* firm in our sample. The PPI measures changes in selling prices from the perspective of producers, as compared to the Consumer Price Index (CPI) which looks at price changes from the consumers' perspective. The PPI tracks prices of all goods producing industries such as mining, manufacturing, gas and electricity, as well as the service sector. The PPI covers about three quarters of the service sector output.

The BLS applies a three stage procedure to determine the individual goods included in the PPI. In the first step, the BLS compiles a list of all firms filing with the Unemployment Insurance system. This information is then supplemented with additional publicly available data which is of particular importance for the service sector to refine the universe of establishments.

In the second step, individual establishments within the same industry are combined into clusters. This step ensures that prices are collected at the price forming unit as several establishments owned by the same company might constitute a profit maximizing center. Price forming units are selected for the sample based on the total value of shipments or the number of employees.

After an establishment is chosen and agrees to participate, a probability sampling technique called *disaggregation* is applied. In this final step, the individual goods and services to be included in the PPI are selected. BLS field economists combine individual items and services of a price forming unit into categories, and assign sampling probabilities proportional to the value of shipments. These categories are then further broken down based on price

return volatility also hold for firm profits. Therefore, sophisticated investors can reasonably identify firms with increased volatility after monetary policy shocks and trade on this information using option strategies such as straddles. A straddle consists of simultaneously buying a call and a put option on the same stock with the same strike price and time to maturity and profits from increases in volatility. It is an interesting question to analyze the identity of traders around macroeconomic news announcements: private investors or rational arbitrageurs and institutional investors. Results of Erenburg et al. (2006) and Green (2004) and the fact that news are incorporated into prices within minutes indicate the important role of sophisticated traders around macroeconomic news announcements.

determining characteristics until unique items are identified. If identical goods are sold at different prices due to e.g. size and units of shipments, freight type, type of buyer or color then these characteristics are also selected based on probabilistic sampling.

The BLS collects prices from about 25,000 establishments for approximately 100,000 individual items on a monthly basis. The BLS defines PPI prices as "net revenue accruing to a specified producing establishment from a specified kind of buyer for a specified product shipped under specified transaction terms on a specified day of the month".[5] Taxes and fees collected on behalf of federal, state or local governments are not included. Discounts, promotions or other forms of rebates and allowances are reflected in PPI prices insofar as they reduce the revenues received by the producer. The same item is priced month after month. The BLS undertakes great efforts to adjust for quality changes and product substitutions so that only true price changes are measured.

Prices are collected via a survey which is emailed or faxed to participating establishments. The survey asks whether the price has changed compared to the previous month and if yes, the new price is asked.[6] Individual establishments remain in the sample for an average of seven years until a new sample is selected in the industry. This resampling occurs to account for changes in the industry structure and changing product market conditions within the industry.

We calculate the frequency of price adjustment as the mean fraction of months with price changes during the sample period of an item. For example, if an observed price path is $4 for two months and then $5 for another three months, there is one price change during five months and hence the frequency is 1/5.[7] When calculating the frequency of price adjustment, we exclude price changes due to sales. We identify sales using the filter employed by Nakamura and Steinsson (2008). Including sales does not affect our results in any material way because, as documented in Nakamura and Steinsson (2008), sales are rare in producer prices.

We aggregate frequencies of price adjustments at the establishment level and further aggregate the resulting frequencies at the company level. The first aggregation is performed via internal establishment identifiers of the BLS. To perform the firm level aggregation, we *manually* check whether establishments with the same or similar names are part of the same company. In addition, we search for names of subsidiaries and name changes e.g. due to

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[5] See Chapter 14, BLS Handbook of Methods, available under http://www.bls.gov/opub/hom/.

[6] This two stage procedure might lead to a downward bias in the frequency of price adjustment. Using the anthrax scare of 2001 as a natural experiment, Nakamura and Steinsson (2008) show, however, that the behavior of prices is insensitive to the collection method: during October and November 2001 all government mail was redirected and the BLS was forced to collect price information via phone calls. Controlling for inflation and seasonality in prices, they do not find a significant difference in the frequency of price adjustment across the two collection methods.

[7] We do not consider the first observation as a price change and do not account for left censoring of price spells. Bhattarai and Schoenle (2012) verify that explicitly accounting for censoring does not change the resulting distribution of probabilities of price adjustments. Our baseline measure treats missing price values as interrupting price spells. Appendix A contains results for alternative measures of the frequency of price adjustment; results are quantitatively and statistically very similar.

mergers, acquisitions or restructurings occurring during our sample period for all firms in our financial dataset.

We discuss the fictitious case of a company Milkwell Inc. to illustrate aggregation to the firm level. Assume we observe product prices of items for the establishments Milkwell Advanced Circuit, Milkwell Aerospace, Milkwell Automation and Control, Milkwell Mint, and Generali Enel. In the first step, we calculate the frequency of product price adjustment at the item level and aggregate this measure at the establishment level for all of the above mentioned establishments.[8] We calculate both equally weighted frequencies (baseline) and frequencies weighted by values of shipments associated with items/establishments (see Appendix A) say for establishment Milkwell Aerospace. We then use publicly available information to check whether the individual establishments are part of the same company. Assume that we find that all of the above mentioned establishments with Milkwell in the establishment name but Milkwell Mint are part of Milkwell Inc. Looking at the company structure, we also find that Milkwell has several subsidiaries, Honeymoon, Pears and Generali Enel. Using this information, we then aggregate the establishment level frequencies of Milkwell Advanced Circuit, Milkwell Aerospace, Milkwell Automation and Control and Generali Enel at the company level, again calculating equally weighted and value of shipments weighted frequencies.

Table 1.1 reports mean probabilities, standard deviations and the number of firm-event observations for our measures of the frequency of price adjustment, both for the total sample and for each industry separately.[9,10] The overall mean frequency of price adjustment (FPA) is 14.66%/month implying an average duration, $-1/ln(1-FPA)$, of 6.03 months. There is a substantial amount of heterogeneity in the frequency across sectors, ranging from as low as 8.07%/month for the service sector (implying a duration of almost one year) to 25.35%/month for agriculture (implying a duration of 3.42 months). Finally, the high standard deviations highlight dramatic heterogeneity in measured price stickiness across firms even within industries. Different degrees of price stickiness of similar firms operating in the same industry can arise due to a different customer and supplier structure, heterogeneous organizational structure or varying operational efficiencies and management philosophies.[11]

[8] Items in our dataset are alpha-numeric codes in a SAS dataset and we cannot identify their specific nature.

[9] The coarse definition of industries is due to confidentiality reasons and also partially explains the substantial variation of our measures of price stickiness within industry.

[10] A potential concern is that our measure of price stickiness is measured with noise which might bias the estimates in our empirical analysis. To alleviate this concern we use the full time series to construct our measure. Focusing on large companies comprising the S&P500 further mitigates this potential issue as these firms have many individual items in the PPI sample. In addition, we find that there is little variation in the frequency of price adjustment over time at the firm level in our sample period which would require a very persistent form of measurement error at the firm level. Allowing for time series variation has little impact on our findings.

[11] Nakamura and Steinsson (2008) report a median frequency of price changes for producer prices between 1998 and 2005 of 10.8%, 13.3% and 98.9% for finished producer goods, intermediate goods and crude materials, respectively corresponding to median implied durations of 8.7, 7 and 0.2 months.

1.3 Framework

In this section, we outline the basic intuition for how returns and price stickiness are related in the context of a New Keynesian macroeconomic model. We will focus on one shock—monetary policy surprises—which has a number of desirable properties.[12] While restricting the universe of shocks to only monetary policy shocks limits our analysis in terms of providing an integral measure of costs of sticky prices, it is likely to greatly improve identification and generate a better understanding of how sticky prices and stock returns are linked. This section also guides us in choosing regression specifications for the empirical part of the paper and describes how variables are constructed.

Static model

We start with a simple, static model to highlight intuition for our subsequent theoretical and empirical analyses. Suppose that a second-order approximation to a firm's profit function is valid so that the payoff of firm i can be expressed as $\pi_i \equiv \pi(P_i, P^*) = \pi_{max} - \psi(P_i - P^*)^2$ where P^* is the optimal price given economic conditions, P_i is the current price of firm i, π_{max} is the maximum profit a firm can achieve and ψ captures the curvature of the profit function.[13] The blue, solid line in Figure 1.1 shows the resulting approximation.

Furthermore assume that a firm has to pay a menu cost ϕ if it wants to reset its price. This cost should be interpreted broadly as not only the cost of re-printing a menu with new prices but also includes costs associated with collecting and processing information, bargaining with suppliers and customers, etc. A firm resets its price from P_i to P^* only if the gains from doing so exceed the menu cost, that is, $\psi(P_i - P^*)^2 > \phi$. If the menu cost is low ($\phi = \phi_L$), then the range of prices consistent with inaction (non-adjustment of prices) is $(\underline{P}_L, \overline{P}_L)$. If the menu cost is high ($\phi = \phi_H$), then the range of price deviations from P^* is wider $(\underline{P}_H, \overline{P}_H)$. As a result, the frequency of price adjustment is ceteris paribus lower for firms with larger menu costs. Denote the frequency of price adjustment with $\lambda \equiv \lambda(\phi)$ with $\partial\lambda/\partial\phi < 0$. We can interpret $1 - \lambda$ as degree of price stickiness.

Without loss of generality, we can assume that prices of low-menu-cost and high-menu-cost firms are spread in $(\underline{P}_L, \overline{P}_L)$ and $(\underline{P}_H, \overline{P}_H)$ intervals, respectively, because firms are hit with idiosyncratic shocks (e.g. different timing of price adjustments as in Calvo (1983), firm-specific productivity, cost and demand shocks) or aggregate shocks we are not controlling for in our empirical exercise. Suppose there is a nominal shock which moves P^* to the right (denote this new optimal price with P^*_{new}) so that the payoff function is now described by the red, dashed line. This shift can push some firms outside their inaction bands and they

[12] Bernanke and Kuttner (2005) emphasize the importance of financial markets for the conduct of monetary policy: "The most direct and immediate effects of monetary policy actions, such as changes in the Federal funds rate, are on financial markets; by affecting asset prices and returns, policymakers try to modify economic behavior in ways that will help to achieve their ultimate objectives."

[13] This expansion does not have a first-order term in $(P_i - P^*)$ because firm optimization implies that the first derivative is zero in the neighborhood of P^*.

will reset their prices to P^*_{new} and thus weakly increase their payoffs, (i.e. $\pi(P^*_{new}, P^*_{new}) - \pi(P_i, P^*_{new}) \geq \phi$). If the shock is not too large, many firms will continue to stay inside their inaction bands.

Obviously, this non-adjustment does not mean that firms have the same payoffs after the shock. Firms with negative $(P_i - P^*)$ will clearly lose (i.e. $\pi(P_i, P^*_{new}) - \pi(P_i, P^*) < 0$) as their prices become even more suboptimal. Firms with positive $(P_i - P^*_{new})$ will clearly gain (i.e. $\pi(P_i, P^*_{new}) - \pi(P_i, P^*) > 0$) as their suboptimal prices become closer to optimal. Firms with positive $(P_i - P^*)$ and negative $(P_i - P^*_{new})$ may lose or gain. In short, a nominal shock to P^* redistributes payoffs.

Note that there are losers and winners for both low-menu-cost and high-menu-cost firms. In other words, if we observe an increased payoff, we cannot infer that this increased payoff identifies a low-menu-cost firm. If we had information about $(P_i - P^*_{new})$ and/or $(P_i - P^*)$, that is, *relative* prices of firms, then we could infer the size of menu costs directly from price resets. It is unlikely that this information is available in a plausible empirical setting as P^* is hardly observable.

Fortunately, there is an unambiguous prediction with respect to the variance of changes in payoffs in response to shocks. Specifically, firms with high menu costs have larger variability in payoffs than firms with low menu costs. Indeed, high-menu-cost firms can tolerate a loss of up to ϕ_H in profits while low-menu-cost firms take at most a loss of ϕ_L. This observation motivates the following empirical specification:

$$(\Delta\pi_i)^2 = b_1 \times v^2 + b_2 \times v^2 \times \lambda(\phi_i) + b_3 \times \lambda(\phi_i) + error.$$

where $\Delta\pi_i$ is a change in payoffs (return) for firm i, v is a shock to the optimal price P^*, $error$ absorbs movements due to other shocks. In this specification, we expect $b_1 > 0$ because a shock v results in increased volatility of payoffs. We also expect $b_2 < 0$ because the volatility increases less for firms with smaller bands of inaction and hence with more flexible prices. Furthermore, the volatility of profits should be lower for low-menu-cost firms unconditionally so that $b_3 < 0$. In the polar case of no menu costs, there is no volatility in payoffs after a nominal shock as firms always make π_{max}. Therefore, we also expect that $b_1 + b_2 \approx 0$. To simplify the exposition of the static model, we implicitly assumed that nominal shocks do not move the profit function up or down. If this assumption is relaxed, $b_1 + b_2$ can be different from zero. We do *not* make this assumption in either the dynamic version of the model presented in Section 1.5 or our empirical analyses. We find in simulations and in the data that $b_1 + b_2 \approx 0$.

While the static model provides intuitive insights about the relationship between payoffs and price stickiness, it is obviously not well suited for quantitative analyses for several reasons. First, when firms decide whether to adjust their product prices they compare the cost of price adjustment with the present value of future increases in profits associated with adjusting prices. Empirically, we measure returns that capture both current dividends/profits and changes in the valuation of firms. Since returns are necessarily forward looking, we have to consider a dynamic model. Second, general equilibrium effects may attenuate or amplify effects of heterogeneity in price stickiness on returns. Indeed, strategic interaction between firms is often emphasized as the key channel of gradual price adjustment in response to aggregate shocks. For example, in the presence of strategic interaction and some firms with sticky prices, even flexible price firms may be reluctant to change their prices by large amounts and thus may appear to have inflexible prices (see e.g. Haltiwanger and Waldman (1991) and Carvalho (2006)). Finally, the sensitivity of returns to macroeconomic shocks is likely to depend on the cross-sectional distribution of relative prices which varies over time and may be difficult to characterize analytically.

To address these concerns and check whether the parameter estimates in our empirical analysis of Section 1.4 are within reasonable ranges, we calibrate the dynamic multi-sector model developed in Carvalho (2006) where firms are heterogeneous in the degree of price stickiness in Section 1.5.

Identification

Identification of unanticipated, presumably exogenous shocks to monetary policy is central for our analysis. In standard macroeconomic contexts (e.g. structural vector autoregressions), one may achieve identification by appealing to minimum delay restrictions where monetary policy is assumed to be unable to influence the economy (e.g. real GDP or unemployment rate) within a month or a quarter. However, asset prices are likely to respond to changes in monetary policy within days if not hours or minutes. Balduzzi et al. (2001) show for bonds and Andersen et al. (2003) for exchange rates that announcement surprises are almost immediately incorporated into asset prices. Furthermore, Rigobon and Sack (2003) show that monetary policy is systematically influenced by movements in financial markets within a month. In short, stock prices and monetary policy can both change following major macroeconomic news and can respond to changes in each other even in relatively short time windows.

To address this identification challenge, we employ an event study approach in the tradition of Cook and Hahn (1989) and more recently Kuttner (2001), Bernanke and Kuttner (2005) and Gürkaynak et al. (2005). Specifically, we examine the behavior of returns and changes in the Fed's policy instrument in narrow time windows (30 minutes, 60 minutes, daily) around FOMC press releases. In these narrow time windows, the only relevant shock (if any) is likely due to changes in monetary policy.

However, not every change in policy rates affects stock prices at the time of the change. In informationally efficient markets, anticipated changes in monetary policy are already incorporated into prices and only the surprise components of monetary policy changes should matter for stock returns.[14] To isolate the unanticipated part of the announced changes of the target rate, we use federal funds futures which provide a high-frequency market-based measure of the anticipated path of the fed funds rate. This measure has a number of

[14]Bernanke and Kuttner (2005) perform a decomposition in expected and unexpected changes in the federal funds target rate and indeed show that only the unanticipated component systematically moves the stock market.

advantages: i) it allows for a flexible characterization of the policy reaction function; ii) it can accommodate changes in the policy reaction function of decision makers at the FOMC; and iii) it aggregates a vast amount of data processed by the market. Krueger and Kuttner (1996) show that federal funds futures are an efficient predictor of future federal funds rates. Macroeconomic variables such as the change in unemployment rate or industrial production growth have no incremental forecasting power for the federal funds rate once the federal funds futures is included in forecasting regressions. In similar spirit, Gürkaynak et al. (2007) provide evidence that the federal funds futures dominate other market based instruments in forecasting the federal funds rate. In short, fed funds futures provides a powerful and simple summary of market expectations for the path of future fed funds rates. Using this insight, we can calculate the surprise component of the announced change in the federal funds rate as:

$$v_t = \frac{D}{D-t}(ff^0_{t+\Delta t^+} - ff^0_{t-\Delta t^-}) \tag{1.1}$$

where t is the time when the FOMC issues an announcement, $ff^0_{t+\Delta t^+}$ is the fed funds futures rate shortly after t, $ff^0_{t-\Delta t^-}$ is the fed funds futures rate just before t, and D is the number of days in the month.[15] The $D/(D-t)$ term adjusts for the fact that the federal funds futures settle on the average effective overnight federal funds rate. We follow Gürkaynak et al. (2005) and use the unscaled change in the next month futures contract if the event day occurs within the last seven days of the month. This ensures that small targeting errors in the federal funds rate by the trading desk at the New York Fed, revisions in expectations of future targeting errors, changes in bid-ask spreads or other noise, which have only a small effect on the current month average, is not amplified through multiplication by a large scaling factor.

Using this shock series, we apply the following empirical specification to assess whether price stickiness leads to differential responses of stock returns:

$$\begin{aligned} R^2_{it} &= b_0 + b_1 \times v^2_t + b_2 \times v^2_t \times \lambda_i + b_3 \times \lambda_i \\ &\quad + FirmControls + FirmControls \times v^2_t + error \end{aligned} \tag{1.2}$$

where R^2_{it} is the squared return of stock i in the interval $[t-\Delta t^-, t+\Delta t^+]$ around event t, v^2_t is the squared monetary policy shock and λ_i is the frequency of price adjustment of firm i. Below, we provide details on how high frequency shocks and returns are constructed and we briefly discuss properties of the constructed variables. Our identification does not

[15] We implicitly assume in these calculations that the average effective rate within the month is equal to the federal funds target rate and that only one rate change occurs within the month. Due to changes in the policy target on unscheduled meetings we have six observations with more than one change in a given month. As these policy moves were not anticipated, they most likely have no major impact on our results. We nevertheless analyze intermeeting policy decisions separately in our empirical analyses. While constructing v_t, we have also implicitly assumed that a potential risk premium does not change in the $[t-\Delta t^-, t+\Delta t^+]$ window, which is consistent with results in Piazzesi and Swanson (2008).

require immediate reaction of inflation to monetary policy shocks but can also operate trough changes in current and future demand and costs which are immediately incorporated in returns through changes in the discounted value of profits.[16]

Data

We acquired tick-by-tick data of the federal funds futures trading on the Chicago Mercantile Exchange (CME) Globex electronic trading platform (as opposed to the open outcry market) directly from the CME. Using Globex data has the advantage that trading in these contracts starts on the previous trading day at 6.30 pm ET (compared to 8.20am ET in the open outcry market). We are therefore able to calculate the monetary policy surprises for all event days including the intermeeting policy decisions occurring outside of open outcry trading hours. To provide some insights into the quality of the data and the adequacy of our high frequency identification strategy we plot the futures based expected federal funds rate for three event date in Figure 1.2.[17] This plot shows two general patterns in the data: high trading activity around FOMC press releases and immediate market reaction following the press release.

The FOMC has eight scheduled meetings per year and starting with the first meeting in 1995, most press releases are issued around 2.15 pm ET. We obtained event dates, time stamps of the press releases, actual target rates changes as well as expected and unexpected changes for the period up to 2004 from Gürkaynak et al. (2005). The time stamps of the press releases in the later part of the sample were provided by the FOMC Freedom of Information Service Act Service Center. The release times are based on the timing of the first FOMC statement related story appearing in the press. We consider "tight" and "wide" time windows around the announcement. The tight (wide) window is 30 (60) minutes and starts $\Delta t^- =$ 10 (15) minutes before the press releases are issued.

Panel A of Table 1.2 reports descriptive statistics for surprises in monetary policy for all 137 event dates between 1994 and 2009 as well as separately for turning points in monetary policy and intermeeting policy decisions. Turning points are target rate changes in the direction opposite to previous changes. Jensen et al. (1996) argue that the Fed is operating under the same fundamental monetary policy regime until the first change in the target rate in the opposite direction. This is in line with the observed level of policy inertia and interest rate smoothing (cf. Piazzesi (2005) and Coibion and Gorodnichenko (2012) as well as Figure 1.3). Monetary policy reversals therefore contain valuable information on the future policy stance.

The average monetary policy shock is approximately zero. The most negative shock is with more than -45 bps about three times larger in absolute value than the most positive

[16]Bernanke and Kuttner (2005) show for a sample period similar to ours that surprises in the federal funds rate on market excess returns operate mainly trough their impact on future dividends highlighting the importance of the cash flow channel in explaining the effects of monetary policy shocks on *aggregate* stock market returns. Vuolteenaho (2002) shows that stock returns at the *firm* level are mainly driven by cash flow news contrary to the findings of Campbell (1991) and Cochrane (1992) for the *aggregate* market.

[17]Similar plots for the earlier part of our sample can be found in Gürkaynak et al. (2005).

shock. Policy surprises on intermeeting event dates and turning points are more volatile than surprises on scheduled meetings. Andersen et al. (2003) point out that financial markets react differently on scheduled versus non-scheduled announcement days. Lastly, the monetary policy shocks are almost perfectly correlated across the two event windows (see also Figure 1.4).[18]

We sample returns for all constituents of the S&P500 for all event dates. We use the CRSP database to obtain the constituent list of the S&P500 for the respective event date and link the CRSP identifier to the ticker of the NYSE taq database via historical CUSIPs (an alphanumeric code identifying North American securities). NYSE taq contains all trades and quotes for all securities traded on NYSE, Amex and the Nasdaq National Market System. We use the last observation before the start of the event window and the first observations after the end of the event window to calculate event returns. We manually checked all event returns which are larger than 5% in absolute value for potential data entry errors in the tick-by-tick data. For the five event dates for which the press releases were issued before start of the trading session (all intermeeting releases in the easing cycle starting in 2007) we calculate event returns using closing prices of the previous trading day and opening prices of the event day.[19]

Our sample period ranges from February 2, 1994, the first FOMC press release in 1994, to December 16, 2009, the last announcement in 2009 for a total of 137 FOMC meetings. We exclude the rate cut of September 17, 2001—the first trading day after the terrorist attacks of September 11, 2001. Our sample starts in 1994 as our tick-by-tick stock price data is not available before 1993 and the FOMC changed the way it communicated its policy decisions. Prior to 1994, the market became aware of changes in the federal funds target rate through the size and the type of open market operations of the New York Fed's trading desk. Moreover, most of the changes in the federal funds target rate took place on non-meeting days. With the first meeting in 1994, the FOMC started to communicate its decision by issuing press releases after every meeting and policy decision. Therefore, the start of our sample eliminates almost all timing ambiguity (besides the nine intermeeting policy decisions). The increased transparency and predictability makes the use of our intraday identification scheme more appealing as our identification assumptions are more likely to hold.

Panel B of Table 1.2 reports descriptive statistics for the percentage returns of the S&P500 for all 137 event dates between 1994 and 2009, turnings points and intermeeting policy

[18] Only two observations have discernible differences: August 17, 2007 and December 16, 2008 . The first observation is an intermeeting event day on which the FOMC unexpectedly cut the discount rate by 50 bps at 8.15am ET just before the opening of the open-outcry futures market in Chicago. The financial press reports heavy losses for the August futures contract on that day and a very volatile market environment. The second observation, December 16, 2008, is the day on which the FOMC cut the federal funds rate to a target range between 0 and 0.25 percent.

[19] Intermeeting policy decisions are special in several respects as we discuss later. Markets might therefore need additional time to fully incorporate the information contained in the FOMC press release into prices. In a robustness check, we calculate event returns using the first trade after 10am on the event date. Result do not change materially.

decisions. We use the event returns of the 500 firms comprising the S&P500 to calculate index returns using the market capitalization at the end of the previous trading day as weights. The average return is close to zero with an event standard deviation of about one percent. The large absolute values of the tight (30 minute) and wide (60 minute) event returns are remarkable. Looking at the columns for intermeeting press releases and turning points, we see that the most extreme observations occur on non-regular release dates. Figure 1.5, a scatterplot of S&P500 event returns versus monetary policy shocks, highlights this point. Specifically, this figure shows a clear negative relation between monetary policy shocks and stock returns on regular FOMC meetings and on policy reversal dates in line with Bernanke and Kuttner (2005) and Gürkaynak et al. (2005). The scatterplot, however, also documents, that anything goes on intermeeting announcement days: negative (positive) monetary policy shocks induce positive and negative stock market reactions with about equal probabilities. Faust et al. (2004a) argue that intermeeting policy decisions are likely to reflect new information about the state of the economy and hence the stock market reacts to this new information rather than changes in monetary policy. This logic calls for excluding intermeeting announcements.[20]

Firms are heterogeneous in many dimensions. Ehrmann and Fratzscher (2004) and Ippolito et al. (2013) among others show that firms with low cash flows, small firms, firms with low credit ratings, high price earnings multiples and Tobin's q show a higher sensitivity to monetary policy shocks in line with bank lending, balance sheet and interest rate channels of monetary policy. To rule out that this heterogeneity drives our results, we control for an extended set of variables at the firm and industry level. For example, we construct measures of firm size, volatility and cyclical properties of demand, market power, cost structure, financial dependence, access to financial markets, etc. We use data from a variety of sources such as the Standard and Poor's Compustat database, publications of the U.S. Census Bureau, and previous studies. The Appendix A contains detailed information on how these variables are measured.

[20]Romer and Romer (2000) document that the inflation forecasts of the Fed's staff beat commercial forecasts which is consistent with the Fed having an informational advantage over professional forecasters and thus opens a possibility that our measured surprises in the fed funds rate can capture both policy surprises and the Fed's revelation of information about the state of the economy. On the other hand, Coibion and Gorodnichenko (2012) document (see their Table 6) that, at least over the horizons of a few quarters, financial markets are as good in predicting movements in the fed funds rates as the Fed's staff and hence quantitatively the revelation component is probably small. In addition, Faust et al. (2004a) argue that FOMC announcements do not contain superior information about the state of the economy as professional forecasters do not systematically change their forecasts for a wide range of macroeconomic variables following FOMC press releases and these forecasts are efficient given the announcement. Finally, while the revelation component can make the mapping of empirical results to a theoretical model less straightforward, it does not invalidate our empirical analysis as we only need an unanticipated shock that moves optimal reset prices and therefore returns. The nature of this shock is not material.

1.4 Empirical Results

Aggregate Market Volatility

We first document the effects of monetary policy shocks on the return of the aggregate market to ensure that these shocks are a meaningful source of variation. Table 1.3 reports results from regressing returns of the S&P500 on monetary policy surprises as well as squared index returns on squared policy shocks for our tight event window (30 min). Column (1) shows that a higher than expected federal funds target rate leads to a drop in stocks prices. This effect—contrary to findings in the previous literature—is not statistically significant. Restricting our sample period to 1994-2004 (or 1994-2007), we can replicate the results of Bernanke and Kuttner (2005), Gürkaynak et al. (2005), and others: a 25 bps unexpected cut in interest rates leads to an increase of the S&P500 by more than 1.3%. In column (3), we find a highly statistically significant impact of squared policy shocks on squared index returns. Conditioning on different types of meetings shows that the overall effect is mainly driven by turning points in monetary policy. In summary, monetary policy surprises are valid shocks for our analysis.

Baseline

Table 1.4 presents results for the baseline specification (1.2) where we regress squared event returns at the firm level on the squared policy surprise, the frequencies of price adjustments and their interactions. To account for correlation of error terms across time and firms, we report Driscoll and Kraay (1998) standard errors in parentheses.[21]

Column (1) of Table 1.4 shows that squared surprises have a large positive impact on squared stocks returns. The point estimate is economically large and statistically significant at the 1% level: a hypothetical policy surprise of 25 bps leads to an increase in squared returns of roughly $8\%^2$ ($0.25^2 \times 128.50 = 8.03$). The estimated coefficient on the interaction of the frequency of price adjustment and the squared shock indicates that this effect is lower for firms with more flexible prices. For the firms with the most flexible prices in our sample (which have a probability of price adjustment of roughly 0.5 per month), the impact of squared monetary policy shocks is reduced by a factor of three, that is, $(\beta_1 - 0.5 \times \beta_3)/\beta_1 \approx 1/3$. Importantly, this sensitivity is broadly in line with the estimates we obtain for simulated data from a calibrated New Keynesian model (see Section 1.5).

The differential response of conditional volatility for sticky and flexible price firms is a very robust result. Controlling for outliers (column (2)),[22] adding firm fixed effects (columns (3) and (4)), firm and event (time) fixed effects (columns (5) and (6)), or looking at a 60 minutes event window (columns (7) and (8)) does not materially change point estimates

[21] Note that we have 956 unique firms in sample due to changes in the index composition during our sample period out of which we were able to merge 760 with the BLS pricing data.

[22] We use a standard approach of identifying outliers by jackknife as described in Belsley, Kuh, and Welsch (1980) and Bollen and Jackman (1990).

and statistical significance for the interaction term between squared policy surprises and the frequency of price adjustment.

While in the baseline measurement of stock returns we use only two data ticks, we find very similar results (Table 1.5 columns (1) and (2)) when we weight returns by trade volume in time windows before and after our events. The results also do not change qualitatively when we use absolute returns and policy shocks (columns (3) and (4) of Table 1.5) instead of squared returns and squared shocks.

One may be concerned that the heterogeneity in volatility across firms is largely driven by market movements or exposure to movements of other risk factors rather than forces specific to the price stickiness of particular firms. To address this concern, we consider squared CAPM-adjusted returns (i.e. $(R_{it} - \beta_i R_t^{SP})^2$) and squared Fama-French-adjusted returns ($(R_{it} - \beta_{iFF} R_t^{FF})^2$) where β_i and β_{iFF} are time series factor loadings of the excess returns of firm i on the market excess returns and the three Fama-French factors. Both adjustments (Table 1.5: columns (5) and (6) and columns (7) and (8)) take out a lot of common variation, reducing both explanatory power and point estimates somewhat but leaving statistical significance and relative magnitudes unchanged or even increasing it slightly. Thus, conditional volatility responds differentially across firms even after we adjust for movements of the aggregate market and other risk factors which itself could be influenced by nominal rigidities as no firm in our sample has perfectly flexible prices.

The sensitivity of the conditional volatility to monetary policy shocks may vary across types of events. For example, Gürkaynak et al. (2005) and others show that monetary policy announcements about changes in the path/direction of future policy are more powerful in moving markets. Table 1.6 contains results for different event types. We restrict our sample in columns (3) and (4) to observations before 2007 to control for the impact of the Great Recession and the zero lower bound. The effect of price flexibility increases both statistically and economically in the restricted sample. In the next two columns, we follow Bernanke and Kuttner (2005) and restrict the sample only to episodes when the FOMC changed the policy interest rate. While this reduces our sample size by more than 50%, it has no impact on estimated coefficients. The next column conditions on reversals in monetary policy (i.e. turning points in policy). The coefficient on the interaction term between the probability of price adjustment and squared policy shocks increases by a factor of three. The effect of policy shocks is somewhat reduced for intermeeting releases as shown in the last column.

Additional controls and subsamples

In Table 1.7, we add a wide range of controls to disentangle the effect of price stickiness from potentially confounding firm and industry effects. In the first column we repeat the baseline regression excluding outliers. In the first set of controls, we focus on measures of market power and profitability. For example, in column (2) we include the squared shock interacted with the price cost margin (*pcm*) as an additional regressor. While firms with larger *pcm* appear to have volatility more sensitive to monetary policy shocks, the sensitivity of the volatility across firms with different frequencies of price adjustment is barely affected by including *pcm*. Likewise, controlling directly for market power with industry concentration (the share of sales by the four largest firms, $4F - conc\ ratio$, column (3)) does not change our main result. We also find that our results for b_2 in equation (1.2) do not alter when we control for the book to market ratio (column (4)) or firm size (column (5)).[23]

The differential sensitivity of volatility across sticky and flexible price firms may arise from differences in the volatility of demand for sticky and flexible price firms. For example, all firms could face identical menu costs but firms which are hit more frequently by idiosyncratic shocks have a higher frequency of price adjustment and hence may be closer to their optimal reset prices which in turn entails that they could have a lower sensitivity to nominal shocks. To disentangle this potentially confounding effect, we explicitly control for the volatility of sales (standard deviation of sales growth rates, *std sale*,[24] column (6)) and for durability of output (columns (7) and (8)) using the classifications of Gomes et al. (2009) and Bils et al. (2012), respectively. The latter control is important as demand for durable goods is particularly volatile over the business cycle and consumers can easily shift the timing of their purchases thus making price sensitivity especially high. Even with these additional regressors, we find that the estimated differential sensitivity of volatility across sticky and flexible price firms is largely unchanged.

In columns (9) to (17), we additionally control for fixed costs to sales ($FC2Y$) as a higher ratio might decrease the flexibility to react to monetary policy shocks, receivables minus payables to sales ratio ($RecPay2Y$) to control for the impact of short term financing, investment to sales ratio ($I2Y$) to control for investment opportunities, depreciation to assets ratio ($D2A$) as a measure of capital intensity, Engel-curve slopes (*angel*), the rate of synchronization in price adjustments within a firm (*sync*), the number of products at the firm level (*#prod*) as well as the S&P long term issuer rating (*Rat*) and the Kaplan - Zingales index (KZ) to investigate the impact of financial constraints. Overall, none of the controls—neither individually nor jointly—attenuates the effect of price stickiness which is highly statistically and economically significant.

In Table 1.8 we run our baseline regression at the industry level to control for possible unobserved industry heterogeneity. In this exercise, we have typically much fewer firms and thus estimates have higher sampling uncertainty. Despite large reductions in sample sizes, for four out of the six industries we find a statistically significant negative coefficient on the interaction term between the frequency of price adjustment and squared monetary policy surprises. For the finance industry, this coefficient is not statistically significant. For the service sector, the estimate for the full sample is positive and significant but this result is driven by a handful of outliers. Once these outliers are removed, the point estimate

[23]Note that the coefficient on the squared policy surprise now turns negative. This coefficient, however, can no longer be as easily interpreted as before in the presence of additional control variables. If we report results evaluating additional controls at their mean level, coefficients are similar in size to our benchmark estimation.

[24]We use the standard deviation of annual sales growth at the quarterly frequency to control for seasonality in sales. Ideally, we would want to have higher frequency data to construct this variable but publicly available sources only contain sales at the quarterly frequency.

becomes much smaller and statistically insignificantly different from zero. This test uses only variation of our measure of price stickiness within industry. We see these results as comforting insofar as they document that our baseline effects are not driven by unobserved industry characteristics.

An alternative possibility which could drive our results is a general return sensitivity to monetary policy surprises independent of price stickiness. To rule out that this alternative explanation, we directly add the return sensitivity to monetary policy shocks.[25] To perform this test we first estimate the sensitivity (β_{v_t}) by regressing firm-level event returns on monetary policy shocks in our narrow event window. Then we add the return sensitivity interacted with the squared monetary policy surprise in various specifications as an additional control variable in our baseline regression. Table 1.9 shows that a higher squared return sensitivity to monetary policy surprises indeed leads to an increase in event return volatilities but this additional control has a negligible effect on the interaction term of our measure of price stickiness and squared monetary policy shocks.

Relative Volatility and Placebo Test

In this subsection, we perform two additional economically motivated robustness checks to further examine potentially confounding unobserved firm heterogeneity: one in which price stickiness should matter and one where we do not expect to find an effect of price stickiness.

Specifically, the first check is built on the idea that if inflexible price firms have unconditionally higher volatility than flexible price firms and this drives the previously documented effects, then we should find no effects of price stickiness once we scale the event volatilities by their unconditional volatilities. To implement this test, we pick a pseudo event window in the middle of two adjacent event dates t and $t-1$ (date $\tau = t - 1/2$) and calculate a pseudo event volatility $(1+R_{i\tau})^2$ in a 30 minute window bracketing 2.15pm at date τ. We then scale the event volatilities of the following event date with these volatilities, $(1+R_{it})^2/(1+R_{i\tau})^2$, and run our baseline regression with $(1+R_{it})^2/(1+R_{i\tau})^2$ as the dependent variable.

Column (1) of Table 1.10 shows that this story cannot explain our result that flexible price firms have lower conditional volatilities than sticky price firms. Monetary policy surprises increase event volatility compared to non-event dates. This conditional increase is completely offset for the most flexible firms with both coefficients being highly statistically significant. Controlling for outliers in column (2), firm fixed effects, event fixed effects or both in columns (3) to (8) does not change this conclusion.

The second check on whether unobserved heterogeneity can drive our results is to directly run our baseline regression on the pseudo event volatilities $(1+R_{i\tau})^2$. We perform this test in Table 1.11: all coefficients are economically small, none of them is statistically significant and once we exclude outliers, the coefficient on the interaction term between the monetary policy surprise and the frequency of price adjustment changes sign.

[25] We thank David Romer for suggesting this test.

Profits

The large differential effects of price stickiness on the volatility of returns suggest that firms with inflexible prices should experience an increased volatility of profits relative to firms with flexible prices. This response in fundamentals may be difficult to detect as information on firm profits is only available at quarterly frequency. To match this much lower frequency, we add shocks v_t in a given quarter and treat this sum as the unanticipated shock. Denote this shock with $\tilde{v}_t$. We also construct the following measure of change in profitability between the previous four quarters and quarters running from $t+H$ to $t+H+3$:

$$\Delta\pi_{it,H} = \frac{\frac{1}{4}\sum_{s=t+H}^{t+H+3} OI_{is} - \frac{1}{4}\sum_{s=t-4}^{t-1} OI_{is}}{TA_{it-1}} \times 100$$

where OI is quarterly operating income before depreciation, TA is total assets, and H can be interpreted as the horizon of the response. We use four quarters before and after the shock to address seasonality of profits. Using this measure of profitability, we estimate the following modification of our baseline specification:

$$(\Delta\pi_{it,H})^2 = b_0 + b_1 \times \Delta\tilde{v}_t^2 + b_2 \times \tilde{v}_t^2 \times \lambda_i + b_3 \times \lambda_i + error \quad (1.3)$$

We find (Table 1.12) that flexible price firms have a statistically lower volatility in operating income than sticky price firms ($b_2 < 0$). This effect is increasing up to $H = 6$ quarters ahead and then this difference becomes statistically insignificant and gradually converges to zero. Firms with more inflexible prices (smaller FPA) tend to have larger volatilities of profits. Interestingly, the estimate of b_1 is statistically positive only at $H = 0$ and turns statistically negative after $H = 5$.

1.5 Dynamic General Equilibrium Model

While the static version of the New Keynesian model in Section 1.3 was useful in guiding our empirical specifications it is not well suited for a quantitative analysis. To assess whether our empirical findings can be rationalized by a dynamic multi-sector New Keynesian model we calibrate the Carvalho (2006) model and run our baseline specification on simulated data from the model.

In the interest of space, we only verbally discuss the model and focus on key equations.[26] In this model, a representative household lives forever. The instantaneous utility of the household depends on consumption and labor supply. The intertemporal elasticity of substitution for consumption is σ. Labor supply is firm-specific. For each firm, the elasticity of labor supply is η. Household's discount factor is β. Households have a love for variety and have a CES Dixit-Stiglitz aggregator with the elasticity of substitution θ.

Firms set prices as in Calvo (1983). There are k sectors in the economy with each sector populated by a continuum of firms. Each sector is characterized by a fixed λ_k, the probability

[26] Appendix A contains a more detailed description of the model.

of any firm in industry k to adjust its price in a given period.[27] The share of firms in industry k in the total number of firms in the economy is given by the density function $f(k)$. Firms are monopolistic competitors and the elasticity of substitution θ is the same for all firms both within and across industries. While this assumption is clearly unrealistic, it greatly simplifies the algebra and keeps the model tractable. The production function for output Y is linear in labor N which is the only input. The optimization problem of firm j in industry k is then to pick a reset price X_{jkt}:

$$\max \mathbb{E}_t \quad \sum_{s=0}^{\infty} Q_{t,t+s}(1-\lambda_k)^s [X_{jkt}Y_{jkt+s} - W_{jkt+s}N_{jkt+s}]$$

subject to its demand function and production technology where variables without subscripts k and j indicate aggregate variables, W is wages (taken as given by firms) and Q is the stochastic discount factor. Wages are determined by the household's intratemporal elasticity between labor and consumption. The central bank follows a Taylor rule.

After substituting in optimal reset prices and firm-specific demand and wages, the value of the firm V with price P_{jkt} is given by:

$$V(P_{jkt}) = \mathbb{E}_t\left\{Y_t^{\sigma} P_t\left[\Delta_{kt}^{(1)}\left(\frac{P_{jkt}}{P_t}\right)^{1-\theta} - \Delta_{kt}^{(2)}\left(\frac{P_{jkt}}{P_t}\right)^{-\theta(1+1/\eta)} + \Upsilon_{kt}^{(1)} - \Upsilon_{kt}^{(2)}\right]\right\},$$

where $\Upsilon_{kt}^{(1)}$, $\Delta_{kt}^{(1)}$, $\Upsilon_{kt}^{(2)}$ and $\Delta_{kt}^{(2)}$ follow simple recursions and are not indexed by j, which allows particularly easy solution and simulation of this non-linear model.

We calibrate the model at quarterly frequency using standard parameter values in the literature (see Panel A of Table 1.13). Ashenfelter et al. (2010) survey the literature on the elasticity of labor supply faced by firms. They document that the short-run elasticity is in the 0.1-1.5 range while the long-run elasticity is between 2 and 4. We take the middle of the range of these elasticities and set $\eta = 2$. The elasticity of demand θ is often calibrated at 10 in macroeconomic studies. However, since firms in our model compete not only with firms in the same sector but also with firms in other sectors we calibrate $\theta = 7$ which captures the notion that the elasticity of substitution across sectors is likely to be low. Other preference parameters are standard: $\sigma = 2$ and $\beta = 0.99$. Parameters of the policy reaction function are taken from Taylor (1993) and Coibion and Gorodnichenko (2012). We follow Carvalho (2006) and calibrate the density function $f(k) = 1/5$ and use the empirical distribution of frequencies of price adjustment reported in Nakamura and Steinsson (2008) to calibrate $\{\lambda_k\}_{k=1}^{5}$. Specifically, we sort industries by the degree of price stickiness and construct five synthetic sectors which correspond to the quintiles of price stickiness observed in the data. Each sector covers a fifth of consumer spending. The Calvo rates of price adjustment range

[27]The fixed probability of price adjustment should be interpreted as a metaphor that allows particularly fast *non-linear* solutions to multi-sector models with large state spaces as well as easy interpretation of results. We find similar results in the Dotsey et al. (1999) model with state-dependent price adjustment.

from 0.094 to 0.975 per quarter with the median sector having a Calvo rate of 0.277 (which implies that this sector updates prices approximately once a year).

We solve the model using a third-order approximation as implemented in *dynare* and simulate the model for 100 firms per sector for 2000 periods, but discard the first 1000 periods as burn-in. For each firm and each time period, we calculate the value of the firm $V(P_{jkt})$ and the value of the firm net of dividend $\tilde{V}(P_{jkt}) \equiv V(P_{jkt}) - (P_{jkt}Y_{jkt+s} - W_{jkt+s}N_{jkt+s})$ as well as the implied return $R_{jkt} = V(P_{jkt})/\tilde{V}(P_{jkt-1}) - 1$. As we discussed in the case of the static model, realized returns can increase or decrease in response to a nominal shock. Hence, we consider the specification suggested previously:

$$R^2_{jkt} = b_0 + b_1 \times v_t^2 + b_2 \times v_t^2 \times \lambda_j + b_3 \times \lambda_j + error \quad (1.4)$$

We report resulting estimates of b_1, b_2 and b_3 in Panel C of Table 1.13 for the baseline calibration as well as for alternative parametrizations. We find that a large, positive $\hat{b}_1$ and a large, negative $\hat{b}_2$ are very robust features of the model with estimates in the ballpark of our empirical findings in Section 1.4. Magnitudes of the coefficients are such that $\hat{b}_1 + \hat{b}_2 \approx 0$. The estimates of $\hat{b}_3$ are negative, as predicted, but generally close to zero.

We can also use this model to calculate lost profits due to price stickiness: we compute the median profit $\bar{\pi}_k$ for each firm type k and then use $(\bar{\pi}_k - \bar{\pi}_5)/\bar{\pi}_5$ to assess how an increase in the duration of price spells from $(1/\lambda_5)$ (the sector with practically flexible prices) to $(1/\lambda_k)$ influences profits. We find that going from flexible prices to prices fixed for roughly one year (sector 3) reduces profits by about 25%. While in the model the only source of firm heterogeneity is the duration of price spells and thus differences in profits can be attributed to price stickiness, the duration of price spells in the data is affected by heterogeneous costs and benefits of price adjustment so that the mapping of lost profits to the size of menu costs is likely to be complex. However, the magnitudes we observe in our simulations appear broadly in line with those observed in the data. Zbaracki et al. (2004) show that a manufacturing firm with an average duration of price spells of one year spends about 20 percent of its net profit margin on nominal price adjustment.

Obviously, these calculations of menu-cost estimates depend of structural parameters of the model. One may use empirical moments to infer these structural parameters. The answer in this exercise is likely to depend on the details of the model, which can limit the robustness. However, these simulations highlight the relationship between price stickiness and returns and provides a sense of magnitudes one may expect in a reasonably calibrated New Keynesian model with heterogeneous firms.

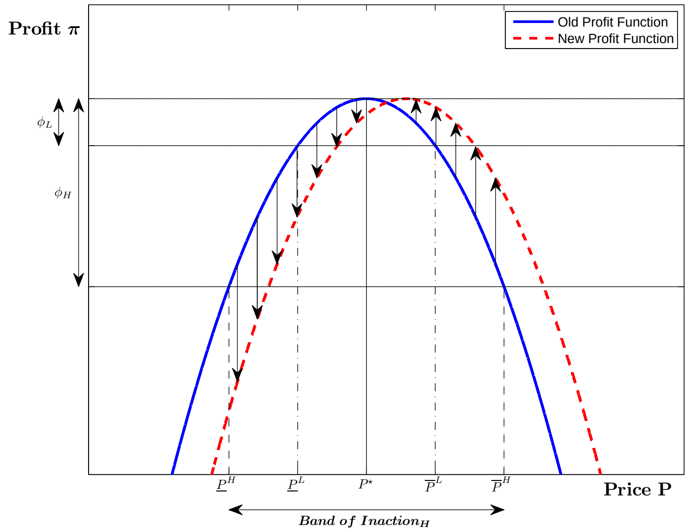
1.6 Concluding Remarks

Are sticky prices costly? We propose a simple framework to address this question using the conditional volatility of stock market returns after monetary policy announcements. We document that the conditional volatility rises more for firms with stickier prices than for firms with more flexible prices. This differential reaction is economically and statistically large as well as strikingly robust to a broad spectrum of checks. This result suggests that menu costs—broadly defined to include physical costs of price adjustment, informational frictions, etc.—are an important factor for nominal price rigidity. Our empirical evidence lends support to the New Keynesian interpretation of the observed nominal price rigidity at the microlevel: sticky prices are costly. Our results are qualitatively and, under plausible calibrations, quantitatively consistent with New Keynesian macroeconomic models where firms have heterogeneous price stickiness. Our "model-free" evidence unambiguously suggests that sticky prices are indeed costly for firms, which is consistent with the tenets of New Keynesian macroeconomics.

Our results have a number of policy implications. First, our findings provide foundations for policy-workhorse macroeconomic models such as Christiano et al. (2005) in which nominal frictions play a prominent role. Second, increasing trend inflation—a policy suggested by a number of economists to combat deflationary spirals in the Great Recessions—has possibly non-negligible costs in the light of our results. Third, the presence of sticky prices is likely to generate larger fiscal multipliers (especially in times of a binding zero lower bound on interest rates, see Christiano et al. (2011)) and thus potentially justifies more activist fiscal policy aimed at stabilizing business cycles. Finally, as emphasized by Bernanke and Kuttner (2005), monetary policy can influence the economy via changes in asset prices and our results can provide a new perspective on this channel as well as highlight its distributional aspects.

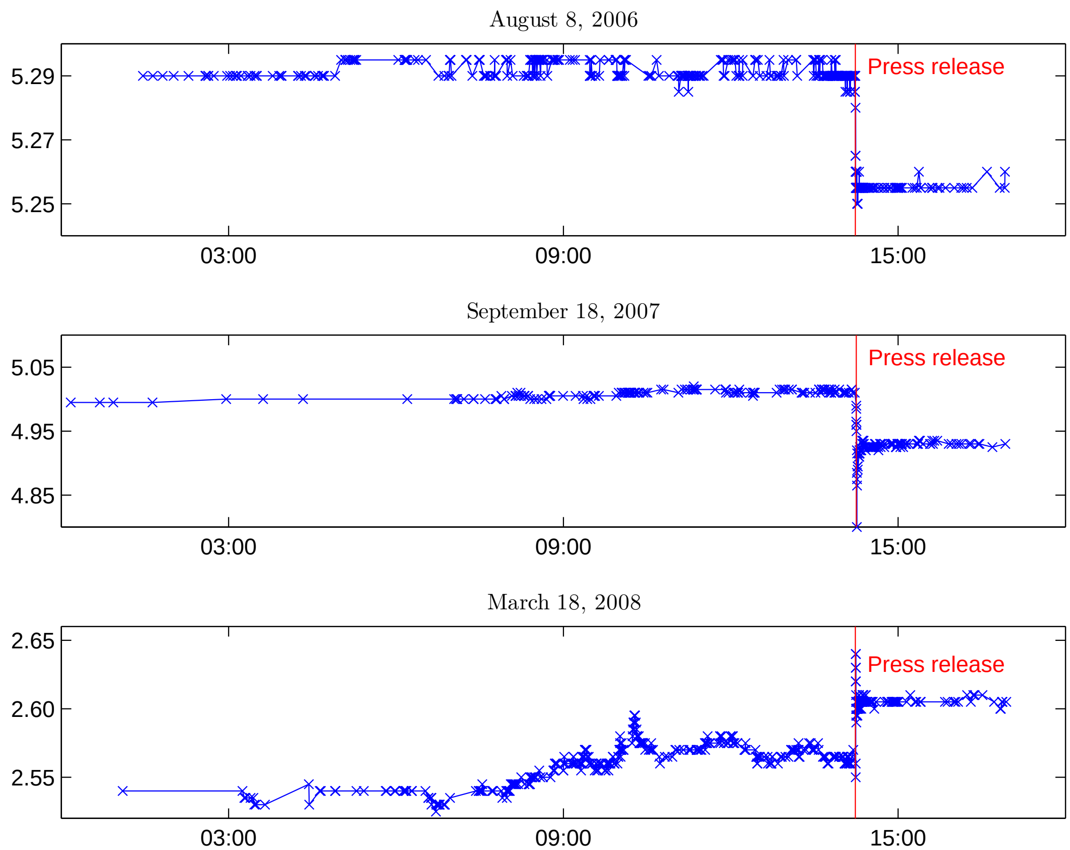
The high-frequency identification of causal effects of monetary shocks on the volatility of stock returns suggests that connecting stock returns and measures of price stickiness is a fruitful avenue for future research. For example, Weber (2014) studies how firm-level and portfolio returns vary with measured price stickiness which can provide a simple metric of the size of menu costs and shed new light on the sources of the cross-sectional distribution of returns. Alternatively, one may integrate asset prices into fully fledged DSGE models to obtain structural estimates of menu costs. We anticipate that using information on stock returns in conjunction with firm-level measures of price stickiness can help to discriminate between alternative models explaining the large real effect of monetary policy with moderate degrees of price stickiness and the inertial reaction of inflation, improve our understanding of how to price securities, and further bridge finance and macroeconomics.

Figure 1.1: Impact of a Nominal Shock on Stock Returns via a Shift in Firm's Profit Function



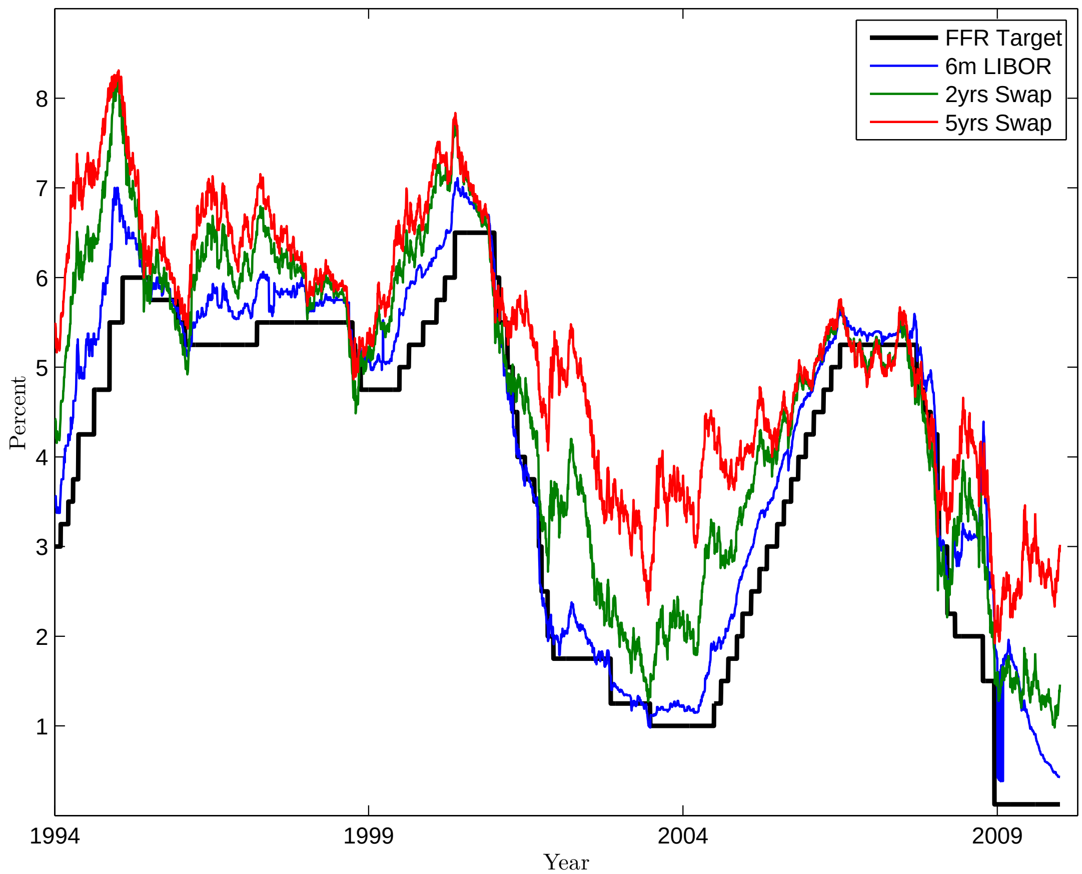
This figure plots profit at the firm level as a function of price. Low and high menu costs (ϕ_L and ϕ_H) translate into small and large bands of inaction within which it is optimal for a firm not to adjust prices following nominal shocks. The blue, solid line indicates the initial profit function and P^* is the initial optimal price. For example an expansionary monetary policy shock shifts the profit function to the right, indicated by the dashed, red line. Depending on the initial position, this shift can either lead to an increase or a decrease in profits as exemplified by the arrows.

Figure 1.2: Intraday Trading in Globex Federal Funds Futures



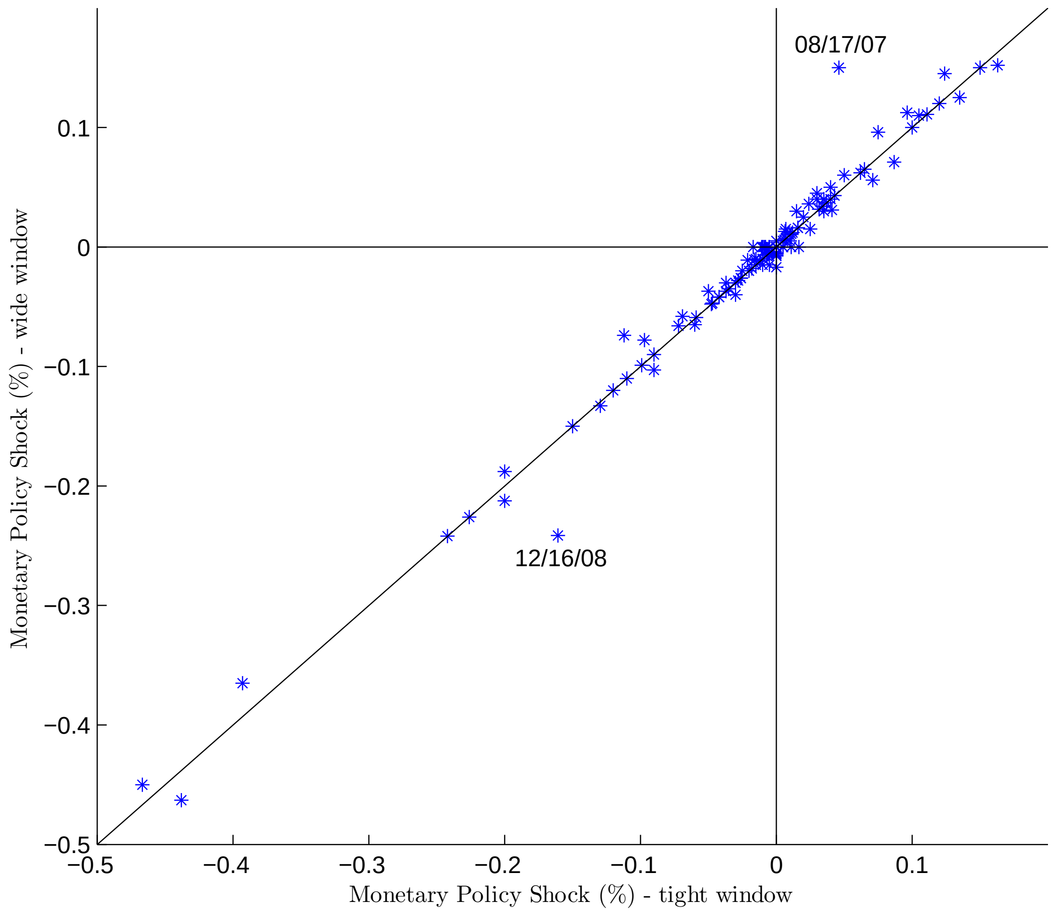
This figure plots the tick–by–tick trades in the Globex Federal funds futures for three different FOMC press release dates with release times at 2.14pm on August 8th 2006, 2.15pm on September 18th 2007 and 2.14pm on March 18th 2008, respectively.

Figure 1.3: Time Series of Interest Rates



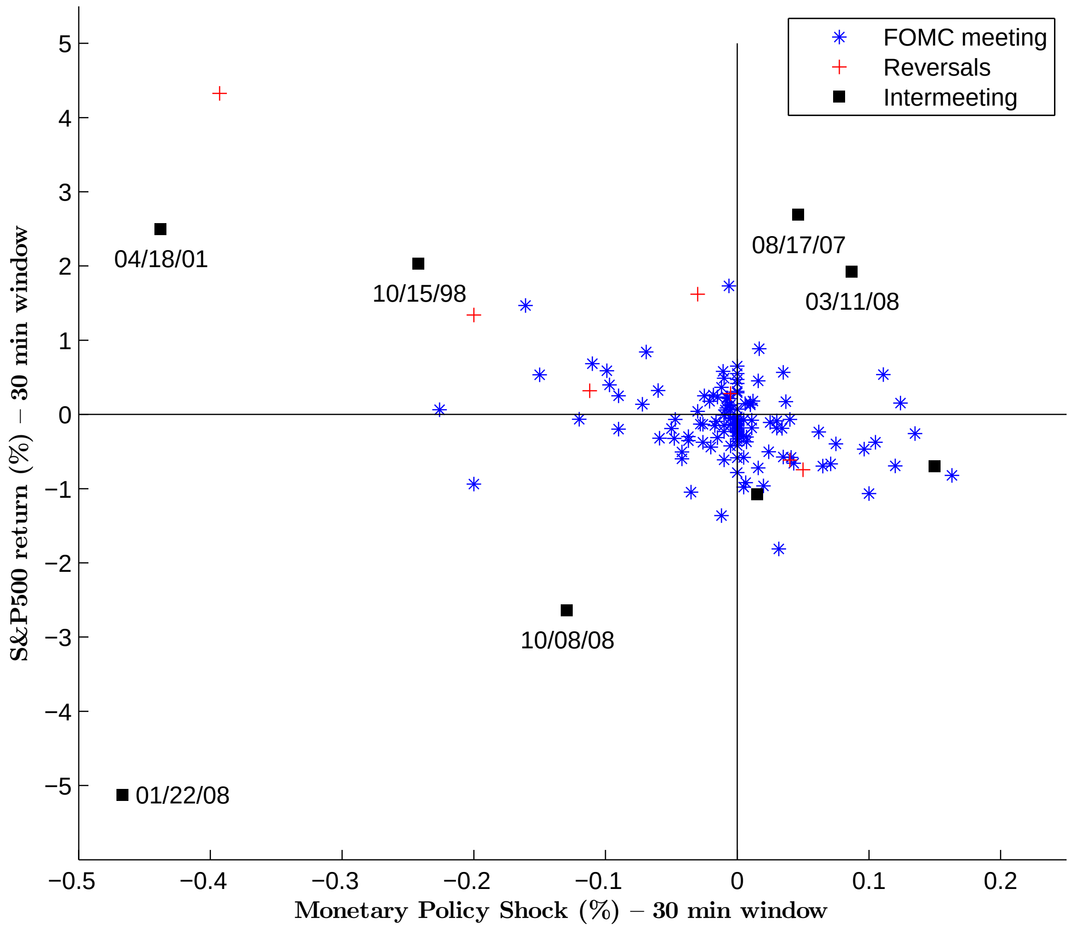
This figure plots the time–series of the federal funds target rate, the six months Libor as well as the two and five year swap rates from 1994 to 2009.

Figure 1.4: Futures–based Measure of Monetary Policy Shocks



This figure is a scatterplot of the federal funds futures based measure of monetary policy shocks calculated according to equation (1.1) for the wide (60min) event window versus the tight (30min) event window. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations.

Figure 1.5: Return of the S&P500 versus Monetary Policy Shocks (tight window)



This figure is a scatterplot of the percentage returns on the S&P500 versus the federal funds futures based measure of monetary policy shocks calculated according to equation (1.1) for the tight (30min) event window. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. We distinguish between regular FOMC meetings, turning points in monetary policy and intermeeting press releases.

Table 1.1: Frequency of Price Adjustment by Industry

This table reports average frequencies of price adjustments at the industry and aggregate levels with standard deviations in parentheses. Equally weighted frequencies of price adjustments are calculated at the firm level using the microdata underlying the producer price index.

	Total	Agriculture	Manufacturing	Utilities	Trade	Finance	Service
Mean	14.66%	25.35%	11.88%	21.45%	22.19%	13.82%	8.07%
Std	(12.90%)	(17.23%)	(11.12%)	(13.44%)	(13.71%)	(11.41%)	(7.72%)
#	57,541	3,634	27,939	7,397	3,845	9,856	4,870

Table 1.2: Descriptive Statistics For High-Frequency Data

This table reports descriptive statistics for monetary policy shocks (bps) in Panel A and for the returns of the S&P500 in Panel B, separately for all 137 event days between 1994 and 2009, turning points in monetary policy and intermeeting policy decisions. The policy shock is calculated according to equation (1.1) as the scaled change in the current month federal funds futures in a 30 minutes (tight) window bracketing the FOMC press releases and a 60 minutes (wide) event window around the release times, respectively. The return of the S&P500 is calculated as weighted average of the constituents' returns in the respective event windows using the market capitalization at the end of the previous trading day as weights.

Panel A. Monetary Policy Shocks

	All Event Days		Turning Points		Intermeeting Releases	
	Tight	Wide	Tight	Wide	Tight	Wide
Mean	−1.60	−1.46	−6.09	−5.68	−12.23	−11.09
Median	0.00	0.00	−1.75	−2.75	−5.73	−5.15
Std	8.94	9.11	17.28	16.40	23.84	25.23
Min	−46.67	−46.30	−39.30	−36.50	−46.67	−46.30
Max	16.30	15.20	16.30	15.20	15.00	15.00
Correlation	0.99		0.99		0.99	
#	137		8		8	

Panel B. S&P500 Returns

	All Event Days		Turning Points		Intermeeting Releases	
	Tight	Wide	Tight	Wide	Tight	Wide
Mean	−0.05%	0.05%	0.71%	0.71%	−0.04%	−0.06%
Median	−0.12%	0.02%	0.30%	0.50%	0.64%	0.42%
Std	0.91%	0.97%	1.73%	1.52%	2.83%	2.90%
Min	−5.12%	−5.12%	−0.81%	−0.78%	−5.12%	−5.12%
Max	4.32%	3.61%	4.32%	3.61%	2.69%	2.69%
Correlation	0.90		0.99		0.99	
#	137		8		8	

Table 1.3: Response of the S&P500 to Monetary Policy Shocks

This table reports the results of regressing returns and squared returns in percent of the S&P500 in a 30 minutes event window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy shocks calculated according to equation (1.1), v_t, and the squared shocks, v_t^2, for different event types. The return of the S&P500 is calculated as a weighted average of the constituents' return in the respective event window using the market capitalization at the end of the previous trading day as weights. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Robust standard errors are reported in parentheses.

	Returns		Squared Returns			
		pre 2005	All	Regular	Turning Point	Intermeeting
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	−0.08	−0.12*	0.13	0.23***	−0.36	2.68
	(0.06)	(0.05)	(0.13)	(0.05)	(0.77)	(1.64)
v_t	−1.66	−5.31***				
	(2.93)	(1.41)				
v_t^2			84.38***	9.57	116.60***	67.15
			(23.18)	(8.67)	(9.68)	(38.79)
R^2	0.03	0.44	0.69	0.02	0.92	0.53
#	137	92	137	121	8	8

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.4: Response of the Constituents of the S&P500 to Monetary Policy Shocks

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in different event windows bracketing the FOMC press releases on the federal funds futures based measure of monetary policy shocks calculated according to equation (1.1), v_t^2, the frequency of price adjustment, FPA, as well as their interactions. See specification (1.2). Equally weighted frequencies of price adjustments are calculated at the firm level using the microdata underlying the producer price index. Columns (1) and (2) consider a 30 minutes event window, (3) and (4) add firm fixed effects, (5) and (6) firm and event fixed effects, whereas (7) and (8) focus on a 60 minutes event window. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	Tight Window		Firm FE		Firm & Event FE		Wide Window	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2	128.50***	76.95***	127.50***	76.59***			119.60***	95.38***
	(23.05)	(15.25)	(22.80)	(15.13)			(30.71)	(20.87)
$FPA \times v_t^2$	−169.80**	−67.26***	−168.00**	−69.05***	−166.60**	−41.33***	−130.40*	−78.07***
	(78.50)	(5.33)	(75.55)	(5.04)	(76.18)	(5.89)	(67.08)	(27.67)
FPA	0.41	0.09					0.55	0.08
	(0.34)	(0.18)					(0.68)	(0.22)
FE Fixed Effects	No	No	No	No	Yes	Yes	No	No
Firm FE	No	No	Yes	Yes	Yes	Yes	No	No
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.12	0.12					0.03	0.09
Number of firms	760	760	760	760	760	760	760	760
#	57,541	57,441	57,541	57,440	57,541	57,420	57,541	55,022

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.5: Response of the Constituents of the S&P500 to Monetary Policy Shocks (variations)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy shocks calculated according to equation (1.1), v_t^2, the frequency of price adjustment, FPA, as well as their interactions. See specification (1.2). Equally weighted frequencies of price adjustments are calculated at the firm level using the microdata underlying the producer price index. Columns (1) and (2) focus on volume weighted returns where the pre- and post-event prices are the volume weighted prices of all trades within 10 minutes before start and after end of the event window, (3) and (4) look at absolute returns and monetary policy surprises, v_t^{abs}, (5) and (6) CAPM adjusted returns $(R_{it} - \beta_i R_t^{SP})^2$, whereas (7) and (8) look at Fama & French adjusted returns $(R_{it} - \beta_F FR_t^{FF})^2$. The return of the S&P500 is calculated as a weighted average of the constituents' returns in the event window, where the market capitalization of the previous trading day is used to calculate the weights and the returns of the size and book to market factors are calculated following the methodology of Fama and French (1993). The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	Volume Weighted		Absolute Returns & Shocks		CAPM adj		Fama & French adj	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2/v_t^{abs}	144.50***	86.42***	6.33***	5.37***	43.80***	27.71***	38.29***	25.80***
	(34.71)	(14.39)	(1.17)	(1.06)	(8.87)	(5.32)	(6.05)	(3.68)
$FPA \times v_t^2/v_t^{abs}$	−205.90*	−64.59***	−4.11*	−2.84***	−52.96***	−18.35***	−42.57**	−22.52***
	(110.20)	(24.52)	(2.20)	(0.83)	(15.99)	(5.32)	(18.79)	(3.61)
FPA	0.82	0.45	0.11	0.06	−0.12	−0.23	0.05	−0.12
	(0.68)	(0.58)	(0.07)	(0.04)	(0.22)	(0.21)	(0.23)	(0.19)
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.06	0.04	0.21	0.19	0.03	0.03	0.02	0.02
Number of firms	760	760	760	760	760	760	760	760
#	55,065	54,996	57,541	57,426	57,541	57,491	57,541	57,497

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.6: Response of the Constituents of the S&P500 to Monetary Policy Shocks (conditional on event type)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.1), v_t^2, the frequency of price adjustment, FPA, as well as their interaction for different event types. See specification (1.2). Columns (1) and (2) repeat the baseline specification, (3) and (4) focus on a subsample ending in 2006, (5) and (6) condition on a change in the Federal Funds Rate, (7) and (8) look at turning points in monetary policy and at intermeeting press releases, respectively. Equally weighted frequencies of price adjustments are calculated at the firm level using the microdata underlying the producer price index. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. No outliers were identified for samples in columns (9) and (10). Driscoll-Kraay standard errors are reported in parentheses.

	baseline		pre 2007		change in FFR		turning point	intermeeting
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2	128.50***	76.95***	123.10***	53.81***	133.50***	83.76***	235.10***	78.25***
	(23.05)	(15.25)	(38.51)	(4.46)	(26.39)	(16.03)	(10.41)	(22.19)
$FPA \times v_t^2$	−169.80**	−67.26***	−245.80***	−77.75***	−178.10**	−64.97***	−512.20***	−99.31**
	(78.50)	(5.33)	(88.51)	(11.33)	(83.12)	(9.59)	(26.87)	(32.93)
FPA	0.41	0.09	0.54*	0.02	1.01*	0.48	5.48*	1.66
	(0.34)	(0.18)	(0.31)	(0.10)	(0.58)	(0.34)	(2.68)	(3.22)
Correction for outliers	No	Yes	No	Yes	No	Yes	No/Yes	No/Yes
R^2	0.12	0.12	0.11	0.13	0.14	0.13	0.15	0.04
Number of firms	760	760	694	694	742	742	705	713
#	57,541	57,441	45,891	45,775	24,752	24,676	3,407	3,300

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.7: Response of the Constituents of the S&P500 to Monetary Policy Shocks (firm & industry level controls)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.1), v_t^2, the frequency of price adjustment, FPA, as well as their interactions. See specification (1.2). Equally weighted frequencies of price adjustments are calculated at the firm level using the microdata underlying the producer price index. Variables are defined in Appendix A. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses. All specifications have firms fixed effects and correct for outliers.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
v_t^2	76.59***	53.49***	83.02***	48.19	−185.60***	57.33***	81.12***	70.80***	46.45*
	(15.13)	(18.92)	(16.31)	(33.61)	(30.83)	(11.43)	(10.75)	(17.03)	(23.94)
$FPA \times v_t^2$	−69.05***	−43.62***	−67.94***	−66.98***	−63.72***	−71.98***	−57.56***	−58.82***	−24.07***
	(5.04)	(7.84)	(7.05)	(5.42)	(4.86)	(8.72)	(14.06)	(6.92)	(4.65)
$v_t^2 \times pcm$		50.42 **							
		(20.42)							
$v_t^2 \times 4F - conc\ ratio$			−46.87***						
			(10.24)						
$v_t^2 \times bm$				−1.97					
				(1.69)					
$v_t^2 \times size$					16.31***				
					(2.54)				
$v_t^2 \times std\ sale$						338.90***			
						(60.12)			
$v_t^2 \times nondur$							−33.93***		
							(5.19)		
$v_t^2 \times serv$							−27.46***		
							(4.17)		
$v_t^2 \times invest$							7.3		
							(9.01)		
$v_t^2 \times gov$							28.01***		
							(5.97)		
$v_t^2 \times nx$							−0.75		
							(10.47)		
$v_t^2 \times dura$								11.77***	
								(2.27)	
$v_t^2 \times FC2Y$									136.50 **
									(55.74)
Number of firms	760	728	670	760	760	728	565	633	746
#	57,440	51,929	50,123	57,440	57,442	51,941	42,990	47,421	56,474

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

continued on next page

	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
v_t^2	76.50***	74.50***	84.99***	19.99	95.92***	83.05***	145.80***	71.83***	−224.90***
	(15.24)	(12.82)	(16.04)	(25.53)	(16.59)	(15.31)	(15.51)	(16.53)	(69.66)
$SAU \times v_t^2$	−72.58***	−61.55***	−62.56***	−25.60***	−50.45***	−26.68***	−63.81***	−74.98***	−112.20***
	(6.01)	(5.23)	(6.27)	(4.84)	(6.25)	(9.34)	(5.94)	(6.94)	(20.76)
$v_t^2 \times pcm$									−17.25
									(13.81)
$v_t^2 \times 4F - conc\ ratio$									8.92
									(7.08)
$v_t^2 \times bm$									−1.87
									(1.29)
$v_t^2 \times size$									20.90***
									(5.10)
$v_t^2 \times std\ sale_a$									565.90***
									(82.78)
$v_t^2 \times nondur$									−39.01***
									(3.78)
$v_t^2 \times serv$									−51.25***
									(14.82)
$v_t^2 \times invest$									2.11
									(5.73)
$v_t^2 \times gov$									14.04
									(8.78)
$v_t^2 \times nx$									62.93***
									(11.12)
$v_t^2 \times RecPay2Y$	−1.75*								19.47
	(1.01)								(30.07)
$v_t^2 \times I2Y$		−12.42							−8.87
		(37.62)							(42.46)
$v_t^2 \times D2A$			−251.60**						194.00
			(108.00)						(138.90)
$v_t^2 \times angel$				56.20***					
				(13.65)					
$v_t^2 \times sync$					−65.94**				22.32
					(28.53)				(27.81)
$v_t^2 \times \#prod$						−0.38***			0.1
						(0.03)			(0.15)
$v_t^2 \times Rat$							−21.18***		−24.90***
							(2.98)		(6.01)
$v_t^2 \times KZ$								5.80**	−0.2
								(2.83)	(2.31)
Number of firms	737	723	737	633	759	760	743	746	473
#	55,884	55,565	56,145	47,415	57,322	57,431	53,283	56,352	33,067

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.8: Response of the Constituents of the S&P500 to Monetary Policy Shocks (within industry)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.1), v_t^2 *and the interaction term with the frequency of price adjustment, FPA. See specification (1.2). Equally weighted frequencies of price adjustments are calculated at the firm level using the microdata underlying the producer price index. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.*

	All		Agro	Mnfg	Util	Trade	Finance	Service	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
v_t^2	127.50***	76.59***	81.73*	71.85***	73.68***	74.38***	86.48***	61.28***	80.15***
	(22.80)	(15.13)	(45.87)	(12.33)	(20.59)	(15.99)	(19.15)	(13.08)	(13.78)
$FPA \times v_t^2$	−168.00**	−69.05***	−106.60*	−35.98***	−125.0***	−54.99*	−20.11	168.6***	33.97
	(75.55)	(5.04)	(58.58)	(11.55)	(16.28)	(29.91)	(24.98)	(53.54)	(69.23)
Correction for outliers	No	Yes	No	No	No	No	No	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of firms	760	760	58	346	112	50	140	77	77
#	57,541	57,440	3,629	27,887	7,394	3,839	9,836	4,856	4,815

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.9: Response of the Constituents of the S&P500 to Monetary Policy Shocks (controlling for return sensitivity to monetary policy surprises

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy shocks calculated according to equation (1.1), v_t^2, the frequency of price adjustment, FPA, as well as their interactions controlling for the sensitivity of returns to monetary policy shocks, β_{v_t}. See specification (1.2). Equally weighted frequencies of price adjustments are calculated at the firm level using the microdata underlying the producer price index. Columns (1) and (2) repeat the baseline results, (3) and (4) add the squared interaction of the return sensitivity and monetary policy shocks, (5) and (6) the interaction of the return sensitivity and squared monetary policy shocks, (7) and (8) the interaction of the absolute return sensitivity and squared monetary policy shocks, whereas (9) and (10) control for the squared interaction of the CAPM beta adjusted return sensitivity and monetary policy shocks. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	baseline		sq return sens		return sens		abs return sens		sq rel return sens	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
v_t^2	128.50***	76.95***	93.83***	62.03***	117.10***	70.63***	71.95**	49.89**	89.98***	58.08***
	(23.05)	(15.25)	(20.05)	(19.62)	(24.32)	(20.66)	(27.93)	(24.58)	(21.05)	(19.61)
$FPA \times v_t^2$	−169.80**	−67.26***	−157.90**	−62.11***	−160.80**	−61.02***	−170.70**	−62.17***	−147.30**	−52.86***
	(78.50)	(5.33)	(68.89)	(8.64)	(65.63)	(4.70)	(77.89)	(7.29)	(63.68)	(5.58)
FPA	0.41	0.09	0.81*	0.28	0.47	0.01	0.61	0.16	0.77*	0.26
	(0.34)	(0.18)	(0.46)	(0.19)	(0.38)	(0.14)	(0.39)	(0.19)	(0.45)	(0.20)
$\beta_{v_t}^2 \times v_t^2$			5.54*	2.71**						
			(2.93)	(1.09)						
$\beta_{v_t} \times v_t^2$					−13.52	−6.42				
					(19.11)	(7.92)				
$\beta_{v_t}^{abs} \times v_t^2$							35.20*	17.21**		
							(19.43)	(7.90)		
(rel $\beta_{v_t})^2 \times v_t^2$									4.37*	2.30**
									(2.38)	(0.99)
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.12	0.12	0.15	0.14	0.12	0.09	0.14	0.13	0.14	0.14
Number of firms	760	760	760	760	760	760	760	760	760	760
#	57,541	57,441	57,541	57,433	57,541	57,436	57,541	57,429	57,541	57,433

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.10: Response of the Constituents of the S&P500 to Monetary Policy Shocks (relative volatilities)

This table reports the results of regressing the ratio of squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases over the squared percentage returns in a pseudo event window between adjacent event dates on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.1), v_t^2 and the interaction term with the frequency of price adjustment, FPA. See specification (1.2). Equally weighted frequencies of price adjustments are calculated at the firm level using the microdata underlying the producer price index. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	Tight Window		Firm FE		Event FE		Firm & Event FE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2	0.57***	0.32***	0.57***	0.33***				
	(0.08)	(0.05)	(0.07)	(0.05)				
$FPA \times v_t^2$	−1.07***	−0.65***	−1.05***	−0.64***	−1.06***	−0.57***	−1.05***	−0.56***
	(0.19)	(0.17)	(0.17)	(0.16)	(0.19)	(0.18)	(0.17)	(0.18)
FPA	0.00***	0.00***			0.00***	0.00***		
	(0.00)	(0.00)			(0.00)	(0.00)		
Event FE	No	No	No	No	Yes	Yes	Yes	Yes
Firm FE	No	No	Yes	Yes	No	No	Yes	Yes
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.07	0.02			0.12	0.10		
Number of firms	758	758	758	758	758	758	758	758
#	53,682	53,547	53,682	53,547	53,682	53,507	53,682	53,507

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.11: Response of the Constituents of the S&P500 to Monetary Policy Shocks (pseudo event window)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes pseudo event window between adjacent event dates on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.1), v_t^2 and the interaction term with the frequency of price adjustment, FPA. See specification (1.2). Equally weighted frequencies of price adjustments are calculated at the firm level using the microdata underlying the producer price index. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	Tight Window		Firm FE		Event FE		Firm & Event FE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2	2.26	2.01	2.33	2.04				
	(3.79)	(2.96)	(3.14)	(2.68)				
$FPA \times v_t^2$	5.68	−2.046	5.25	−2.11	5.96	−2.19	5.51	−2.33
	(7.60)	(4.33)	(6.78)	(3.35)	(7.83)	(4.11)	(6.83)	(3.20)
FPA	−0.17***	−0.15***			−0.17***	−0.15***		
	(0.04)	(0.05)			(0.05)	(0.05)		
Event FE	No	No	No	No	Yes	Yes	Yes	Yes
Firm FE	No	No	Yes	Yes	No	No	Yes	Yes
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.00	0.00			0.06	0.07		
Number of firms	758	758	758	758	758	758	758	758
#	53,262	53,248	53,262	53,248	53,262	53,247	53,262	53,247

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.12: Response of the Constituents of the S&P500 to Monetary Policy Shocks (profitability)

This table reports the results of regressing squared percentage changes in mean quarterly operating income before depreciation between quarters $t+H$ till $t+H+3$ and $t-4$ till $t-1$ normalized by $t-1$ total assets of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.1) and accumulated to quarterly frequency, $\tilde{v}_t^2$, the frequency of price adjustment, FPA, as well as their interaction. See specification (1.3). Equally weighted frequencies of price adjustments are calculated at the establishment level using the microdata underlying the producer price index. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	H = 0	H = 1	H = 2	H = 3	H = 4	H = 5	H = 6	H = 7	H = 8
$\tilde{v}_t^2$	2.47*	1.75	−0.03	−2.10	−3.69	−7.98**	−10.51*	−15.99***	−21.55***
	(1.35)	(1.66)	(1.81)	(2.04)	(2.90)	(3.61)	(5.46)	(5.89)	(7.00)
$FPA \times \tilde{v}_t^2$	−19.68***	−23.98***	−25.62***	−30.91**	−36.81**	−35.18**	−41.58**	−29.98	−29.68
	(5.24)	(7.42)	(9.06)	(11.87)	(15.17)	(15.39)	(19.50)	(20.23)	(22.85)
FPA	2.10***	2.68***	3.24***	3.78***	4.07***	4.01**	4.77**	4.70*	4.88
	(0.39)	(0.59)	(0.86)	(1.16)	(1.43)	(1.70)	(2.24)	(2.70)	(3.34)
Correction for outliers	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Number of firms	685	682	678	671	668	661	660	653	642
#	20,756	20,428	20,117	19,814	19,646	19,449	19,295	18,921	18,475

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 1.13: Calibration

This table shows in Panel A calibrated parameter values for the dynamic New Keynesian multisector model described in Section 1.5, the sectoral distribution of the frequency of price adjustment in Panel B and the parameter estimates of equation (1.4) with simulated data from the model in Panel C.

Panel A. Calibration Parameter

Parameter	Value	Source
η	2	Ashenfelter et al. (2010)
σ	2	standard
θ	7	standard
β	0.99	standard
ϕ_π	1.5	Taylor (1993)
ϕ_y	0.5	Taylor (1993)
ρ_{mp}	0.9	Coibion and Gorodnichenko (2012)
$std(v_t)$	0.0043	Coibion et al. (2012)

Panel B. Sectoral Distribution

Sector k	Share	Frequency of Price Adjustment
1	0.2	0.094
2	0.2	0.164
3	0.2	0.277
4	0.2	0.638
5	0.2	0.985

Panel C. Simulation Results

Calibration	$\hat{b}_1$	$\hat{b}_2$	$\hat{b}_3$
baseline	163.2	-178.8	-0.006
$\sigma = 3$	117.0	-118.2	-0.004
$\eta = 1$	348.8	-401.5	-0.011
$\theta = 6$	81.7	-77.5	-0.003
$\phi_\pi = 2$	85.7	-98.3	-0.003
$\phi_y = 0.75$	181.7	-203.7	-0.007
$\rho_{mp} = 0.91$	321.2	-378.6	-0.011
$std(v_t) = 0.004$	143.1	-154.8	-0.004

Chapter 2

Nominal Rigidities and Asset Pricing

2.1 Introduction

The cover price of the Wall Street Journal was constant during the Roaring Twenties, the Great Depression, and the Second World War despite large swings in economic conditions.[1] Although this example is certainly extreme, rigid product prices are pervasive at the micro level.[2] Nominal rigidities play a central role in macroeconomics in explaining business-cycle dynamics of aggregate real variables and are key ingredients of dynamic models at policy institutions such as the Federal Reserve.[3] Most importantly, price rigidities are the cornerstone of many economic models that rationalize the effects of purely *nominal* shocks on the *real* side of the economy.[4]

In this paper, I study whether infrequent product-price changes at the firm level are a source of macroeconomic risk, which is priced in the cross section of stock returns. I document for the first time that firms with sticky prices earn a return premium of more than 4% per year compared to firms with flexible prices. The premium for sticky-price firms is in the order of magnitude of the size and value premia that are the most studied cross-sectional return-premia in finance. The premium is robust to controlling for standard return predictors at the firm and industry level and is fully explained by differences in exposure to systematic risk. Hence sticky-price firms are risky and command a return premium. To rationalize these findings, I develop a multi-sector production-based asset-pricing model in which sectors differ in the degree of price stickiness.

[1] See Knotek II (2008) and Figure 2.1.

[2] Prices at the good level remain unchanged for roughly six months. See, for example, Bils and Klenow (2004) and Nakamura and Steinsson (2008).

[3] See Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007). Galí (2009) starts his textbook with "That framework has emerged as the workhorse for the analysis of monetary policy and its implications for inflation, economic fluctuations, and welfare. It constitutes the backbone of the new generation of medium-scale models under development at [...] the Federal Reserve Board, [...] and many other central banks."

[4] Kehoe and Midrigan (2012) express this notion in the first line of their paper: "A widely held view in macroeconomics is that monetary policy can be effective primarily because aggregate prices are sticky."

Price rigidities are therefore not only central to explaining the business-cycle dynamics of aggregate real variables such as gross domestic output or investment, they also predict the cross section of stock returns. A firm's exposure to systematic risk is a function of many parameters and factors. The frequency of product price adjustment is a simple variable at the firm level that can account for a considerable part of the variation in firms' exposure to systematic risk.

Specifically, I measure price stickiness as the average frequency of product price adjustment at the firm level. I construct this metric using the confidential microdata underlying the Producer Price Index (PPI) at the Bureau of Labor Statistics (BLS), and merge it with financial data from the Center for Research in Security Prices (CRSP) and Compustat. I show that portfolios of firms sorted on the frequency of price adjustment generate a return spread of 4.4% per year between sticky- and flexible-price firms. Portfolio returns monotonically decrease in the degree of price flexibility.

The return premium for sticky-price firms is a robust feature of the data. In panel regressions, moving from a firm with rigid prices to a firm with flexible prices leads to an annual return differential of 6%. Adding year fixed effects and additional covariates at the firm and industry level has no impact on this finding. A specification with all controls implies an annual return premium of 4%. The premium for sticky-price firms is also not driven by non-linear relationships between firm characteristics and returns. Controlling non-parametrically for return predictors in double sorts, I show that the premium for sticky-price firms is still highly statistically significant and similar in magnitude to the value premium. Exploiting only variation in the frequency of price adjustment within industry, I document that my previous findings are not due to unobserved industry-level characteristics.

I then investigate the properties of the return premium. First, I test whether differential exposure to systematic risk can explain the portfolio returns. The Capital Asset Pricing Model (CAPM) cannot explain the *level* of portfolio returns, but it can explain the *cross-sectional dispersion*: the sticky-price portfolio has a conditional β with the market excess return of 1.29. βs decrease monotonically in price flexibility, resulting in a β differential of 0.37 between the sticky- and flexible-price portfolios. Sticky price firms are risky and earn a return premium.

Second, I investigate the empirical success of the CAPM that is typically rejected in the data. Campbell and Vuolteenaho (2004) argue that variations in the aggregate stock market can occur either due to news about future discount rates or news about future cash flows. Differential exposure to these two sources of fundamental risk across portfolios can explain why the overall β might not be a sufficient statistic in case of different market prices of risk. I find that sticky-price firms have higher exposure to both sources of fundamental risk and are unambiguously riskier than firms with flexible prices.

Third, I study the conditional association between portfolio returns and monetary policy shocks. Sixty to eighty percent of the realized equity premium is earned around scheduled macroeconomics news announcements such as the press releases of the Federal Open Market Committee (FOMC) which highlights the importance of monetary policy shocks for aggregate risk premia. I document that the sensitivity of portfolio returns to monetary policy shocks varies substantially across portfolios. Sticky-price firms fall most following a contractionary monetary policy shock, whereas the flexible price portfolio shows the least reaction. The differential reaction across portfolios is broadly in line with the CAPM. Therefore, the CAPM has high explanatory power for the cross section of stocks sorted on the frequency of price adjustment, both unconditionally and conditional on the realization of monetary policy shocks. These results underline the role of the frequency of price adjustment as a strong determinant of the cross section of stock returns and the power of monetary policy to affect the real side of the economy.

Last, I examine the time-series characteristics of the return premium. I construct a zero-cost portfolio, which invests in stocks with low frequency of price adjustment, and funds this investment by selling short flexible price firms (L-H in the following). I check if the premium for sticky price firms varies systematically over the business cycle and if it can be predicted in long-horizon regressions. I find that the premium is higher in recessions and times of low market returns. The Lettau and Ludvigson (2001) proxy for the consumption-wealth ratio (cay) can explain up to 60% of the time-series variation.

To organize these facts in a coherent setting, I develop a multi-sector production-based asset-pricing model. Households derive utility from a composite consumption good and leisure. The production side is organized in different sectors. Firms are monopolistically competitive and set prices as a markup over a weighted average of future marginal costs. The only heterogeneity across sectors is a different degree of price stickiness motivated by the empirical findings of Nakamura and Steinsson (2008). The basic structure of my model is similar to Carvalho (2006).[5] Mine differs in several ways. I add external habit formation in consumption and wage stickiness to get a reasonable equity premium.[6] I also allow for different elasticities of substitution in consumption varieties within and across sectors as they play a distinct role for cross-sectional return premia.

I calibrate the model using standard parameters to the empirical distribution of price stickiness from Nakamura and Steinsson (2008). In portfolio sorts, the model generates a spread in returns of 2.4% per year between firms with low and high frequencies of price adjustment. In regressions of annual stock returns on the monthly frequency of price adjustment, coefficients are quantitatively in line with my empirical results. The premium for firms with low frequency of price adjustment varies substantially over the business cycle and is highly predictable by habit-adjusted consumption. The model-implied equity premium is in the range of historical estimates.

Low relative payoffs in times of high marginal utility are central for cross-sectional return premia. I show that three margins determine the return difference between sticky- and flexible-price firms: a quantity margin, a price margin, and an inefficiency margin associated with price dispersion. The quantity margin captures the sensitivity of sectoral output to

[5]Carvalho (2006) studies the persistent effects of nominal shocks on aggregate real outcomes in the presence of differences in the frequency of price adjustment.

[6]I use habit-formation preferences instead of Epstein and Zin (1989) and Weil (1989) recursive utility, because they are more standard in macro models (see, e.g., Boldrin, Christiano, and Fisher (2001), Christiano et al. (2005), and Smets and Wouters (2007)).

price differentials across sectors, which is the price margin, while the inefficiency margin reflects lost output due to dispersion in prices. To gain intuition for the three margins, consider the effects of a contractionary monetary policy shock. Aggregate output decreases after the shock, as does the aggregate wage rate, whereas marginal utility goes up. Firms want to lower their product prices to accommodate the lower demand and marginal costs. Sticky-price firms, however, are stuck at their currently too high prices. Consumers therefore substitute away to firms in the flexible-price sector because of their lower relative prices. In terms of revenues, firms in the sticky-price sector gain along the price margin but lose along the quantity margin. In addition, the dispersion in prices is higher in the sticky-price sector, resulting in lower output and dividends. The three margins combined result in lower dividends for sticky-price firms in times of high marginal utility compared to firms with flexible prices.

The key condition for a sizeable return premium for sticky-price firms is a sufficiently large elasticity of substitution between consumption varieties within sectors. I show that the disadvantage of sticky-price firms along the quantity margin and the advantage along the price margin decrease in the within-sector elasticity, whereas the disadvantage along the price-dispersion margin increases in this elasticity. The effects on the price and inefficiency margins are quantitatively more important than the impact on the quantity margin, and the return differential increases in the within-sector elasticity.

Wage stickiness increases the level of the equity premium in the model. Dividends equal output minus wages. In an economy with frictionless labor markets, wages equal the marginal product of labor and are therefore perfectly correlated with output. A drop in demand leads to a drop in output, but at the same time, it also decreases the wage bill. Hence dividends exhibit too little variation in any reasonable calibration. The Calvo (1983)-style wage-setting friction de-couples the average wage paid by a firm from the marginal product of labor. In times of low output and high marginal utility, the wage rate of some labor types cannot be adjusted downward. Firms therefore have to incur higher wages in bad times. This mechanism makes claims on dividends riskier than claims on production, and boosts the level of the equity premium.[7]

The paper is organized as follows. The next subsection reviews the related literature. Section 2.2 describes how I measure the frequency of price adjustment at the firm level and my data sources. In Section 2.3, I first document cross-sectional patterns at the portfolio level. I then move on to panel regressions and double sorts before I perform CAPM and long-horizon regressions again at the portfolio level. Section 2.4 develops and calibrates a multi-sector New Keynesian production-based asset-pricing model to organize the empirical facts in a unified framework. Section 2.5 concludes and lays out directions for future research.

[7]Wage stickiness is equal across sectors and therefore primarily affects the level of the equity premium.

Related Literature

The paper is related to a large literature in macroeconomics documenting stylized facts about the pricing behavior of firms, and the asset-pricing literature on production-based asset pricing, the equity premium, and the relationship between firm characteristics and cross-sectional return-premia. I contribute to the macroeconomics literature by documenting that differences in the frequency of price adjustment are associated with differences in expected returns. Price stickiness therefore has real costs for firms; it increases the cost of capital, and firms might forgo profitable investment projects. I contribute to the finance literature by documenting that the frequency of price adjustment is a strong determinant of exposure to systematic risk and is a priced risk factor in the cross section of stock returns.

Macroeconomics

This paper builds on the literature on price stickiness. Using data from retail catalogs, Kashyap (1995) shows that nominal prices are fixed for more than one year. Zbaracki, Ritson, Levy, Dutta, and Bergen (2004) document in detail for a large U.S. manufacturer the costs associated with changing prices, such as data collection, managerial costs, physical costs, or negotiation costs. The total cost of changing nominal prices can be as high as 1.22% of total revenue and 20.03% of the company's net profit margin. Bils and Klenow (2004) and Nakamura and Steinsson (2008) use the microdata underlying the Consumer Price Index (CPI) at the BLS to show that prices are fixed for roughly six months and that substantial heterogeneity is present in price stickiness across industries. Goldberg and Hellerstein (2011) confirm these findings for producer prices.[8] More recent research exploits information in asset prices to answer macro questions linking the micro data of the BLS with financial data from CRSP and Compustat. Gorodnichenko and Weber (2013) use the micro data underlying the PPI to test alternative theories of price stickiness in the micro data. Performing high-frequency-event studies around the press releases of the Federal Open Market Committee, they document costs associated with nominal price adjustments. Their findings support the New Keynesian interpretation of price stickiness. Gilchrist, Schoenle, Sim, and Zakrajsek (2013) investigate inflation dynamics during recessions at the industry level and for firms close to default.

Finance

This paper is also related to the literature on production-based asset pricing and the equity premium. The external-habit formation model of Campbell and Cochrane (1999) and the

[8] Other recent contributions to this literature are Golosov and Lucas Jr. (2007), Klenow and Willis (2007), Klenow and Kryvtsov (2008), Knotek II (2008), Eichenbaum, Jaimovich, and Rebelo (2011), Midrigan (2011), Anderson, Jaimovich, and Simester (2012), Kehoe and Midrigan (2012), Bhattarai and Schoenle (2012), Eichenbaum, Jaimovich, Rebelo, and Smith (2012), Kaplan and Menzio (2013), and Vavra (2013). Klenow and Malin (2010) and Nakamura and Steinsson (2013) provide excellent reviews of the recent literature on price rigidity using micro price data.

long-run risk model of Bansal and Yaron (2004) as well as rare disasters in the tradition of Rietz (1988), Barro (2006) and Gabaix (2012) have been successful in generating empirically plausible levels of the equity premium in endowment economies. The equity-premium puzzle of Mehra and Prescott (1985), however, reappears if one puts these frameworks in a frictionless production economy: Lettau and Uhlig (2000) and Boldrin, Christiano, and Fisher (2001) show that habits alone cannot generate an equity premium, because agents can use the production technology and labor supply to smooth consumption. Jermann (1998), Zhang (2005), and others introduce investment-adjustment costs to address this problem and generate a sizeable equity premium. Kaltenbrunner and Lochstoer (2010) and Croce (2012) document that long-run risk can generate an equity premium in a production economy. More recent research focuses on the potential of wage and price rigidities to explain aggregate stock market patterns. Uhlig (2007) shows that external habits and real-wage stickiness generate an equity premium. Favilukis and Lin (2013) develop a production-based asset-pricing model with sticky wages and employment-adjustment costs. Li and Palomino (2011) develop a multi-sector production-based asset-pricing model with sticky prices and wages. Both papers have Epstein and Zin (1989) and Weil (1989) recursive preferences and are able to generate empirically reasonable levels of the equity risk premium in calibrations.[9] I contribute to this literature by theoretically showing the impact of heterogeneity in price stickiness on cross-sectional return premia. To the best of my knowledge, this paper is the first to test for the effects of nominal rigidities on stock returns at the firm level.

In addition, I contribute to the literature linking firm characteristics to stock returns in the cross section. Fama and French (1992) offer a concise treatment of the size effect of Banz (1981), the value premium of Rosenberg, Reid, and Lanstein (1985), and other cross-sectional relationships in a unified setting. Berk, Green, and Naik (1999), Carlson, Fisher, and Giammarino (2004), Gomes, Kogan, and Zhang (2003), and Kogan (2004) document that these premia naturally arise from firms' optimal production and investment behavior. Hou and Robinson (2006), Bustamante and Donangelo (2012), and Donangelo (2013) relate industry concentration, product market competition, and labor mobility across industries to expected returns in the cross section. Van Binsbergen (2012) studies the impact of good-specific habit formation and finds that cross-sectional variation in the demand for goods leads to differences in expected returns.[10]

I add to this literature by documenting that different pricing technologies in product markets lead to different exposure to systematic risk. A difference in average conditional βs of almost 0.40 explains the return spread between sticky- and flexible-price firms.

[9] Kuehn, Petrosky-Nadeau, and Zhang (2012) incorporate search and matching frictions in a production-based asset-pricing model and show that this friction endogenously generates consumption disasters.

[10] See also Gomes, Kogan, and Yogo (2009), Novy-Marx (2011), Gârleanu, Kogan, and Panageas (2012), Kogan and Papanikolaou (2012), Ahern (2012), and Jones and Tuzel (2012), among many others.

2.2 Data

This section describes both my measure of the frequency of product price adjustment at the firm level, and the financial data I use.

Measuring Price Stickiness

A key ingredient of my analysis is a measure of price stickiness at the firm level. I use the confidential microdata underlying the PPI at the BLS to calculate the frequency of price adjustment at the firm level. The PPI measures changes in selling prices from the perspective of producers, and tracks prices of all goods-producing industries such as mining, manufacturing, gas and electricity, as well as the service sector.[11]

The BLS applies a three-stage procedure to determine the individual sample goods. In the first stage, the BLS compiles a list of all firms filing with the Unemployment Insurance system to construct the universe of all establishments in the United States. In the second and third stages, the BLS probabilistically selects sample establishments and goods based on the total value of shipments or on the number of employees. The BLS collects prices from about 25,000 establishments for approximately 100,000 individual items on a monthly basis. The BLS defines PPI prices as "net revenue accruing to a specified producing establishment from a specified kind of buyer for a specified product shipped under specified transaction terms on a specified day of the month." Prices are collected via a survey that is emailed or faxed to participating establishments. Individual establishments remain in the sample for an average of seven years until a new sample is selected to account for changes in the industry structure.

I calculate the frequency of price adjustment at the good level, SA, as the ratio of price changes to the number of sample months. For example, if an observed price path is $4 for two months and then $5 for another three months, one price change occurs during five months and the frequency is 1/5.[12] I calculate both equally weighted frequencies, U, and frequencies weighted by values of shipments associated with items/establishments, W.

I then first aggregate goods-based frequencies to the establishment level via internal identifiers of the BLS. To perform the firm-level aggregation, I check whether establishments with the same or similar names are part of the same company. In addition, I use publicly available data to search for names of subsidiaries and name changes due to, for example, mergers, acquisitions, or restructuring occurring during the sample period for all firms in the dataset. Appendix B discusses in more detail how the aggregations are performed.

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[11]The BLS started sampling prices for the service sector in 2005. The PPI covers about 75% of the service sector output. My sample of micro price data ranges from 1982 to 2011. The data until 1998 are equivalent to the data used in Nakamura and Steinsson (2008).

[12]When calculating the frequency of price adjustment, I exclude price changes due to sales, using the filter of Nakamura and Steinsson (2008). Including sales does not affect my results because sales are rare in producer prices (see Nakamura and Steinsson (2008)). My baseline measure treats missing price values as interrupting price spells. Appendix B contains results for alternative measures of the frequency of price adjustment; results are quantitatively and statistically similar.

Table 2.1 reports mean frequencies, standard deviations, and the number of firm-month observations for the frequency of price adjustment, both for the total sample and at the industry level.[13] I focus on the unweighted frequency of price adjustment, SAU, because results are similar across the two measures. The overall mean monthly frequency of price adjustment is 14.86%, which implies an average duration, $-1/ln(1-SAU)$, of 6.22 months. Substantial heterogeneity is present in the frequency across sectors, ranging from as low as 8.13% for the service sector (duration of 1 year) to 22.75% for agriculture (duration of 3.9 months). Finally, the high standard deviations highlight large heterogeneity in measured price stickiness across firms even within industries.

Different degrees of price stickiness of similar firms operating in the same industry can arise due to differences in the costs of negotiating with customers and suppliers, in the physical costs of changing prices, or in the managerial costs such as information gathering, decision making, and communication.[14]

Financial Data

Stock return, shares outstanding and volume data are from the CRSP Monthly Stock file. I focus on firms that have been part of the S&P500 between 1994 and 2009 because of the availability of the PPI data and to keep the manual merging between the two datasets manageable.[15] Size of year t is the natural logarithm of the total market capitalization at the firm level as of December t-1. β (Beta) is the regression coefficient in rolling time-series regressions of monthly excess returns on a constant and the excess returns of the CRSP value-weighted index over a 60-month period. Turnover is the ratio of volume to shares outstanding (in percent). Spread is the monthly average of the daily bid-ask spreads from the CRSP Daily Stock file.

I obtain balance-sheet data from the Standard and Poor's Compustat database. I define book equity (BE) as total stockholders' equity plus deferred taxes and investment tax credit (if available) minus the book value of preferred stock. Based on availability, I use the redemption value, liquidation value, or par value (in that order) for the book value of preferred stock. I prefer the shareholders' equity number as reported by Compustat. If not available, I calculate shareholders' equity as the sum of common and preferred equity. If none of the two are available, I define shareholders' equity as the difference between total assets and total liabilities. The book-to-market (BM) ratio of year t is then the book equity for the fiscal year ending in calendar year t-1 over the market equity as of December t-1.

[13] The coarse definition of industry is due to confidentiality reasons and partially explains the substantial variation of the measures of price stickiness within industry.

[14] These differences might arise because of, for example, differences in customer and supplier structure, heterogeneous organizational structure, or varying operational efficiencies and management philosophies (see Zbaracki et al. (2004)).

[15] I have 956 unique firms in my sample due to changes in the index composition during my sample period, out of which I was able to merge 760 with the BLS pricing data. The merged and overall sample of firms look virtually identical with respect to the studied firms characteristics (see Table B.13 in Appendix B).

Leverage (Lev) is the ratio of total long-term debt and debt in current liabilities over the sum of the numerator and shareholders' equity. Cash flow (CF) is the sum of income before extraordinary items and depreciation and amortization over total assets. I calculate the price-to-cost margin (PCM) as net sales minus cost of goods sold over net sales and HHI as the Herfindahl-Hirschman index of sales at the Fama & French 48 industry level at an annual frequency.[16]

Table 2.2 summarizes time-series averages of annual means and standard deviations of the return predictors in Panel A as well as contemporaneous correlations in Panel B. I have on average more than 500 firms per year. My sample consists of large major U.S. companies with a mean size of more than \$3 billion and a β of slightly above 1. In Panel B, we see that firms with more flexible prices have higher book-to-market ratios and leverage, but also lower βs and price-to-cost margins. The positive correlation with leverage might indicate that price flexibility in product markets increases the debt capacity of firms via reduced default costs. The higher β for sticky-price firms suggests higher riskiness. The positive correlation with the price-to-cost margin highlights the importance of disentangling the frequency of price adjustment from other covariates. Firms with low frequencies of price adjustment might have *market power* and therefore be unresponsive to changes in costs or demand instead of facing *costs* of changing nominal prices.

2.3 Empirical Results

I first sort stocks into five portfolios based on their frequency of price adjustment to test if differences in price stickiness are associated with differences in returns. I then run a series of panel regressions to disentangle a return premium for price stickiness from other cross-sectional-return predictors. I also perform conditional double sorts on characteristics and the frequency of price adjustment to allow for non-linearities between returns and characteristics. Lastly, I test whether the CAPM can explain the cross-sectional-return difference. I investigate the conditional association between portfolio returns and monetary policy shocks, and I look at business-cycle variation in the return premium.

Portfolio Level

I sort stocks into five portfolios based on the frequency of price adjustment, SAU. The frequency of price adjustment is by construction monotonically increasing from as low as 0.01 for portfolio 1 to 0.35 for the flexible price portfolio (see Table B.3 in Appendix B for firm characteristics at the portfolio level). I measure annual returns from July of year t to June of year t+1, and I weight returns equally within each portfolio.[17]

[16] I winsorize all variables at the 2.5% level to minimize the effect of extreme observations and outliers. Results are similar if I perform my analysis on unwinsorized data (see Appendix B).

[17] Because the frequency of price adjustment at the firm level shows little variation over time, I do not rebalance portfolios but only sort once at the beginning of the sample period.

Panel A of Table 2.3 reports average annual returns for various sample periods. The sorting generates a spread in returns between the sticky- and flexible-price portfolios of 2.7%–6.7% per year. This premium is statistically significant and economically large. Mean returns decrease monotonically in the degree of price flexibility. The return premium is larger after the Volcker disinflation, with a non-binding zero lower bound on interest rates and before the start of the Great Recession. In the rest of the paper, I focus on a period from July of 1982 to June of 2007. The micro data I use to construct the frequency of price adjustment start in 1982. I limit the analysis to 2007 because doing so allows me to circumvent the concerns associated with a binding zero lower bound on nominal interest rates and the effects of the Great Recession. Results for the full sample are similar (see Appendix B).

In Panel B, I report returns adjusted for firm characteristics associated with stock returns in the cross section. Following Daniel, Grinblatt, Titman, and Wermers (1997), I sequentially sort all common stocks of the CRSP universe into one of 125 benchmark portfolios based on size, industry-adjusted book-to-market, and momentum. I then assign each stock in my sample to a benchmark portfolio based on its size, book-to-market ratio, and previous 12-month return. I calculate benchmark-adjusted returns by subtracting the assigned portfolio returns from the individual stock returns. An adjusted return of zero implies the total stock return is explained by the stock's characteristics.

Standard stock characteristics cannot explain the return premium for sticky-price firms. We see in Panel B that differences in the frequency of price adjustment still lead to a differential return of 2.1%–5.6% even after controlling for these characteristics. Portfolio returns are monotonic in the portfolio number.

For comparison, Panel C reports the average annual returns for the CRSP value-weighted and equally weighted indexes and the size (SMB) and value premia (HML) of Fama and French (1993). The average annual return for the CRSP indexes is 15% and 16.8%, respectively, during my benchmark sample period. The size premium is less than 1% and statistically insignificant, whereas the value premium is 5.6%. The premium for sticky-price firms is therefore economically large and in the order of magnitude of two of the most studied cross-sectional-return premia in finance.

Panel Regressions

A limitation of the portfolio analysis is that returns may differ across portfolios for reasons other than price stickiness, such as heterogeneity in market power or cyclicality of demand. I therefore exploit the rich cross-sectional variation in returns, measured price rigidities, and other firm characteristics to differentiate between these alternative explanations. Specifically, I run various panel regressions of annual returns at the firm level, $R_{i,t}$, on the firm-specific measure of price stickiness, SAU_i, firm- and industry-level controls, $X_{i,n,t}$, and year fixed effects, μ_t:

$$R_{i,t} = \alpha + \beta_{SAU_i} \times SAU_i + \sum_n \beta_n \times X_{i,n,t} + \mu_t + \epsilon_{i,t}. \tag{2.1}$$

Table 2.4 reports results for annual, non-overlapping percentage returns. Standard errors are clustered at the firm level and reported in parentheses. The coefficient on SAU in column (1) is negative and highly statistically significant: moving from a firm that never changes product prices to a firm with the most flexible prices leads to a return differential of 6% per year.[18] Adding year fixed effects in column (2) increases the coefficient on SAU in absolute value. In columns (3)–(5), we see that larger firms have lower returns (*size* effect); firms with high book value of equity compared to market value command a positive return premium (*value* effect); and firms with higher βs earn on average higher returns ($CAPM$). Controlling for these factors, however, has little impact on the coefficient on SAU. The coefficient varies between -8.04 and -12.94, which implies a return differential between sticky- and flexible-price firms of 4.8%–7.8% per year. Controlling for additional covariates in columns (6)–(11) has no material effect on the economic or statistical significance of the coefficient of interest. In the last column, I add all explanatory variables jointly. The coefficient on the frequency of price adjustment remains negative and highly statistically significant, contrary to the coefficients on some of the return predictors. The specification with all controls implies an annual return premium of 4.2%. The coefficient on SAU in the panel regressions implies a similar spread in returns as the portfolio analysis in Table 2.3: the difference in the frequency of price adjustment between the two extreme portfolios of 0.34 (see Table B.3 in Appendix B) implies a return differential of 2.4%–4.4%, depending on the controls employed.

Table 2.5 repeats the baseline analysis at the industry level to control for possibly unobserved industry heterogeneity. This exercise exploits only variation in the frequency of price adjustment within industry. I typically have fewer observations, and thus my estimates have higher sampling uncertainty. For all industries, I find a negative coefficient on SAU, which is statistically significant for three out of the six industries. These results indicate that the baseline effects are not driven by unobserved industry characteristics. Instead of running regressions at the industry level and relying on small sample sizes, I add industry dummies in the last column of Table 2.5. The coefficient on the frequency of price adjustment is highly statistically significant, economically large, and consistent with previous estimates. The return premium for sticky-price firms is therefore not driven by differences in mean return across industries for reasons orthogonal to the frequency of price adjustment.

[18] I calculate this premium by multiplying the regression coefficient on SAU by the difference in the frequency of price adjustment: 10.04×0.6 (see Table 2.1). The interquartile range in the frequency of price adjustment implies an annual return difference of 1.8%. A one-standard-deviation change in SAU is associated with a differential return of 1.3% per year.

Double Sorts

In Table 2.6, I perform conditional double sorts to allow for a potentially non-linear association between firm characteristics and returns. Specifically, I first sort all stocks into three baskets based on a cross-sectional-return predictor. Within each basket, I further sort stocks into three baskets based on price stickiness. For each category of price stickiness, I then take the average across sorts of the firm characteristic and report them in Table 2.6. In column (1), for example, I compare portfolios differing in price stickiness but with similar composition of market capitalization.

In column (0), I report the results of an unconditional sort into tertiles based on the frequency of price adjustment. This sorting generates a statistically-significant spread in returns of more than 3% between the sticky- and flexible-price portfolios. Looking at the sorting conditional on size in column (1), we see that returns decrease monotonically in price flexibility. The spread in returns between sticky- and flexible-price firms is a statistically significant 2.5% per year. Focusing on this difference across conditioning variables in columns (2)–(9), we see that price stickiness always commands a statistically significant premium between 2.7% and 3.5% per year. These premia are similar in size to the unconditional premium in column (0).

To get a feeling for the magnitude of the return differential, I perform two more conditional double sorts in the last two columns. First, I sort all stocks into three brackets based on size. Second, within each size category, I sort stocks based on β and book-to-market. These sorts generate an annual return differential between high- and low-β stocks and value and growth sorts of 3.5% and 1.8%, respectively, after controlling for size. The conditional premium for high-β stocks is barely statistically significant, and the conditional value premium is economically small and statistically insignificant.

The premium for sticky-price firms is hence neither driven by linear nor non-linear relations with standard cross-sectional-return predictors, and is economically significant.

Exposure to Systematic Risk

At the portfolio level, I test whether the CAPM can explain the cross-sectional-return difference. I then decompose the systematic risk exposure into co-movement with aggregate cash-flow news and discount-rates news, and I study the effects of monetary policy shocks on returns.

Capital Asset Pricing Model

To test the CAPM, I perform standard time-series regressions of portfolio excess returns, $R^e_{p,t}$, on a constant and the excess returns of the CRSP value-weighted index, $R^e_{m,t}$:

$$R^e_{p,t} = \alpha_p + \beta_p \times R^e_{m,t} + \epsilon_{p,t}.$$

The CAPM predicts that the expected excess return is fully explained by exposure to market risk, namely, that the α is zero.

Table 2.7 reports αs in percent per month and βs for the unconditional CAPM in Panel A and the conditional CAPM in Panel B.[19] I evaluate statistical significance using the time-series variability of the slope and intercept coefficients following Fama and MacBeth (1973) in parentheses and Newey and West (1987)-corrected standard errors in brackets.

In Panel A, we see that the unconditional CAPM cannot explain the portfolio returns. Monthly αs range between 0.46% and 0.57% per month and are highly statistically significant. In column (6), we also see that the L-H portfolio has a statistically insignificant α of 0.11% per month.

Panel B shows similar findings for the conditional CAPM: αs are positive and statistically significant but similar across portfolios. βs monotonically decrease from 1.29 for portfolio 1 to 0.91 for portfolio 5. The conditional CAPM drives the α of the L-H portfolio all the way to 0. The difference in annual returns between stocks with high and low frequencies of price adjustment of more than 4% is fully explained by their differential exposure to market risk.

Figure 2.2 plots the excess returns of the L-H portfolio and the aggregate market. The two series track each other closely. Times of low market returns typically coincide with times of low returns to the L-H portfolio. The unconditional correlation between the two times series is more than 50%.

Sticky-price firms are riskier and therefore earn higher returns than firms with flexible prices.[20] These findings imply that the frequency of price adjustment, a simple measure of a firm's pricing technology, is a significant predictor of systematic risk.

Discount-Rate and Cash-Flow News

Differences in the frequency of price adjustment lead to a spread in returns that is fully explained by differential exposure to systematic risk. The empirical success of the CAPM is surprising because the data generally reject this model.[21] Campbell and Vuolteenaho (2004) argue that variations in the aggregate stock market can occur either due to news about

[19] I estimate the conditional CAPM monthly on a rolling basis over the previous year, following Lewellen and Nagel (2006). In line with their setup, I add both the contemporaneous and one-month lagged market excess return in the rolling short-window regressions and define the conditional β as the sum of the slope coefficients.

[20] Differences in βs fully explain differences in returns in the portfolio analysis, whereas individual firms' βs and the frequency of price adjustment are both individually significant in the panel regressions. Noting that firm-level βs are measured with noise can reconcile this apparent contradiction. The empirical asset-pricing literature has therefore moved away from explaining individual stock returns to explaining returns at the portfolio level sorted on some characteristic of interest (see Fama (1976)).

[21] See e.g. Black, Jensen, and Scholes (1972). Frazzini and Pedersen (2013) show that a sorting on pre-formation βs leads to a spread in realized βs of 1.18, which is only associated with a spread in realized returns of 0.06 per month. They call this phenomenon the "too flat security market line." Lettau, Maggiori, and Weber (2013) show that a simple extension of CAPM, which allows for a separate compensation for comovement with aggregate market returns conditional on low realizations of market returns, has high explanatory power across many important asset classes. Unconditional and downstate sensitivities to market risk for my portfolios sorted on the frequency of price adjustment are almost identical and their model boils down to standard CAPM.

future cash flows or due to news about future discount rates. They derive a decomposition of CAPM β into a cash-flow β, β_{CF}, and a discount-rate β, β_{DR}, and they suggest the price of risk for the covariation with discount-rate news is lower than the price of risk for the covariation with cash-flow news based on the insights of the ICAPM.[22] Differential exposure to these two sources of fundamental risk can explain why the overall β might not be a sufficient statistic to explain expected returns. High-β stocks can earn lower returns than predicted by the CAPM if most of their overall β is due to the covariation with discount-rate news.

In Table 2.8, I perform the Campbell and Vuolteenaho (2004) decomposition to investigate why the CAPM performs well in my setting.

I define cash-flow and discount-rate βs as

$$\beta_{p,CF} \equiv \frac{Cov(r^e_{p,t}, N_{CF,t})}{Var(r^e_{m,t} - \mathbb{E}_{t-1}\, r^e_{m,t})}$$
$$\beta_{p,DR} \equiv \frac{Cov(r^e_{p,t}, -N_{DR,t})}{Var(r^e_{m,t} - \mathbb{E}_{t-1}\, r^e_{m,t})},$$

where $r^e_{p,t}$ is the log excess return of portfolio p, $r^e_{m,t}$ is the log excess return of the market, $N_{CF,t}$ denotes news about future dividends, $N_{DR,t}$ denotes news about future expected returns, and $\mathbb{E}_t$ is the expectation operator conditional on the time t information set. I estimate a VAR with the market excess returns as one of the state variables. The news terms are then simple functions of VAR innovations.[23] I calculate GMM (Hansen (1982)) standard errors conditional on the realized news series from the VAR.

We see in column (1) that cash-flow and discount-rate news contribute almost equally to the overall β of the sticky-price portfolio of 1.15: $\beta_{S1,CF}$ is 0.55 and $\beta_{S1,DR}$ is 0.60. Both βs decrease monotonically in the portfolio number to values of 0.41 and 0.44, respectively. The difference in βs between sticky- and flexible-price portfolios is 0.14 for $\beta_{S1-S5,CF}$, 0.15 for $\beta_{S1-S5,DR}$, and 0.29 for the overall β_{S1-S5}. The difference in discount-rate and cash-flow βs is almost constant across portfolios and varies between 0.03 and 0.04. Sticky price firms have higher exposure to both sources of fundamental risk and are unambiguously riskier than firms with flexible prices. The overall β is therefore sufficient to determine the overall riskiness of a portfolio independent of potentially different prices of risk.[24]

Monetary Policy Shocks and Portfolio Returns

There is a growing literature documenting the importance of monetary policy for risk premia in equity and bond markets. Sixty to eighty percent of the realized equity premium is earned

[22] See Merton (1973), Campbell (1993), and Campbell (1996).

[23] See Appendix B for a detailed discussion and derivation of the key equations.

[24] The reason for the good empirical performance of the CAPM is in line with the findings of Campbell and Vuolteenaho (2004). They document that the CAPM can explain the cross section of size and book-to-market sorted portfolios for a sample from 1928 to 1963 as both discount-rate and cash-flow βs line up with the overall βs.

around macroeconomic news announcements such as the press releases of the FOMC.[25] Monetary policy surprises are purely nominal shocks and are of particular interest in the context of nominal rigidities. A further advantage of monetary policy shocks is that they are easy to construct, well identified, and are the subject of a substantial literature in macroeconomics and finance. In addition, these shocks are the main driver of risk premia in my model.

Table 2.9 reports the results from regressing monthly excess returns, $R^e_{p,t}$, of portfolios sorted on the frequency of price adjustment and the CRSP value-weighted index on the surprise component of the one-month change in the Federal Funds rate, Δi^u_t:

$$R^e_{p,t} = \alpha_p + \beta_{p,FFR} \times \Delta i^u_t + \epsilon_{p,t}.$$

The sample is restricted to a period from June 1989 to June 2007 due to the availability of the Federal Funds futures. The aggregate market falls by more than 9% after a 1% surprise increase in the Federal Funds rate (column (1)). The reaction varies substantially across portfolios. Portfolio 1 is the most responsive (falls by 11%), whereas the flexible price portfolio falls by only 5%.

This differential reaction is broadly in line with CAPM. The sticky-price portfolio is predicted to earn -11% following a Federal Funds rate surprise.[26] The predicted sensitivities decrease monotonically in the degree of price stickiness to a predicted drop of 7% for the flexible-price portfolio. The CAPM slightly underpredicts the cross-sectional dispersion in returns following the Federal Funds rate surprises. This "too flat Capital Market Line" phenomenon is, however, an order of magnitude smaller than the one documented in Frazzini and Pedersen (2013). Therefore, the CAPM has high explanatory power for the cross section of stocks sorted on the frequency of price adjustment, both unconditionally and conditional on the realization of monetary policy shocks. These results underline the role of the frequency of price adjustment as a strong determinant of the cross section of stock returns.

Business-Cycle Variation in Return Premium

A large literature in finance documents variation in expected excess returns over time, which is predictable by scaled stock-price ratios.[27] Lustig and Verdelhan (2012) show that excess returns in the United States and other OECD countries are substantially higher during

[25]Bernanke and Kuttner (2005) show that a 1% surprise increase in the Federal Funds rate leads to a drop in the CRSP value-weighted index of more than 11% in monthly time-series regressions. Savor and Wilson (2013) show that 60% of the equity premium is earned around scheduled macroeconomic news announcements, whereas Lucca and Moench (2013) find that 80% of the equity premium since 1994 is earned in the 24 hours before the FOMC press releases. On the contrary, Campbell, Pflueger, and Viceira (2013) study the impact of monetary policy and macroeconomic shocks on nominal bond premia and the interlinkages with equity markets.

[26]To calculate the predicted reactions, I first re-estimate the CAPM βs and I then multiply the βs and the estimated sensitivity of the CRSP value-weighted index.

[27]See, among many, Fama and French (1988), Campbell and Shiller (1988b), Campbell (1991), Cochrane (2008), Lettau and Ludvigson (2005), and Koijen and Van Nieuwerburgh (2011) for an excellent recent overview of this literature.

recessions than during expansions. Variation in risk premia leads to variation in the cost of capital of firms to evaluate investment projects and has important implications for asset allocation and market-timing investment strategies. Hence variation in return premia is of interest for both macroeconomists and financial economists.

To test whether returns of the L-H portfolio vary systematically with business-cycle conditions, I perform long-horizon forecasting regressions. Specifically, I run m-month forecasting regressions of cumulative log excess returns of the L-H portfolio, r^e_{lh}, on the log dividend-price ratio for the CRSP value-weighted index, *dp* in Panel A, the break-adjusted log dividend-price ratio in Panel B following Lettau and Van Nieuwerburgh (2008), and the proxy for the consumption-wealth ratio of Lettau and Ludvigson (2001), cay,[28] in Panel C:

$$\sum_{s=1}^{m} r^e_{lh,t+s} = a_{lh} + b^{(m)}_{lh} dp_t + \epsilon_{t+m},$$

with similar definitions for the break-adjusted dividend-price ratio and cay.

The rationale behind these regressions is the Campbell and Shiller (1988a) approximation for the log dividend-price ratio. They show that variation in the dividend-price ratio implies predictability of future returns or dividend growth (or an explosive dividend-price ratio). Empirically, the whole variation in the dividend-price ratio comes from variation in expected returns. Low prices and, hence, high dividend-price ratios predict high returns in the future.

Table 2.10 reports regression coefficients for horizons ranging from one month to five years. For each regression, the table reports Newey and West (1987) standard errors in brackets, Hansen and Hodrick (1980) standard errors in curly brackets, and Hodrick (1992) standard errors in angle brackets.[29] Consistent with recent findings for the aggregate stock market (see, e.g., Lettau and Ludvigson (2005)), the log dividend-price ratio has no explanatory power for the L-H portfolio. Lettau and Van Nieuwerburgh (2008) argue that structural changes in the economy have caused the extreme persistence of the dividend-price ratio. This high persistence might explain the failure of the ratio to predict future returns. They recommend using a break-adjusted dividend-price ratio to account for these shifts. Following their procedure, I find evidence for predictability of the L-H portfolio returns at horizons between three to five years. High dividend-price ratios predict positive returns for the L-H portfolio.

Lettau and Ludvigson (2005) show that cay is less persistent and that it drives out the log dividend-price ratio in predicting the aggregate stock market at business-cycle frequencies. In Panel C, we see cay has strong predictive power for the L-H portfolio at all horizons

[28] Lettau and Ludvigson (2001) use quarterly data from the National Income and Product Accounts to construct cay. To get a monthly series, I linearly interpolate the quarterly observations available under http://faculty.haas.berkeley.edu/lettau/data_cay.html. cay is the co-integration residual of consumption (c), asset wealth (a), and labor income (y). They show that it is the asset wealth component which error corrects after a deviation from the equilibrium relation which is therefore predictable.

[29] The overlapping nature of returns in long-horizon regressions induces serial correlation in the error terms. Hansen and Hodrick (1980) and Hodrick (1992) standard errors offer alternative methods to take this feature of the error terms into account.

and explains 60% of the time-series variation at a three-year horizon.[30] In times of a high consumption-wealth ratio, the L-H portfolio has high expected returns going forward.

Figure 2.3 plots cay at the end of June along with the subsequently realized five-years returns of the L-H portfolio. The two times series track each other fairly closely. Times of low asset returns and hence high values of cay predict high future returns of the L-H portfolio. The raw correlation between the two time series is a remarkable 68.73%.

The results from the long-horizon predictive regressions establish that firms with sticky prices have higher expected returns than firms with flexible prices in recessions and in times of low aggregate stock market returns. The higher cost of capital for these firms in bad times has implications for firms' investment decisions and the portfolio allocation and market-timing strategies of investment professionals.[31]

The findings in this section document that the cross-sectional-return premium for firms with sticky product prices is a compensation for risk. The portfolio of stocks with low frequencies of price adjustment has a higher co-movement with the aggregate stock market than the flexible-price portfolio. This return premium varies systematically with business-cycle conditions. In the next section, I develop a multi-sector production-based asset-pricing model to rationalize this return premium theoretically. The only source of heterogeneity across sectors is a varying degree of price stickiness. Key ingredients to quantitatively replicate the empirical results are a sufficiently high elasticity of substitution of consumption varieties within sector for the cross-sectional-return premium. Habit formation as well as wage stickiness are crucial for the level and the predictability of equity returns.

2.4 Model

In this section, I develop a production-based asset-pricing model. Households have external habit formation in consumption and derive utility from a composite consumption good and leisure. They provide different labor services and have market power in setting wages. The production side of the economy is organized in different sectors producing output according to a technology that is linear in labor. Individual firms in each sector are monopolistically-competitive suppliers of differentiated goods and competitive demanders in the market of homogeneous labor input. I consider a cashless economy with nominal bonds in zero net

[30] cay has a marginally statistically significant forecasting power for the log excess return of the CRSP value-weighted index. The maximal R^2 is 35% at a four-year horizon (see Table B.28 in Appendix B).

[31] Appendix B contains additional results. Specifically, I report results for my baseline panel regression specification for overlapping annual returns at the monthly frequency, annualized monthly returns, as well as the previous specification with month fixed effects. Appendix B also contains results of panel regressions for the full sample, for the benchmark sample with unwinsorized variables and for panel regressions at the portfolio level. I also discuss results for realized volatilities and for different measures of the frequency of price adjustment, both at the portfolio level for raw and characteristic adjusted returns and in panel regressions. In addition, I report descriptive statistics at the portfolio level and for the full sample. All additional results are similar to those reported in the main body of the paper and discussed in detail in Section B.5 of the appendix.

supply. The monetary authority sets short-term interest rates according to a Taylor rule. My model features nominal rigidities at the micro level that are necessary to explain the real effects of purely nominal shocks. Specifically, the model exhibits sticky wages and prices. I assume equal wage rigidities across sectors but differing degrees of price stickiness, in line with micro evidence of Nakamura and Steinsson (2008). This empirically motivated setup allows me to theoretically investigate the impact of the heterogeneity in price stickiness on the cross section of stock returns.

Firms

There is a continuum of monopolistically-competitive firms divided into different sectors. Firms are indexed by their sector, $k \in [0,1]$, and by $j \in [0,1]$. The distribution of firms across sectors is given by the density f on [0,1]. Firms have market power and follow time-dependent pricing rules. The time for price adjustment arrives stochastically. Each period, a fraction $1-\theta_k$ of firms in sector k adjusts prices. The probability of price adjustment, or Calvo (1983)-rate, is equal across firms in a given sector and is independent of the time the price has been in effect.[32] These probabilities determine the fraction of price adjusters in the aggregate, the individual firm probabilities of price adjustment in any given period, and the average duration of price spells. Firms are demand constrained and satisfy all demand at posted prices. They rent homogeneous labor services, H_t, taking the wage rate, W_t, as given to produce output according to a linear technology,

$$Y_{kj,t} = A_t H_{kj,t},$$

where $A_t = exp(a_t)$ is aggregate technology evolving according to

$$a_{t+1} = \rho_a a_t + \sigma_a \varepsilon_{a,t+1}.$$

ρ_a is the autoregressive coefficient of log technology, $\varepsilon_{a,t+1}$ is an i.i.d. standard normal random variable and, σ_a is the standard deviation of the technology shock.

The pricing problem of a firm that adjusts in period t is then to set the reset price $X_{kj,t}$ to maximize the expected present value of discounted profits over all future histories in which it will not have a chance to adjust the price:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\Lambda_{t+s}}{\Lambda_t} \left(X_{kj,t} Y_{kj,t+s} - W_{t+s} H_{kj,t+s} \right)$$

$$\text{s.t.} \qquad Y_{kj,t+s} = \left(\frac{X_{kj,t}}{P_{k,t+s}}\right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} Y_{t+s} \tag{2.2}$$

$$Y_{kj,t+s} = A_{t+s} H_{kj,t+s},$$

[32] The Calvo (1983) model is the workhorse New Keynesian model because it is tractable and easily allows aggregation. Modeling price adjustment in a state-dependent framework instead of a time-dependent fashion has very similar implications for macroeconomic aggregates in times of low and stable inflation (see Dotsey, King, and Wolman (1999)).

where Λ_t equals the Lagrange multiplier on the household budget constraint, ε_c and ε_{ck} are the elasticities of substitution in consumption between sectoral subcomposites and within-sector consumption varieties, P_t and $P_{k,t}$ are the composite and sector price indexes defined below, and Y_t is aggregate output. Equation (2.2) represents the demand for consumption variety kj derived below after imposing market clearing in the goods market.

The first-order condition with respect to $X_{kj,t}$ yields[33]

$$\frac{X_{kj,t}}{P_t} = \frac{\varepsilon_{ck}}{\varepsilon_{ck}-1} \frac{\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} \left\{ \left(\frac{W_{t+s}}{P_{t+s}}\right) \left(\frac{1}{A_{t+s}}\right) \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} \left(\frac{P_t}{P_{t+s}}\right)^{-\varepsilon_{ck}} Y_{t+s} \right\}}{\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} \left\{ \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} \left(\frac{P_t}{P_{t+s}}\right)^{1-\varepsilon_{ck}} Y_{t+s} \right\}}, \tag{2.3}$$

where $\lambda_t = \Lambda_t P_t$. Firms charge effectively a constant markup, $\varepsilon_{ck}/(\varepsilon_{ck}-1)$, over a weighted average of current and future real marginal costs. Adjusting firms take into account that they might not have a chance to reset prices in future periods. For example, they set higher prices in case they expect higher marginal costs in the future in order to not sell at a loss in those periods. The Calvo (1983)-probabilities distort the discount factor: the probability that a price set today will still be in effect in period t+s is θ_k^s. Firms therefore heavily discount the effect of future economic conditions for setting current prices if they have a high probability of price adjustment, $(1-\theta_k)^s$.

Adjusting firms in sector k set prices according to equation (2.3), taking the prices of other firms and aggregate prices as given. All price adjusters in a given sector, however, choose identical prices by the symmetry of the problem. Therefore, I can express the optimal reset price in sector k as

$$\frac{X_{k,t}}{P_t} = \frac{\varepsilon_{ck}}{\varepsilon_{ck}-1} \frac{F_{p,k,t}}{K_{p,k,t}}, \tag{2.4}$$

where $F_{p,k,t}$ and $K_{p,k,t}$ are functions of sector k variables only and follow simple recursions. Absent the Calvo (1983) friction, all firms set prices as a markup over current-period marginal costs:

$$\frac{X_t}{P_t} = \frac{\varepsilon_{ck}}{\varepsilon_{ck}-1} \frac{1}{A_t} \frac{W_t}{P_t}.$$

The Calvo (1983) setup allows me to write the sectoral price index as a weighted average of last period's price index and period t's optimal reset price with weights corresponding to the fraction of price (non-)adjusters:

$$P_{k,t} = \left[(1-\theta_k) X_{k,t}^{1-\varepsilon_{ck}} + \theta_k P_{k,t-1}^{1-\varepsilon_{ck}}\right]^{\frac{1}{1-\varepsilon_{ck}}}. \tag{2.5}$$

[33] Detailed derivations are generally delegated to Appendix B.

The value of the firm with current price $P_{kj,t}$ can be written as a simple function of sector k variables:

$$V(P_{kj,t}) = \mathbb{E}_t \left\{ \frac{1}{\lambda_t} P_t \left[RS_{k,t} \left(\frac{P_{kj,t}}{P_t} \right)^{1-\varepsilon_{ck}} - CS_{k,t} \left(\frac{P_{kj,t}}{P_t} \right)^{-\varepsilon_{ck}} + RF_{k,t} - CF_{k,t} \right] \right\}, \quad (2.6)$$

where $RS_{k,t}$, $CS_{k,t}$, $RF_{k,t}$ and $CF_{k,t}$ are the revenues (R) and costs (C) coming from expected price stickiness (S) and flexibility (F), respectively, and follow simple recursions.

Households

There is a large number of identical, infinitely lived households. Households have a love for variety and derive utility from many different consumption goods. Each household supplies all types of differentiated labor services, $h_{i,t}, i \in [0, 1]$.

The representative household has additively separable utility in consumption and leisure and maximizes

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left[\frac{(C_{t+s} - bC_{t+s-1})^{1-\gamma}}{1-\gamma} - \psi_L \int_0^1 \frac{h_{i,t+s}^{1+\sigma}}{1+\sigma} \mathrm{d}i \right]$$

$$\text{s.t.} \qquad P_t C_t = \int_0^1 W_{i,t} h_{i,t} \mathrm{d}i + R_{t-1} B_{t-1} - B_t + D_t,$$

where β is the subjective discount factor, C_t is the composite consumption good defined below, $b \geq 0$ is a habit-persistence parameter in consumption, $h_{i,t}$ denotes hours worked of type i, $\psi_L \geq 0$ is a parameter, $W_{i,t}$, nominal wage for labor type i, R_t is the gross nominal interest rate, B_t denotes nominal bond holdings, and D_t is aggregate dividends from the firm sector. Profits are redistributed via lump-sum transfer at the end of each period. The parameters γ and σ denote the coefficient of relative risk aversion and the inverse of the Frisch elasticity of labor supply, respectively. The per-period budget constraint states that total consumption expenditure equals total disposable income, which consists of labor income from the different labor types, and gross payoffs from previous-period bond holdings net of new bond purchases plus aggregate dividends.

The composite consumption good is a Dixit-Stiglitz aggregate of many individual goods:

$$C_t = \left[\int_0^1 f(k)^{\frac{1}{\varepsilon_c}} C_{k,t}^{\frac{\varepsilon_c - 1}{\varepsilon_c}} \mathrm{d}k \right]^{\frac{\varepsilon_c}{\varepsilon_c - 1}}$$

$$C_{k,t} = f(k) \left[\int_0^1 C_{kj,t}^{\frac{\varepsilon_{ck} - 1}{\varepsilon_{ck}}} \mathrm{d}j \right]^{\frac{\varepsilon_{ck}}{\varepsilon_{ck} - 1}}.$$

$C_{k,t}$ is the subcomposite produced by firms in sector k, and $C_{kj,t}$ is the variety produced by firm j in sector k.

The consumption price indexes P_t and $P_{k,t}$ are given by

$$P_t = \left[\int_0^1 f(k) P_{k,t}^{1-\varepsilon_c} \mathrm{d}k\right]^{\frac{1}{1-\varepsilon_c}} \quad \text{and} \tag{2.7}$$

$$P_{k,t} = \left[\int_0^1 P_{kj,t}^{1-\varepsilon_{ck}} \mathrm{d}j\right]^{\frac{1}{1-\varepsilon_{ck}}}. \tag{2.8}$$

The demand for individual consumption varieties depends on relative prices

$$C_{k,t} = f(k) C_t \left(\frac{P_{k,t}}{P_t}\right)^{-\varepsilon_c} \quad \text{and}$$
$$C_{kj,t} = f(k)^{-1} C_{k,t} \left(\frac{P_{kj,t}}{P_{k,t}}\right)^{-\varepsilon_{ck}}.$$

Wage Rate

The structure of the labor market follows Erceg, Henderson, and Levin (2000). The representative household sells labor services to a representative, competitive labor aggregator. The aggregator transforms the different labor types into aggregate labor input, H_t. Homogeneous labor is a Dixit-Stiglitz aggregate of the different labor types

$$H_t = \left[\int_0^1 h_{i,t}^{\frac{\varepsilon_w - 1}{\varepsilon_w}} di\right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}},$$

where $\varepsilon_w \geq 1$ is the elasticity of substitution between labor types.

The aggregator minimizes the cost of producing a given quantity of aggregate labor, taking the wage rates of the individual labor types as given. It sells homogeneous labor input to individual firms at their unit cost, or equivalently, the aggregate wage rate, W_t:

$$W_t = \left[\int_0^1 W_{i,t}^{1-\varepsilon_w} di\right]^{\frac{1}{1-\varepsilon_w}}. \tag{2.9}$$

The demand curve for labor of type i, $h_{i,t}$, is downward sloping and given by

$$h_{i,t} = \left(\frac{W_{i,t}}{W_t}\right)^{-\varepsilon_w} H_t. \tag{2.10}$$

For each labor type i, a monopoly union represents all workers of this type. Individual unions set wages optimally, subject to a Calvo (1983)-style wage friction. Each period, a fraction $1 - \theta_w$ of labor unions re-optimizes nominal wages.

The optimization problem of adjusting unions is given by

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left\{ -\psi_L \frac{h_{i,t+s}^{1+\sigma}}{1+\sigma} + \frac{\Lambda_{t+s}}{\Lambda_t} U_{i,t} h_{i,t+s} \right\}$$
$$\text{s.t.} \qquad h_{i,t+s} = \left(\frac{U_{i,t}}{W_{t+s}} \right)^{-\varepsilon_w} H_{t+s},$$

where $U_{i,t}$ is the optimal reset wage.

Unions set wages to equalize the expected discounted marginal disutility of providing one additional unit of labor to its expected discounted utility. Again, the optimal reset wage is identical for all unions resetting wages in period t. Therefore, I can express the real reset wage as

$$\left(\frac{U_t}{P_t} \right)^{1+\varepsilon_w\sigma} = \frac{\varepsilon_w}{\varepsilon_w - 1} \psi_L \left(\frac{W_t}{P_t} \right)^{\varepsilon_w\sigma} \frac{F_{w,t}}{K_{w,t}}, \tag{2.11}$$

where $F_{w,t}$ and $K_{w,t}$ follow simple recursions.

In case of perfectly flexible wages, the optimal real reset wage equals a constant markup, $\varepsilon_w/(\varepsilon_w - 1)$, times the marginal rate of substitution between labor and consumption:

$$\frac{U_t}{P_t} = \frac{\varepsilon_w}{\varepsilon_w - 1} \frac{\psi_L h_{i,t}^{\sigma}}{\lambda_t}.$$

Monetary Policy

The monetary authority sets the short-term nominal interest rate according to

$$i_t = \phi_\pi \pi_t + \phi_x x_t + \log\left(\frac{1}{\beta}\right) + u_{m,t},$$

where i_t is $\log R_t$, $\pi_t = \log P_t - \log P_{t-1}$ is aggregate inflation, $x_t = \log Y_t - \log Y_{t-1}$ growth in output, ϕ_π and ϕ_x are parameters, and $u_{m,t}$ is a monetary policy shock.[34] The policy shock follows

$$u_{m,t} = \rho_m u_{m,t-1} + \sigma_{mp} \varepsilon_{mp,t+1}.$$

ρ_m is the autoregressive coefficient of the monetary policy shock, $\varepsilon_{mp,t+1}$ is an i.i.d. standard normal random variable and σ_{mp} is the standard deviation of the policy shock.

[34] Walsh (2003) and Orphanides and Williams (2006) highlight the role of output growth for stabilizing purposes instead of the output gap which might be difficult to measure accurately in real time. Coibion and Gorodnichenko (2011), on the contrary, show that a central bank responding to output growth instead of the output gap makes determinacy of equilibrium more likely.

Equilibrium

General equilibrium is defined by the optimality conditions for the household utility-maximization problem, by every firm kj's profit optimization, by market clearing in the product, labor, and financial markets, and by rational expectations. Product-market clearing requires $C_{kj,t} = Y_{kj,t}$ for all consumption varieties. Labor-market clearing imposes $L_t = \int_0^1 h_{i,t}\mathrm{d}i = \int_0^1 \int_0^1 H_{kj,t}\mathrm{d}j\mathrm{d}k$. Bond-market clearing requires $B_t = 0$, that is, the interest rate set by the monetary authority is in line with the household's optimization problem.

Inefficiency

Knowledge of aggregate labor input, L_t, is not sufficient to determine aggregate output. Cross-sectional dispersion of wage rates across different labor types and product prices within and across sectors increase the required amount of labor input for the production of a given level of the aggregate output index. Different labor types are imperfect substitutes in production, whereas different consumption varieties are imperfect substitutes in the consumption index. As each labor type enters the labor aggregator and the household's utility function symmetrically, optimality requires equal hours across types. Equivalently, as different consumption varieties enter the consumption index symmetrically and firms face identical production technologies, an optimal allocation requires equal production across firms. After a shock, some firms and unions are unable to adjust their product prices and wages, respectively, which leads to dispersion in prices and wages. Wage dispersion across different labor types increases the required amount of labor types for a given level of homogeneous labor. Price dispersion increases the required amount of homogeneous labor for a given level of the output index. Price and wage dispersion and hence *aggregate inefficiency* increase in the curvature of the respective aggregators, that is, the elasticity of substitution across different labor types and the elasticities of substitution of consumption within and across sectoral varieties (see equations (2.7), (2.8), and (2.9)). *Inefficiencies across sectors* are driven by the elasticity of substitution of consumption varieties within sector as wage dispersion is identical across sectors. The more elastic the demand is for varieties of a given sector and the lower the frequency of price adjustment, the larger the price dispersion (see Woodford (2003)).

Calibration

I calibrate a five-sector version of the model at quarterly frequency to compare the implications of differences in the frequency of price adjustment on stock returns to my empirical findings. I use standard parameter values in the literature (see Table 2.11). Specifically, the subjective discount factor β is 0.99, implying an annual risk-free rate of 4% in the non-stochastic steady state. I employ the estimate for the habit-persistence parameter $b = 0.76$ from Altig, Christiano, Eichenbaum, and Linde (2011), which is similar to other estimates in the literature (e.g., Smets and Wouters (2007)). I set the parameters of the utility function

$\gamma = 5$ and $\psi = 1$ following Jermann (1998) and Altig et al. (2011), and I calibrate the inverse of the Frisch elasticity of labor supply, σ, to a value of 2.5. I set the elasticity of substitution of within-sector consumption varieties and across sectoral subcomposites, ε_{ck} and ε_c, to values of 12 and 8, respectively, following Carvalho (2006). The sectoral elasticity implies a steady-state markup of roughly 9%, in line with empirical evidence by Burnside (1996) and Basu and Fernald (1997). I follow Erceg et al. (2000) and set θ_w to a value of 0.825, in line with estimates of Heer, Klarl, and Maussner (2012) and the empirical literature (see Taylor (1999)). This value implies an average duration of wage contracts of five quarters. ε_w is calibrated to a value of 8, which corresponds to a wage markup of 14% in the range of estimates used in the literature.[35] I set the parameter values of the monetary policy reaction function, ϕ_π and ϕ_y, to standard values of 1.24 and 0.33/4, respectively, in line with results reported in Rudebusch (2002). I use the empirical distribution of the frequencies of price adjustment of Nakamura and Steinsson (2008) to calibrate $\langle 1 - \theta_k \rangle_{k=1}^{5}$, and I follow Carvalho (2006) to calibrate the density function $f(k) = 1/5$, giving equal weight to each sector. In particular, I sort industries by their frequency of price adjustment and construct five synthetic sectors. The sectors correspond to the quintiles of the distribution of the frequency of price adjustment observed in the data. Each sector covers one fifth of consumer spending. The Calvo rates of price adjustment range from 0.105 to 0.985 per quarter. I calibrate the autoregressive parameters of the two shock processes to $\rho_a = 0.95$ and $\rho_m = 0.90$ – well within the range of empirical estimates (e.g., Smets and Wouters (2007) and Coibion and Gorodnichenko (2012)). I set the standard deviations of the shocks, σ_a and σ_{mp}, to 0.0085 to match the historical standard deviation of log quarterly real gross domestic product (GDP) for my sample period.[36]

In the benchmark case, I solve the model numerically using a second-order approximation as implemented in *dynare*, and simulate the model for 400 firms in each sectors and 500 periods, discarding the first 250 periods as burn in.[37] For each firm and time period, I then calculate the firm value, $V(P_{kj,t})$, dividends, $D(P_{kj,t})$, and returns as $R_{kj,t} = \frac{V(P_{kj,t})}{V(P_{kj,t-1}) - D(P_{kj,t-1})}$.

[35] Altig et al. (2011) set the wage markup to 5%, whereas Erceg et al. (2000) calibrate ε_w to 4, implying a markup of 33%. As displayed in Table 2.12 and Table B.31 in Appendix B, results are not very sensitive to changes in this parameter.

[36] I download real GDP from the FRED database of the Federal Reserve Bank of St. Louis with series-ID GDPC1. This series is seasonally adjusted at an annual rate and expressed in billions of chained 2009 dollars. The standard deviation of Hodrick-Prescott-filtered log quarterly real GDP is 0.0095 in the data and 0.0102 in the model. Consistent with findings of Gorodnichenko and Ng (2010), I apply the Hodrick-Prescott filter with a smoothing parameter of 1600 to both historical and model-generated data to calibrate the shock standard deviations.

[37] I employ the pruning package of Andreasen, Fernández-Villaverde, and Rubio-Ramírez (2013) to ensure the simulated sample paths do not explode. Pruning leaves out terms of higher order than the approximation order.

Simulation Results

Table 2.12 reports annualized mean excess returns over the risk-free rate at the sector level, the spread in mean returns between the portfolios containing firms with low and high frequencies of price adjustment, and the annualized equity risk premium and Sharpe ratio, as well as the regression coefficient of annualized returns at the firm level on the monthly frequency of price adjustment

$$R_{kj,t} = \alpha + \beta \times (1 - \theta_k) + \epsilon_{kj,t}.$$

The baseline calibration in line (1) results in annualized excess returns of almost 8% for the sticky-price sector. Excess returns decrease monotonically in the degree of price flexibility to as low as 5.5% for the flexible-price sector. The return differential between the sticky- and flexible-price sectors is almost 2.4% per annum, in line with my empirical findings in Table 2.4. The model displays an equity premium of 6.6% and an annual Sharpe ratio of 0.39. The coefficient of annual firm-level returns on the frequency of price adjustment is negative and highly statistically significant. The coefficient implies that moving from a firm with totally sticky prices to a firm with totally flexible prices is associated with a decrease in annual returns of 2.5% per annum.

The baseline calibration documents that heterogeneity in the frequency of price adjustment leads to a cross-sectional difference in returns. The following lines of Table 2.12 evaluate the robustness of this finding and carve out the key driving forces behind this result. Lines (2) and (3) look at specifications in which all sectors have identical frequencies of price adjustment. In line (2), $\langle 1 - \theta_k \rangle_{k=1}^{5} = 0.77$, which implies the same average duration of price spells across sectors as the baseline calibration, and line (3) looks at an economy with flexible prices. All sectors earn similar returns with an equity premium of 7% and 7.5% per year, respectively.

In lines (4) and (5), I investigate the importance of differential elasticities of substitution across and within sector consumption varieties. Increasing the elasticity of substitution of across-sector varieties, ε_c, to 12 has no effect on the return differential and leaves the overall equity premium largely unchanged. On the other hand, lowering ϵ_{ck} to a value of 8 eliminates the cross-sectional difference in returns. These results indicate that the difference in elasticities is not what drives the premium for price stickiness in firm-level simulations, but rather it is the absolute size of the elasticity of substitution of within-sector consumption varieties. I will come back to this finding below.

The following four lines ((6)–(9)) further investigate the impact of within- and across-sector elasticities on the equity premium and the return differential. In lines (6) and (7), we see that changes in ϵ_{ck} have an immediate effect on the premium for sticky-price firms while hardly affecting the overall level of the equity premium. In particular, increasing ϵ_{ck} from a baseline value of 12 to 13 increases the cross-sectional spread in returns by almost 50%. On the other hand, varying the across-sector elasticity of substitution (lines (8) and (9)) has only small effects on the level of the risk premium or the cross-sectional-return difference. In lines (10) and (11), we see that lowering the elasticity of substitution between different labor types has only negligible effects, whereas calibrating the Frisch elasticity of labor supply to a value of 1 increases both the cross-sectional spread in returns and the overall equity premium.

In the next exercise, I evaluate the effects of higher aggregate risk. Specifically, I increase the standard deviations for both the monetary policy and the technology shocks. Higher aggregate risk increases the returns for all sectors, but disproportionately for sectors with lower frequencies of price adjustment. The premium for sticky-price firms doubles and the equity premium increases by almost 1% per year. In the following line, I investigate whether the accumulation of higher-order terms has any effect on my results.[38] If I do not discard terms of higher order than the desired level of approximation, I find that the cross-sectional-return difference is magnified, whereas the overall equity premium decreases.

Lines (14) and (15) check how changes in the responsiveness of monetary policy affect the findings. A more aggressive stance on inflation dampens the equity premium by 1% and reduces the dispersion in returns across sectors by a factor of four. Changes in the reaction to output growth, however, have little impact on stock returns. Lines (16) and (17) disentangle the contributions of the two shocks: the cross-sectional and the level effects are almost exclusively driven by monetary policy shocks.

Increasing the persistence of technology shocks in line (18) increases the cross-sectional premium for price stickiness and the overall level of the equity premium. Finally, Coibion and Gorodnichenko (2012) show that the persistence of monetary policy in the Greenspan and Bernanke era is better described by interest-rate smoothing than by persistent shocks. Modeling policy inertia via interest-rate smoothing has no impact on my findings.

Two-Sector Model

To gain a better understanding of the different margins behind the cross-sectional-return premium, I work with a two-sector version of the model in the following.[39] The advantage of the two-sector model is that I can directly relate movements in aggregate variables to movements in the sticky- and flexible-price sectors. This advantage comes at the cost of some of the real effects of nominal rigidities being lost due to a lower level of strategic interaction in price setting (see Carvalho (2006)).

Instead of simulating dividends and valuations at the firm level, I report returns for a claim on aggregate dividends at the sector level. Figures 2.4 and 2.5 plot the impulse response functions of several aggregate and sector-level variables to a one-standard-deviation monetary policy shock.

[38] Kim, Kim, Schaumburg, and Sims (2008) coin the notion of *garbage* terms for terms with higher-order effects than the approximation order and show that accumulation of these terms deteriorates the accuracy of the approximation and leads to explosive sample paths in simulations. The current exercise also runs into the problem of explosive sample paths using an unpruned system and a second-order approximation, which is why I report the results of a third-order approximation.

[39] Appendix B contains additional results and replicates the different calibration exercises of the previous section for the two-sector economy.

Contractionary monetary policy shocks lead to a drop in real output, Y. Inflation, π, decreases, as does the aggregate real-wage rate, w. Marginal utility, λ, however, goes up. Note that due to wage stickiness and habit formation, the drop in real wages is less than the drop in output, and the increase in marginal utility is an order of magnitude larger. As for sectoral variables, the relative price of sector 1, $P1$, increases compared to sector 2, in line with the real reset price of sector 1, $X1$. The last two panels of Figure 2.4 show that monetary policy shocks lead to an increase in price dispersion, DS. The dispersion in prices, however, is substantially larger for the sticky-price sector.

Figure 2.5 documents that the drop in aggregate output leads to a decrease in output at the sector level. The decline in output for the sticky-price sector is larger compared to sector 2 due to the higher relative price. The decrease in sector output translates into lower sector dividends, D, stock prices, S, and returns, ret, with more negative reactions for sector 1. Negative returns in times of high marginal utility is the key condition for a positive equity premium.

Figure 2.6 graphically analyzes the cross-sectional-return premium for sticky-price firms. I plot the average difference in dividends between the sectors with low and high frequencies of price adjustment, $(Div_{sticky} - Div_{flexible})$, and marginal utility, $(C_t - bC_{t-1})^{-\gamma}$, as a function of aggregate output. I simulate the model 500 times, sort the difference in sector dividends and marginal utility based on the realization of aggregate output, and take the average across simulations. In times of low aggregate output and high marginal utility, the sector with low frequency of price adjustment has lower dividends than the flexible price sector. Negative payoffs in times of high marginal utility are key for a positive cross-sectional-return premium for sticky price firms.

In Appendix B, I show that the difference in log expected excess returns is approximately given by

$$\begin{aligned}\mathbb{E}_t\, r_{1,t+1} - \mathbb{E}_t\, r_{2,t+1} + \left[\frac{1}{2}\operatorname{var} r_{1,t+1} - \frac{1}{2}\operatorname{var} r_{2,t+1}\right] &\approx -(\varepsilon_{ck} - \varepsilon_c)\operatorname{cov}_t(m_{t,t+1}, (p_{1,t+1} - p_{2,t+1})) \\ &\quad - (1 - \varepsilon_{ck})\operatorname{cov}_t(m_{t,t+1}, (ds_{p,1,t+1} - ds_{p,2,t+1})).\end{aligned}$$

Cross-sectional-return premia are therefore determined by two covariance terms, the covariance of the log stochastic discount factor between period t and t+1, $m_{t,t+1}$, and the relative price between the sticky- and flexible-price sectors, $(p_{1,t+1} - p_{2,t+1})$, and the covariance with the relative price dispersion between the two sectors, $(ds_{p,1,t+1} - ds_{p,2,t+1})$. Both covariance terms are positive. The model therefore implies a premium for firms with lower frequencies of price adjustment in three cases: when (i) the elasticity of substitution of consumption varieties across sectors, ε_c, is not much smaller than the elasticity within sector varieties, ε_{ck}; (ii) the elasticity across sector consumption goods, ε_{ck}, is larger than unity; or (iii) a combination of the two.[40]

[40] This expression approximately holds under joint log normality for claims to sector dividends that pay off only in period t+1. Numerically, I find that the first covariance term still results in a premium for sticky price firms as long as ε_c is only slightly smaller than ε_{ck}.

Figures 2.4 and 2.5 also plot impulse response functions for different values of the elasticity of substitution of within-sector consumption composites to gain intuition for the effects of ε_{ck} on the cross-sectional-return premium documented in Table 2.12.[41] I show in Appendix B that sector dividends are given by sector output times the sector profit margin, which can be expressed as the sector markup, $\mu_{k,t}$, minus one over the markup

$$\begin{aligned} D_{k,t} &= Y_{k,t}\left(1-\frac{1}{\mu_{k,t}}\right) \\ &= Y_{k,t}\left[1-\left(\frac{W_t}{P_t}\right)\left(\frac{1}{A_t}\right)\left(\frac{P_{k,t}}{P_t}\right)^{-1} DS_{p,k,t}\right]. \end{aligned}$$

The last expression documents that the markup margin can be further decomposed into a price and an inefficiency component.

Expressing this relation in percentage deviations from the steady state,[42]

$$\check{D}_{k,t} = \check{Y}_{k,t} - \frac{Y_k - D_k}{D_k}\left[\left(\frac{\check{W}_t}{P_t}\right) - \check{A}_t - \left(\frac{\check{P}_{k,t}}{P_t}\right) + \check{DS}_{p,k,t}\right]. \tag{2.12}$$

Differences in sector dividends, $\check{D}_{1,t} - \check{D}_{2,t}$, are therefore determined by three margins: (i) a quantity margin, $(\check{Y}_{1,t} - \check{Y}_{2,t})$; (ii) a relative price margin, $(\check{P}_{1,t} - \check{P}_{2,t})$; and (iii) an inefficiency or price-dispersion margin, $-(\check{DS}_{p,1,t} - \check{DS}_{p,2,t})$. After a contractionary monetary policy shock, a larger share of firms in the sticky-price sector cannot adjust their prices downward. The high relative price of sector 1 leads to a drop in demand compared to sector 2. In addition, the dispersion in prices is higher in the sticky-price sector. Therefore, firms in sector 1 gain along the price margin but lose along the quantity and inefficiency margins. We see in Figure 2.4 and Figure 2.5 that the disadvantage in the quantity margin and the advantage in the price margin decrease in the elasticity of substitution of within-sector consumption varieties. The negative effect of price dispersion on dividends increases in ε_{ck}. Taken together, the effects on the price and price-dispersion margins are quantitatively more important. Hence the difference in sector dividends decreases and the premium for sticky-price firms increases in ε_{ck}.

I show in Appendix B that the elasticity of substitution of consumption varieties across sectors, ε_c, only affects the quantity margin $(\check{Y}_{1,t} - \check{Y}_{2,t})$. Increasing ε_c translates into larger negative difference in dividends between the sticky- and flexible-price sector and therefore increases the cross-sectional-return difference. This channel, however, is quantitatively small and of second order compared to the effects of ε_{ck}.[43]

[41] ε_{ck} low, medium, and high correspond to values of 8, 12, and 16, respectively. The premium for sticky-price firms increases from 0.92% to 6.73% per year.

[42] $\check{D}_{k,t} \equiv \frac{D_{k,t} - D_k}{D_k}$, where variables without time subscript indicate steady-state quantities.

[43] Figure B.1 and Figure B.2 in Appendix B show why technology shocks command only a small risk premium. Mean reversion in technology leads to a small reaction in aggregate output following the shock, translating into a small reaction in marginal utility of consumption and finally dividends, stock prices, and returns.

Habit formation in consumption implies that expected returns vary over time and are particularly high during recessions. To test this hypothesis, I define recessions and expansions as months in the bottom and top 25^{th} percentile of the GDP growth distribution, respectively, and measure the subsequently realized return spread between sticky- and flexible-price sectors in simulated data. The spread in annual returns in the two years after recessions is 4.1%, whereas it is only 1.1% after expansions, indicating substantial variation in expected returns.

To test more systematically for time variation in expected returns, I run long-horizon regressions on simulated data. I regress the cumulative log excess returns of the L-H portfolio on log consumption surplus. Table 2.13 shows the classical patterns: high consumption compared to habit predicts low future excess returns. The regression coefficients increase in absolute value from -0.14 for one-quarter-ahead excess returns to -0.81 for the three-years horizon and then start to decline. The explanatory power peaks at a two-years horizon with consumption-surplus explaining 22% of the time-series variation.

The model therefore replicates my key empirical findings: a large cross-sectional premium for sticky-price firms that varies over the business cycle, and an equity premium in line with historical estimates.

2.5 Conclusions

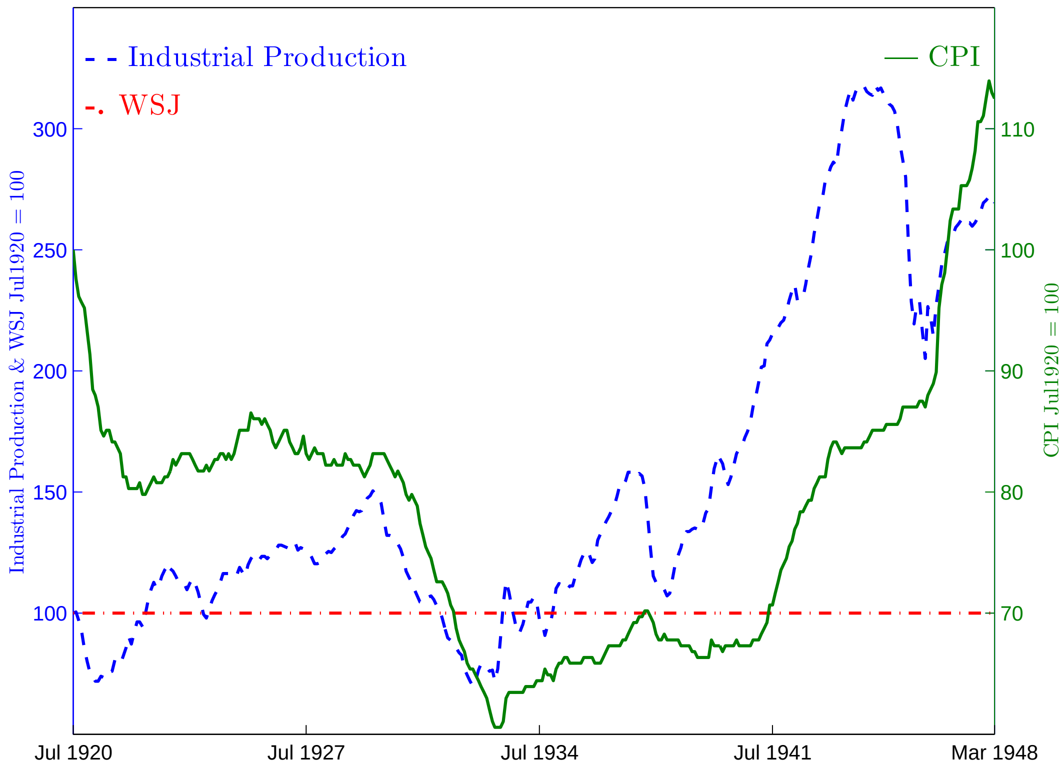
Sticky prices have a long history in such different fields as macroeconomics, industrial organization, and marketing, and are key to explaining the business-cycle dynamics of real gross domestic output, consumption, and investment. I document that price rigidities are also a strong predictor of the cross section of stock returns. CAPM βs are a function of many parameters and factors, and we have little knowledge about the fundamental drivers. The frequency of product price adjustment is a simple statistic at the firm level that can account for a considerable part of the determinants of firms' systematic risk. To the extent that firms equalize the costs and benefits of price adjustment, the higher cost of capital for sticky price firms reflects a holistic measure of the total costs of sticky prices. Therefore, price rigidities explain both business-cycle dynamics in aggregate quantities and cross-sectional variation in stock returns, and further bridge macroeconomics and finance.

To explain these effects in a consistent framework, I develop a multi-sector production-based asset-pricing model in which firms differ in their frequency of price adjustment. A sufficiently high elasticity of substitution between consumption varieties within sectors, ε_{ck}, is the central condition for obtaining a large cross-sectional-return premium for sticky-price firms. Three margins determine the cross-sectional-return difference: a quantity margin, a price margin, and an inefficiency margin associated with price dispersion. Whereas the first margin ceteris paribus lowers the return premium, the other two margins increase the difference in returns between sticky- and flexible-price firms with increasing ε_{ck}.

There are several potential extensions for future research. Labor is the only production factor in my current setup. Allowing for capital and investigating how investment at the firm level interacts with price stickiness would be interesting.[44] New Keynesian models have strong predictions on how production is distributed across firms and sectors after aggregate shocks, with interesting implications for firm level investment. Furthermore, the current setup completely abstracts from capital-structure considerations. It assumes firms are fully equity-financed. The positive correlation between leverage and the frequency of price adjustment indicates that a departure from this assumption could be a fruitful avenue for future research. In addition, my current analysis neglects potential heterogeneity in wage stickiness across firms and industries. The importance of wage stickiness for the aggregate level of equity risk premia and the interaction with price stickiness underlines the importance of this question for future research. Ultimately, the cause of sticky prices and the determinants of differences in the frequency of price adjustment across firms within industry are the vital questions for future research. Access to large-scale micro datasets will hopefully allow us to make progress toward answering these important questions.

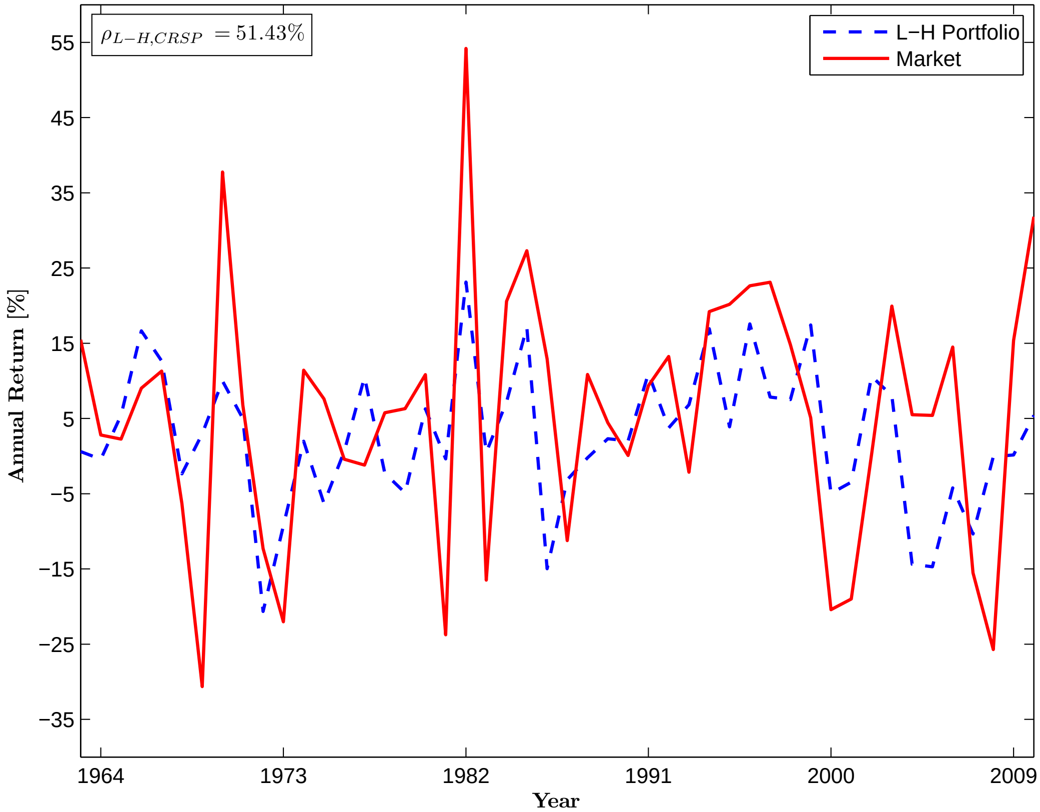
[44] To get interesting macro and asset-pricing implications, one has to depart from the convenient modeling tool of economy-wide rental markets for capital (see, e.g., Altig et al. (2011) and Lettau and Uhlig (2000)) and allow for firm-specific capital. This departure makes reset price at the firm level history dependent, and hence aggregation at the industry level less straightforward in a fully non-linear model. Appendix B contains a sketch of optimal reset prices and capital stocks at the firm level in this setup.

Figure 2.1: Price of Wall Street Journal and Level of Industrial Production and Consumer Price Index



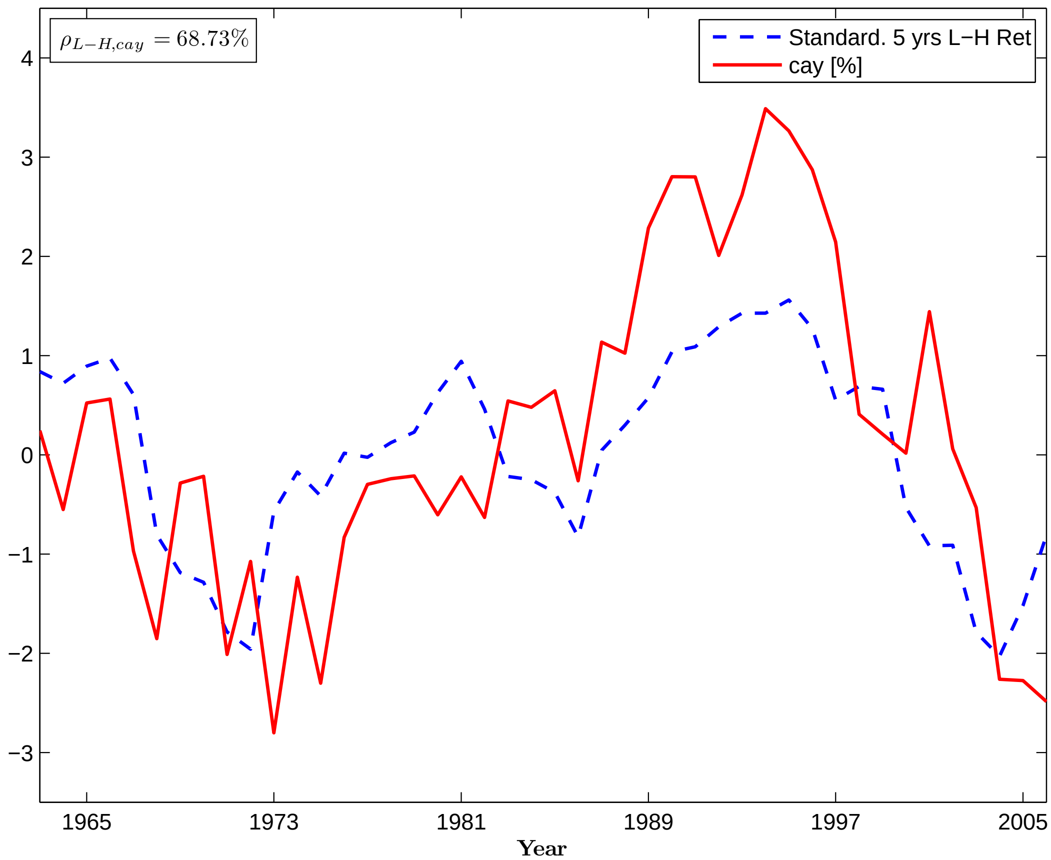
This figure plots the price of the Wall Street Journal (WSJ), Industrial Production (IP) and the Consumer Price Index (CPI) for a period from July 1920 to March 1948. The price of the WSJ, IP and the CPI are normalized to a value of 100 in July 1920. The price of the WSJ and IP are measured on the left y-axis whereas the CPI is measured on the right y-axis.

Figure 2.2: Market Excess Return and Sticky minus Flexible Price Portfolio



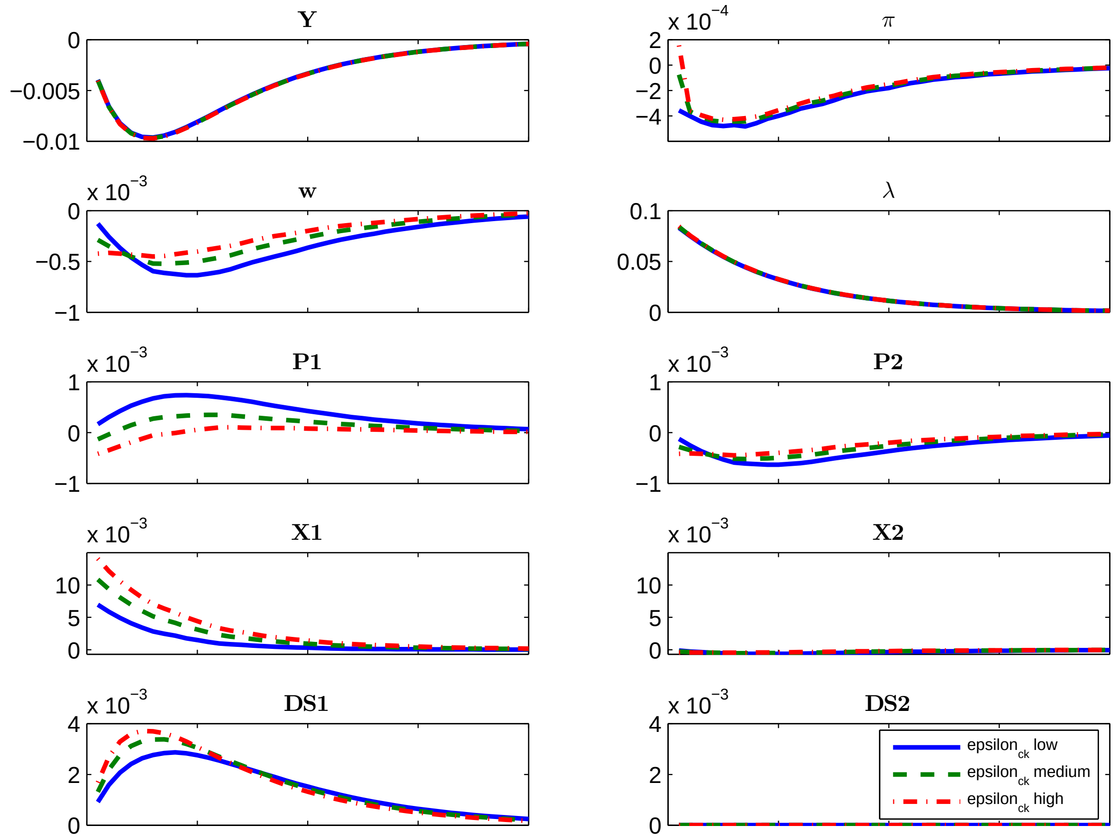
This figure plots the annual excess return of the CRSP value-weighted index (market) and the annual return of the zero-cost portfolio of going long the portfolio of stocks with low frequencies of price adjustment and shorting the portfolio of stocks with high frequencies of price adjustment, L-H. The sampling frequency is annual. The sample period is July 1963 to June 2011.

Figure 2.3: Consumption Wealth Ratio (cay) and Following 5 Years Returns



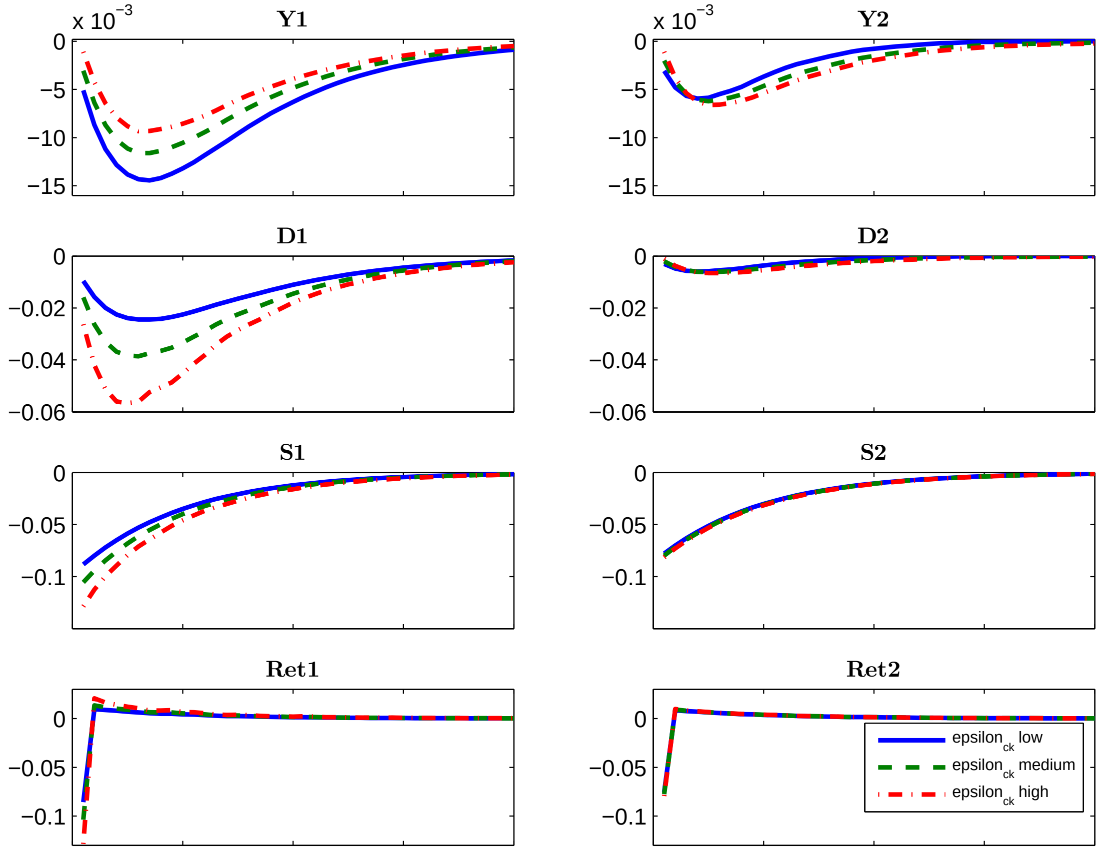
This figure plots the Lettau and Ludvigson (2001) proxy for the consumption wealth ration, cay, and the subsequently realized five years return of the zero-cost portfolio of going long the portfolio of stocks with low frequencies of price adjustment, and shorting the portfolio of stocks with high frequencies of price adjustment, L-H. The sampling frequency is annual with cay observed at end of June of year t and returns measured from July of year t to June of year t+5. The sample period for cay is June 1963 to June 2006.

Figure 2.4: Impulse Response Functions to Monetary Policy Shock (varying ε_{ck})



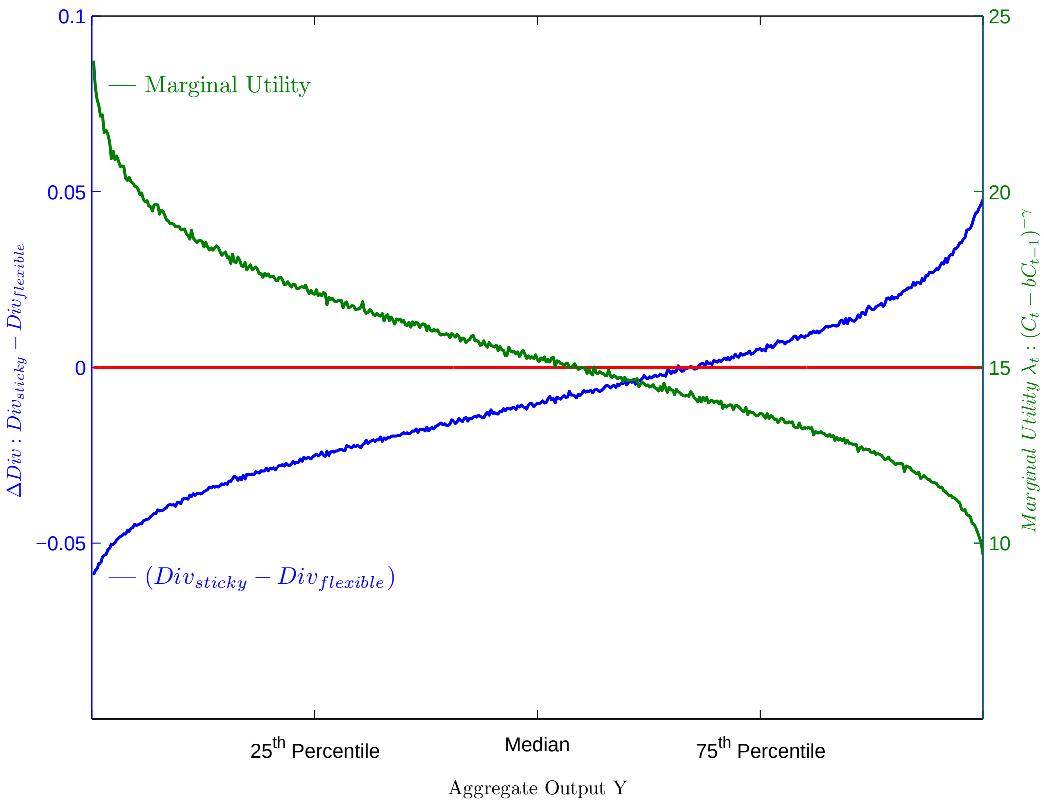
This figure plots the impulse response functions of several macroeconomic variables of the model of Section 2.4 to a one standard deviation contractionary monetary policy shock for different values of the elasticity of substitution of within sector consumption varieties, ε_{ck}. ε_{ck} low, medium, and high correspond to values of 8, 12, and 16, respectively. Y is output, π inflation, w aggregate real wage, λ the marginal utility of consumption, P1 and P2 the relative prices of sectors one and two, X1 and X2 the optimal real reset prices, and DS1 and DS2 the price dispersion in the two sectors.

Figure 2.5: Impulse Response Functions to Monetary Policy Shock (varying ε_{ck})



This figure plots the impulse response functions of several macroeconomic variables and asset returns of the model of Section 2.4 to a one standard deviation contractionary monetary policy shock for different values of the elasticity of substitution of within sector consumption varieties, ε_{ck}. ε_{ck} low, medium, and high correspond to values of 8, 12, and 16, respectively. Y1 and Y2 are the output of sectors one and two, D1 and D2 sector level dividends, S1 and S2 the prices of claims to aggregate sector dividends and Ret1 and Ret2 the returns of these claims.

Figure 2.6: Difference in Sector Dividends and Marginal Utility



This figure plots the average difference in dividends of the sectors with low and high frequencies of price adjustment, $(Div_{sticky} - Div_{flexible})$, and marginal utility, $(C_t - bC_{t-1})^{-\gamma}$, as a function of aggregate output, Y. I simulate a two sector version of the model of Section 2.4 500 times, sort the difference in sector dividends and marginal utility based on the realization of aggregate output and take the average across simulations. The difference in dividends is measured on the left y-axis whereas marginal utility is measured on the right y-axis.

Table 2.1: Frequency of Price Adjustment by Industry

This table reports average monthly frequencies of price adjustment, SA, at the industry and aggregate levels with standard deviations in parentheses. Panel A reports equally weighted frequencies, SAU, whereas Panel B weights frequencies with associated values of shipments, SAW. Probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is July 1963 to June 2011.

	Agriculture (1)	Manufacturing (2)	Utilities (3)	Trade (4)	Finance (5)	Service (6)	Total (7)
Panel A. Measure SAU							
Mean	22.75%	12.03%	22.66%	20.41%	13.14%	8.13%	14.86%
Std	(17.49%)	(11.35%)	(12.79%)	(13.74%)	(11.31%)	(9.19%)	(13.00%)
Max	59.39%	60.00%	53.89%	60.00%	45.65%	60.00%	60.00%
Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
N	16,754	139,235	42,425	19,124	40,380	15,618	273,536
Panel B. Measure SAW							
Mean	25.03%	13.12%	23.03%	20.75%	13.65%	9.20%	15.79%
Std	(19.11%)	(13.41%)	(13.52%)	(13.80%)	(12.61%)	(9.94%)	(14.37%)
Max	59.39%	60.00%	55.83%	60.00%	46.84%	60.00%	60.00%
Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
N	16,082	136,667	41,948	19,124	39,737	14,823	268,381

Table 2.2: Summary Statistics and Correlations for Firm Characteristics and Return Predictors (Benchmark Sample)

This table reports time series averages of annual cross-sectional means and standard deviations for firm characteristics and return predictors used in the subsequent analysis in Panel A and contemporaneous correlations of these variables in Panel B. SAU measures the frequency of price adjustment. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	SAU (1)	Size (2)	BM (3)	Beta (4)	Lev (5)	CF (6)	Turnover (7)	Spread (8)	PCM (9)	HHI (10)
				Panel A. Means and Standard Deviations						
Mean	0.14	14.76	0.63	1.09	0.40	0.09	10.43	1.31	0.37	0.13
Std	0.13	1.25	0.37	0.42	0.23	0.06	8.34	0.64	0.18	0.32
N	554	554	545	534	551	551	554	554	551	530
				Panel B. Contemporaneous Correlations						
Size	0.07									
BM	0.26	−0.14								
Beta	−0.16	−0.18	−0.26							
Lev	0.17	0.00	0.26	−0.20						
CF	−0.04	0.18	−0.44	0.02	−0.50					
Turnover	−0.03	−0.18	−0.10	0.46	−0.17	0.05				
Spread	0.02	−0.30	0.13	0.11	0.07	−0.14	−0.01			
PCM	−0.16	0.11	−0.34	0.12	−0.09	0.28	0.10	−0.13		
HHI	−0.06	0.04	−0.06	−0.04	0.01	0.09	−0.06	0.01	0.01	

Table 2.3: Mean Portfolio Returns (SAU)

This table reports time series averages of annual equally weighted portfolio raw returns in Panel A and characteristic adjusted (DGTW) returns following Daniel et al. (1997) in Panel B for various sample periods with Newey and West (1987) standard errors in parentheses. Stocks are assigned to one of five baskets based on the frequency of price adjustment, SAU. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Panel C reports time series averages of annual returns for the CRSP value weighted index (CRSP VW), the CRSP equally weighted index (CRSP EW), the size (SMB) and value (HML) factors of Fama and French (1993).

	Sticky (1)	S2 (2)	S3 (3)	S4 (4)	Flexible (5)	S1-S5 (6)
Panel A. Annual Mean Returns						
07/1963 - 06/2011	18.84***	18.42***	18.26***	16.97***	16.10***	2.74*
	(2.85)	(2.02)	(2.03)	(2.19)	(1.97)	(1.46)
07/1982 - 06/2007	24.22***	21.98***	22.03***	21.00***	19.84***	4.38 **
	(3.08)	(2.66)	(2.35)	(2.46)	(2.47)	(1.91)
07/1982 - 06/1998	28.77***	25.59***	25.20***	24.39***	22.05***	6.72***
	(3.53)	(2.93)	(3.23)	(2.64)	(2.89)	(1.61)
Panel B. Annual DGTW adjusted Returns						
07/1963 - 06/2011	4.42***	4.50***	4.14***	3.01***	2.34***	2.08*
	(1.32)	(0.52)	(0.40)	(0.49)	(0.81)	(1.26)
07/1982 - 06/2007	6.81***	5.39***	4.36***	4.09***	3.11***	3.71 **
	(1.09)	(0.27)	(0.69)	(0.63)	(1.13)	(1.63)
07/1982 - 06/1998	6.93***	4.97***	3.60***	3.03***	1.29***	5.64***
	(0.51)	(0.39)	(0.38)	(0.36)	(0.54)	(0.91)
Panel C. Annual Factor Returns						
		CRSP VW	CRSP EW	SMB	HML	
07/1963 - 06/2011		11.28***	15.77***	3.37 **	5.10***	
		(2.12)	(2.08)	(1.58)	(1.04)	
07/1982 - 06/2007		14.99***	16.75***	0.80	5.64***	
		(2.81)	(2.40)	(1.67)	(1.60)	
07/1982 - 06/1998		19.52***	17.77***	−1.50	4.63***	
		(2.61)	(3.58)	(1.15)	(1.13)	

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2.4: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SAU	−10.04***	−10.97***	−8.04***	−12.94***	−8.54***	−10.99***	−10.98***	−9.83***	−10.16***	−9.52***	−10.79***	−7.07***
	(2.16)	(2.28)	(2.44)	(2.50)	(2.29)	(2.32)	(2.31)	(2.27)	(2.34)	(2.25)	(2.36)	(2.73)
Size			−4.38***									−4.97***
			(0.29)									(0.33)
BM				3.22***								3.21***
				(0.84)								(1.11)
Beta					4.12***							0.10
					(0.75)							(1.06)
Lev						1.06						4.35**
						(1.38)						(1.84)
CF							−10.97**					3.76
							(5.55)					(7.49)
Turnover								52.39***				37.00***
								(3.87)				(4.94)
Spread									−5.45***			−7.37***
									(0.54)			(0.57)
PCM										5.61***		7.84***
										(1.66)		(1.98)
HHI											0.23	1.79*
											(0.70)	(0.99)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,810	13,810	13,810	13,582	13,319	13,735	13,746	13,810	13,810	13,744	13,210	13,029
R^2	0.11%	19.96%	21.99%	20.07%	20.37%	19.86%	19.88%	21.45%	20.99%	19.93%	19.80%	24.93%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2.5: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, Within Industry)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors, year fixed effects and industry fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is July 1982 to June 2007.

	Baseline (1)	Agriculture (2)	Manufacturing (3)	Utilities (4)	Trade (5)	Finance (6)	Services (7)	Dummies (8)
SAU	−10.97***	−15.28 * *	−7.34*	−9.13 * *	−9.35	−2.32	−11.38	−7.80***
	(2.28)	(6.96)	(4.17)	(4.18)	(8.92)	(4.89)	(19.63)	(2.44)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Industry FE	N	N	N	N	N	N	N	Y
#	13,810	753	6,811	2,029	1,051	2,249	917	13,810
R^2	19.96%	27.15%	20.50%	25.51%	38.89%	44.58%	21.07%	20.24%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2.6: Mean of Double Sortings

This table reports average annual returns for double sorted portfolios. I first assign stocks into tertiles based on various firm characteristics and then within each portfolio I assign stocks into tertiles based on the frequency of price adjustment, SAU. I report mean returns across characteristic sorts for the sticky, intermediate and flexible price portfolios as well as the difference between the two extreme portfolios. Newey and West (1987) standard errors are reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The last two columns report results for conditional double sorts of Beta and BM on size. The sample period is July 1982 to June 2007.

	Uncond (0)	Size (1)	BM (2)	Beta (3)	Lev (4)	Spread (5)	PCM (6)	Turnover (7)	CF (8)	HHI (9)	Beta cond Size (10)	BM cond Size (11)
Sticky	23.32	21.56	22.08	21.89	22.07	21.83	22.20	21.51	21.92	21.75	19.83	22.22
S2	21.81	20.59	19.86	20.19	20.13	20.43	19.76	21.00	20.09	20.87	19.91	19.87
Flexible	20.31	19.10	19.01	19.14	18.95	18.96	19.22	18.82	19.17	18.25	23.36	20.45
S1-S3	3.02***	2.45**	3.07***	2.74**	3.12***	2.87**	2.98***	2.69**	2.75***	3.50***	−3.53*	1.78
	(1.24)	(1.23)	(0.94)	(1.24)	(1.19)	(1.16)	(0.91)	(1.20)	(0.96)	(1.26)	(1.81)	(1.51)

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2.7: CAPM Regressions (Benchmark Sample)

This table reports results for the unconditional CAPM in Panel A and the conditional CAPM in Panel B. Stocks are assigned to one of five baskets based on the frequency of price adjustment, SAU and returns are equally weighted at the portfolio level. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. α is the intercept and β the slope of times series regressions of monthly portfolio excess returns on a constant and the excess return of the CRSP value weighted index. OLS and Fama and MacBeth (1973) standard errors are reported in parentheses and Newey and West (1987) standard errors in brackets. The conditional CAPM is monthly estimated on a rolling basis over the last twelve months following the methodology of Lewellen and Nagel (2006). The sample period is July 1982 to June 2007.

	Sticky (1)	S2 (2)	S3 (3)	S4 (4)	Flexible (5)	S1-S5 (6)
			Panel A. Unconditional CAPM			
α_p	0.57	0.47	0.49	0.48	0.46	0.11
SE_{OLS}	(0.10)***	(0.09)***	(0.10)***	(0.10)***	(0.13)***	(0.12)
SE_{NW}	[0.20]***	[0.13]***	[0.17]***	[0.15]***	[0.18]**	[0.14]
β_p	1.12	1.08	1.03	0.97	0.86	0.26
SE_{OLS}	(0.02)***	(0.02)***	(0.02)***	(0.02)***	(0.03)***	(0.03)***
SE_{NW}	[0.05]***	[0.04]***	[0.06]***	[0.05]***	[0.07]***	[0.04]***
			Panel B. Conditional CAPM			
α_p	0.41	0.35	0.38	0.37	0.40	0.00
SE_{FMB}	(0.05)***	(0.03)***	(0.04)***	(0.04)***	(0.04)***	(0.05)
SE_{NW}	[0.19]**	[0.12]***	[0.14]***	[0.13]***	[0.14]***	[0.14]
β_p	1.29	1.21	1.15	1.08	0.91	0.37
SE_{FMB}	(0.02)***	(0.01)***	(0.01)***	(0.01)***	(0.02)***	(0.02)***
SE_{NW}	[0.05]***	[0.04]***	[0.05]***	[0.04]***	[0.06]***	[0.05]***

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2.8: Cash Flow and Discount Rate Betas (Benchmark Sample)

This table reports results for a beta decomposition into cash-flow β, β_{CF}, and discount-rate β, β_{DR}, following Campbell and Vuolteenaho (2004) as well as their sum. GMM (Hansen (1982)) standard errors conditional on the estimated news series are reported in parentheses. Stocks are assigned to one of five baskets based on the frequency of price adjustment, SAU and returns are equally weighted at the portfolio level. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is from July 1982 to June 2007.

	Sticky (1)	S2 (2)	S3 (3)	S4 (4)	Flexible (5)	S1-S5 (6)
$\beta_{p,CF}$	0.55 * **	0.54 * **	0.51 * **	0.48 * **	0.41 * **	0.14 * **
	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)	(0.03)
$\beta_{p,DR}$	0.60 * **	0.57 * **	0.54 * **	0.50 * **	0.44 * **	0.15 * **
	(0.067	(0.06)	(0.06)	(0.06)	(0.07)	(0.03)
β_p	1.15	1.11	1.05	0.98	0.85	0.29

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2.9: Return Sensitivities to Federal Funds Rate Surprises

This table reports results from regressing monthly percentage excess returns on a constant and the surprise component of the one-month change in the Federal Funds rate and the CAPM predicted response for five portfolios sorted on the frequency of price adjustment and the CRSP value weighted index (market). OLS standard errors are reported in parentheses and Newey and West (1987) standard errors in brackets. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is June 1989 to June 2007.

	Market (1)	Sticky (2)	S2 (3)	S3 (4)	S4 (5)	Flexible (6)	S1-S5 (7)
$\beta^{actual}_{p,FFR}$	−9.35%	−11.42%	−10.19%	−9.35%	−8.85%	−5.01%	−6.41%
	(2.51)***	(3.01)***	(2.85)***	(2.81)***	(2.66)***	(2.55) **	(1.55)***
	[2.66]***	[4.12]***	[3.46]***	[3.36]***	[3.37]***	[2.98]*	[2.26]***
$\beta^{pred}_{p,FFR}$		−10.88%	−10.65%	−10.02%	−9.38%	−7.45%	−3.41%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2.10: Long Horizon Predictability (Benchmark Sample)

This table reports results for m-month forecasting regressions of log excess returns of the zero-cost portfolio of going long the portfolio of stocks with low frequencies of price adjustment, SAU, and shorting the portfolio of stocks with high frequencies of price adjustment on the log dividend-price ratio in Panel A, the break adjusted log dividend-price ratio in Panel B following the methodology of Lettau and Van Nieuwerburgh (2008) and the proxy for the consumption-wealth ratio of Lettau and Ludvigson (2001) in Panel C. For each regression the table reports OLS standard errors in parentheses, Newey and West (1987) standard errors in brackets, Hansen and Hodrick (1980) standard errors in curly brackets and Hodrick (1992) standard errors in angle brackets. Stocks are assigned to one of five baskets based on the frequency of price adjustment, SAU and returns are equally weighted at the portfolio level. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is July 1982 to June 2007.

Horizon m (Months)	1	6	12	24	36	48	60
Panel A. Dividend Price Ratio							
$b_{lh}^{(m)}$	0.00	0.01	0.01	0.01	0.02	0.03	0.05
SE_{NW}	[0.00]	[0.02]	[0.03]	[0.05]	[0.07]	[0.11]	[0.15]
SE_{HH}	{0.00}	{0.02}	{0.03}	{0.06}	{0.08}	{0.12}	{0.15}
SE_H	⟨0.00⟩	⟨0.02⟩	⟨0.04⟩	⟨0.09⟩	⟨0.12⟩	⟨0.15⟩	⟨0.16⟩
R^2	0.06%	0.15%	0.10%	0.11%	0.36%	0.40%	1.13%
Panel B. Break Adjusted Dividend Price Ratio							
$b_{lh}^{(m)}$	0.00	0.02	0.04	0.10	0.21	0.29	0.39
SE_{NW}	[0.01]	[0.03]	[0.04]	[0.07]	[0.10] **	[0.12] **	[0.14] ***
SE_{HH}	{0.01}	{0.03}	{0.04}	{0.08}	{0.11}*	{0.09}***	{0.11}***
SE_H	⟨0.01⟩	⟨0.04⟩	⟨0.08⟩	⟨0.14⟩	⟨0.19⟩	⟨0.21⟩	⟨0.18⟩ **
R^2	0.07%	0.49%	1.08%	3.68%	11.50%	17.17%	26.11%
Panel C. Consumption Wealth Ratio							
$b_{lh}^{(m)}$	0.24	1.62	3.31	6.32	8.92	10.39	12.39
SE_{NW}	[0.07] ***	[0.26] ***	[0.47] ***	[1.04] ***	[1.59] ***	[1.86] ***	[1.38] ***
SE_{HH}	{0.06}***	{0.29}***	{0.53}***	{1.17}***	{1.61}***	{0.76}***	{0.16}***
SE_H	⟨0.07⟩ ***	⟨0.42⟩ ***	⟨0.85⟩ ***	⟨1.60⟩ ***	⟨2.50⟩ ***	⟨3.76⟩ ***	⟨3.96⟩ ***
R^2	3.23%	22.54%	43.58%	55.57%	60.09%	50.95%	57.51%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2.11: Calibration

This table shows in Panel A calibrated parameter values of the model of Section 2.4 and the sectoral distribution of the frequency of price adjustment in Panel B.

Panel A. Calibration Parameter

Parameter	Value	Source
β	0.99	standard
b	0.76	Altig et al. (2011)
γ	5	Jermann (1998)
σ	2.5	Carvalho (2006)
ψ	1	Altig et al. (2011)
ϵ_c	8	Carvalho (2006)
ϵ_{ck}	12	Carvalho (2006)
θ_w	0.825	Heer et al. (2012)
ϵ_w	8	Altig et al. (2011) / Erceg et al. (2000)
ϕ_π	1.24	Rudebusch (2002)
ϕ_y	0.33/4	Rudebusch (2002)
ρ_a	0.95	Smets and Wouters (2007)
ρ_m	0.90	Coibion and Gorodnichenko (2012)

Panel B. Sectoral Distribution

Sector k	Share	Frequency of Price Adjustment
1	0.2	0.105
2	0.2	0.164
3	0.2	0.277
4	0.2	0.638
5	0.2	0.985

Table 2.12: Model Implied Stock Returns (5 Sectors)

This table reports annualized mean excess returns for simulated data of the model of Section 2.4, the model implied equity risk premium (ERP), the Sharpe ratio (SR) as well as the sensitivity (β_{SAU}) of annualized returns on the monthly frequency of price adjustment: $R_{jk,t} = \alpha + \beta_{SAU} \times (1 - \theta_k)$. A five sector version of the model is calibrated using standard parameter values reported in Table 2.11 and the empirical distribution of the frequency of price adjustment of Nakamura and Steinsson (2008). The model is solved using a second order approximation as implemented in dynare employing the pruning package of Andreasen et al. (2013), calibrated at a quarterly frequency and simulated for 400 firms in each sector for 500 periods discarding the first 250 periods as burn in.

		Sticky	S2	S3	S4	Flexible	S1-S5	ERP	SR	β_{SAU}
(1)	Baseline	7.91	6.84	6.56	5.96	5.51	2.39	6.56	0.39	−2.48∗∗∗
(2)	Equal Frequencies	7.09	7.08	7.07	7.07	7.09	0.00	7.08	0.49	
(3)	Flexible Prices	7.49	7.49	7.49	7.49	7.49	0.00	7.49	0.50	
(4)	$\epsilon_c = \epsilon_{ck} = 12$	8.45	6.88	6.54	5.93	5.48	2.97	6.65	0.39	−2.86∗∗∗
(5)	$\epsilon_c = \epsilon_{ck} = 8$	6.95	7.10	7.06	6.83	6.66	0.29	6.92	0.47	−0.55∗∗∗
(6)	$\epsilon_{ck} = 13$	8.70	6.81	6.41	5.68	5.15	3.55	6.55	0.36	−3.41∗∗∗
(7)	$\epsilon_{ck} = 11$	7.40	6.89	6.70	6.21	5.85	1.55	6.61	0.41	−1.76∗∗∗
(8)	$\epsilon_c = 10$	8.15	6.86	6.55	5.94	5.50	2.66	6.60	0.39	−2.66∗∗∗
(9)	$\epsilon_c = 6$	7.71	6.82	6.57	5.98	5.53	2.18	6.52	0.39	−2.33∗∗∗
(10)	$\epsilon_w = 6$	7.98	7.03	6.72	6.17	5.76	2.22	6.73	0.42	−2.31∗∗∗
(11)	$\sigma = 1$	8.51	7.07	6.70	6.20	5.82	2.69	6.86	0.43	−2.55∗∗∗
(12)	Shock std = 0.009	10.21	7.66	7.19	6.40	5.82	4.39	7.46	0.38	−4.05∗∗∗
(13)	Baseline unpruned	6.13	3.36	2.90	2.27	1.92	4.21	3.32	0.14	−3.60∗∗∗
(14)	$\phi_{pi} = 1.3$	5.98	5.88	5.76	5.41	5.16	0.82	5.64	0.38	−1.08∗∗∗
(15)	$\phi_x = 0.5/4;$	7.90	6.84	6.56	5.96	5.51	2.39	6.55	0.39	−2.47∗∗∗
(16)	MP shocks only	6.81	5.87	5.64	5.03	4.59	2.23	5.59	0.34	−2.37∗∗∗
(17)	Technol shocks only	1.08	0.97	0.89	0.83	0.81	0.27	0.92	0.47	−0.27∗∗∗
(18)	$\phi_x = 0.975$	9.19	7.85	7.46	6.80	6.32	2.87	7.52	0.43	−2.90∗∗∗
(19)	Interest Rate Smoothing	9.54	8.46	8.14	7.57	7.15	2.39	8.17	0.36	−2.45∗∗∗

$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2.13: Long-Horizon Predictability on Simulated Data

This table reports results for q-quarters forecasting regressions of model implied log excess returns of the zero-cost portfolio of going long the claim to dividends of the sector with low frequencies of price adjustment and shorting the claim to dividends of the sector with high frequencies of price adjustment, L-H on log consumption surplus of the model. For each regression the table reports OLS standard errors in parentheses, Newey and West (1987) standard errors in brackets, Hansen and Hodrick (1980) standard errors in curly brackets and Hodrick (1992) standard errors in angle brackets. The sample length is 250 quarters.

Horizon q (Quarters)	1	2	4	8	12	16	20
$b_{lh}^{(q)}$	−0.14	−0.26	−0.48	−0.79	−0.81	−0.77	−0.68
SE_{NW}	[0.05] ∗∗∗	[0.07] ∗∗∗	[0.11] ∗∗∗	[0.20] ∗∗∗	[0.29] ∗∗∗	[0.40]∗	[0.50]
SE_{HH}	{0.05}∗∗∗	{0.08}∗∗∗	{0.13}∗∗∗	{0.23}∗∗∗	{0.31}∗∗∗	{0.43}∗	{0.52}
SE_H	⟨0.05⟩∗∗∗	⟨0.10⟩∗∗∗	⟨0.17⟩∗∗∗	⟨0.26⟩∗∗∗	⟨0.32⟩ ∗∗	⟨0.36⟩ ∗∗	⟨0.38⟩∗
R^2	9.34%	14.28%	21.86%	21.80%	13.75%	8.61%	5.05%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

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Appendix A

Are Sticky Prices Costly?

A.1 Firm and Industry Level Controls

Balance sheet data is obtained from the Standard and Poor's Compustat database. We define book equity (BE) as total shareholders' equity plus deferred taxes and investment tax credit (Compustat item TXDITCQ) minus the book value of preferred stock (Compustat item PSTKQ). We prefer the shareholders' equity numbers as reported by Compustat (Compustat item SEQQ). In case this data is not available, we calculate shareholders' equity as sum of common and preferred equity (Compustat items CEQQ and PSTKQ). If none of the two are available, we define shareholders' equity as the differences of total assets and total liabilities (Compustat items ATQ and LTQ).

The book to market (BM) ratio of event t is then the log of the ratio of book equity for the fiscal quarter ending at least three month before the event date over the market capitalization of the previous trading day. Market capitalization is number of shares outstanding times the closing price (CRSP items SHROUT and PRC). $Size$ is the natural logarithm of the market capitalization as of the previous trading day.

Price to cost margin (PCM) is the ratio of net sales minus costs of goods sold (Compustat item COGS) to net sales. *std sale* is the volatility of annual growth in net sales on a quarterly basis. Fixed costs to sales ($FC2Y$) is defined as the sum of selling, general and administrative expenditures (Compustat item XSGA), advertising (Compustat item XAD) and research and development expenses (Compustat item XRD) over net sales. Receivables minus payables to sales ($RecPay2Y$) is total receivables minus total trade payables (Compustat items RECT and AP) over net sales, investment to sales ($I2Y$) is capital expenditures (Compustat item CAPX) to net sales and depreciation to assets ($D2A$) is depreciation and amortization (Compustat item DP) over total assets (Compustat item AT). These variables are all averaged across our sample period.

Profitability is operating income before depreciation (Compustat item OIBDPQ) over lagged total assets where both variables are measured on a quarterly basis. Rating (Rat) is the S&P domestic long term issuer credit rating (Compustat item SPLTICRM). We assign the highest rating category, AAA, a value of 4.33, decreasing by 1/8 with every rating notch. We use mean ratings within the year and lag them by one year.

We also include the Kaplan - Zingales index (KZ, Kaplan and Zingales (1997)) to control for the impact of financial constraints. This index is defined as:

$$KZ_{it} = -1.002\frac{CF_{it}}{AT_{it-1}} - 39.368\frac{Div_{it}}{AT_{it-1}} - 1.315\frac{C_{it}}{AT_{it-1}} + 3.139Lev_{it} + 0.283Q_{it},$$

where cash flow (CF) is the sum of income before extraordinary items (Compustat item IB) and depreciation and amortization, dividends (Div) are measured as common and preferred dividends (Compustat items DVC and DVP), C is cash and short term investments (Compustat item CHE), leverage (Lev) is the ratio of long term debt and debt in current liabilities (Compustat items DLTT and DLC) to stockholders' equity (Compustat item SEQ), long term debt and debt in current liabilities and Q is the ratio of total assets, the market value of equity from CRSP as of fiscal year end, minus the bookvalue of equity and deferred taxes (Compustat items CEQ and TXDB) to total assets. The first three variables are normalized by lagged total assets. We winsorize all variables at the 1% level before calculating the index and use one year lagged values of the index in our regressions.

Four firm concentration ratios ($4F - conc\ ratio$) are the means of the concentration ratios at the industry level over the years 1997, 2002 and 2007 as reported by the Census Bureau. We assign firms into categories of final demand based on their durability of output using the industry classification of Gomes et al. (2009). They use the 1987 benchmark input-output accounts to assign industries to the classes of final demand to which they have the highest value added: personal consumption expenditure on non-durable goods ($nondur$), durable goods (dur) and services ($serv$), gross private domestic investment ($invest$), government expenditure and gross investment (gov), as well as net export of goods and services (nx).

Engel curve slopes ($angel$) and a different measure of durability of output ($dura$, in years) at the industry level are from Bils et al. (2012). They estimate Engel curve slopes using the micro data underlying the U.S. Consumer Expenditure Surveys Interview Surveys, pooling cross sections from 1982 to 2010. They employ life expectancy tables from a property casualty insurer and estimates from the U.S. Bureau of Economic Analysis to measure durability of output at the industry level.

In a robustness test, we use CAPM and Fama and French adjusted returns as left hand side variables. We calculate factor loadings as full sample time series coefficients of monthly excess returns on the factors. We construct Fama and French factor returns for our 30 minutes event window as in Fama and French (1993) using our sample of firms.

A.2 Dynamic General Equilibrium Model

This section discusses our calibrated mutli-sector New Keynesian model in greater detail. For more information we refer directly to Carvalho (2006). In this model, a representative household lives forever. The instantaneous utility of the household depends on consumption and labor supply. The intertemporal elasticity of substitution for consumption is σ. Labor supply is firm-specific. For each firm, the elasticity of labor supply is η. Household's discount factor is β. Households have a love for variety and have a CES Dixit-Stiglitz aggregator with the elasticity of substitution θ.

Firms set prices as in Calvo (1983). There are k sectors in the economy with each sector populated by a continuum of firms. Each sector is characterized by a fixed λ_k, the probability of any firm in industry k to adjust its price in a given period. The share of firms in industry k in the total number of firms in the economy is given by the density function $f(k)$. Firms are monopolistic competitors and the elasticity of substitution θ is the same for all firms both within and across industries. While this assumption is clearly unrealistic, it greatly simplifies the algebra and keeps the model tractable. The production function for output Y is linear in labor N which is the only input. The optimization problem of firm j in industry k is then to pick a reset price X_{jkt}:

$$\begin{aligned} \max \mathbb{E}_t \quad & \sum_{s=0}^{\infty} Q_{t,t+s}(1-\lambda_k)^s [X_{jkt} Y_{jkt+s} - W_{jkt+s} N_{jkt+s}] \\ s.t.\ Y_{jkt+s} &= N_{jkt+s} \\ Y_{jkt+s} &= Y_{t+s} \left(\frac{X_{jkt}}{P_{t+s}} \right)^{-\theta} \\ Q_{t,t+s} &= \beta^s \left(\frac{Y_{t+s}}{Y_t} \right)^{-\sigma} \end{aligned}$$

where variables without subscripts k and j indicate aggregate variables, W is wages (taken as given by firms) and Q is the stochastic discount factor. Wages paid by firms are determined by the household's optimization problem:

$$\frac{W_{jkt}}{P_t} = \frac{N_{jkt}^{1/\eta}}{C_t^{-\sigma}}.$$

The aggregate price level and output are given by:

$$\begin{aligned} P_t &= \left(\int_0^1 f(k) P_{kt}^{(1-\theta)} dk \right)^{1/(1-\theta)}, P_{kt} = \left(\int_0^1 P_{jkt}^{(1-\theta)} dj \right)^{1/(1-\theta)}, \\ Y_t &= \left(\int_0^1 f(k)^{1/\theta} Y_{kt}^{(\theta-1)/\theta} dk \right)^{\theta/(\theta-1)}, Y_{kt} = f(k) \left(\int_0^1 Y_{jkt}^{(\theta-1)/\theta} dj \right)^{\theta/(\theta-1)}. \end{aligned}$$

The central bank follows an interest rate rule:

$$\begin{aligned} i_t &= \left(\frac{P_t}{P_{t-1}} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\phi_y} \beta^{-1} \exp(mp_t) \\ mp_t &= \rho_{mp} mp_{t-1} + v_t \end{aligned}$$

where $exp(i_t)$ is the nominal interest rate, ϕ_π and ϕ_y measure responses to inflation and output growth, and v_t is an i.i.d. zero-mean policy innovation.

After substituting in optimal reset prices and firm-specific demand and wages, the value of the firm V with price P_{jkt} is given by:

$$
\begin{aligned}
V(P_{jkt}) &= \mathbb{E}_t\left\{Y_t^\sigma P_t\left[\Delta_{kt}^{(1)}\left(\frac{P_{jkt}}{P_t}\right)^{1-\theta} - \Delta_{kt}^{(2)}\left(\frac{P_{jkt}}{P_t}\right)^{-\theta(1+1/\eta)} + \Upsilon_{kt}^{(1)} - \Upsilon_{kt}^{(2)}\right]\right\} \\
\Upsilon_{kt}^{(1)} &= \lambda_k\beta\left(\frac{X_{k,t+1}}{P_{t+1}}\right)^{1-\theta}\Delta_{kt+1}^{(1)} + \beta\Upsilon_{kt+1}^{(1)} \\
\Delta_{kt}^{(1)} &= Y_t^{1-\sigma} + \beta(1-\lambda_k)\left(\frac{P_{t+1}}{P_t}\right)^{\theta-1}\Delta_{kt+1}^{(1)} \\
\Upsilon_{kt}^{(2)} &= \lambda_k\beta\left(\frac{X_{k,t+1}}{P_{t+1}}\right)^{-\theta(1+1/\eta)}\Delta_{kt+1}^{(2)} + \beta\Upsilon_{kt+1}^{(2)} \\
\Delta_{kt}^{(2)} &= Y_t^{1+1/\eta} + \beta(1-\lambda_k)\left(\frac{P_{t+1}}{P_t}\right)^{\theta(1+1/\eta)}\Delta_{kt+1}^{(2)}
\end{aligned}
$$

A.3 Additional Results

As discussed in the main body of the paper we calculate the frequency of price adjustment as the mean fraction of months with price changes during the sample period of an item. Because the collected data may have missing values, we construct different measures of the frequency of price adjustment, FP. In the first approach, labeled A, we treat missing values as interrupting price spells. For example, if a price was \$4 for two months, then misses for a month, and is again observed at \$5 for another three months, we treat the data as reporting two price spells with durations of two and three months where none of the spells has a price change and hence the frequency is zero. In the second approach, labeled B, missing values do not interrupt price histories. In the previous example, approach B concatenates spells of \$4 and \$5 prices and yields one price change in five months so that the frequency is 1/5. Approach C takes the union of A and B, that is, there is a price change if either A or B identify a price change. We employ approach FPA in the main paper weighting item based frequencies equally. Results are very similar if we make use of these alternative measures.

Table A.1 reports mean probabilities, standard deviations and the number of firm-event observations for these different measures of the frequency of price adjustment, both for the total sample and for each industry separately. Results are very similar across the various measures.

Tables A.2 – A.6 repeat the analyses of Table 1.5 for different measures for price stickiness. Results are comparable across our different measures.

Table A.1: Frequency of Price Adjustment by Industry

This table reports average frequencies of price adjustments at the industry and aggregate levels with standard deviations in parentheses for different measures of the frequency of price adjustment. FPA treats missing values as interrupting price spells, for FPB, missing values do not interrupt price spells if the price is the same before and after periods of missing values, and FPC forms the union of the two. Columns (1) to (3) use equally weighted frequencies of price adjustments whereas columns (4) to (6) weight frequencies with associated values of shipments. Frequencies of price adjustments are calculated at the firm level using the microdata underlying the Producer Price Index constructed by the Bureau of Labor Statistics.

		FPA	FPB	FPC	FPAW	FPBW	FPCW
		(1)	(2)	(3)	(4)	(5)	(6)
Agriculture	Mean	25.35%	26.10%	26.32%	29.70%	30.42%	30.71%
	Std	(17.23%)	(16.81%)	(17.12%)	(19.39%)	(18.89%)	(19.22%)
	Nobs		3634			3526	
Manufacturing	Mean	11.88%	12.90%	12.97%	12.76%	13.85%	13.94%
	Std	(11.12%)	(11.25%)	(11.32%)	(12.79%)	(12.83%)	(12.91%)
	Nobs		27939			27561	
Utilities	Mean	21.45%	22.49%	22.62%	22.30%	23.25%	23.36%
	Std	(13.44%)	(12.89%)	(12.94%)	(13.81%)	(13.33%)	(13.38%)
	Nobs		7397			7162	
Trade	Mean	22.19%	24.90%	25.05%	23.01%	25.69%	25.85%
	Std	(13.71%)	(12.70%)	(12.79%)	(13.74%)	(12.42%)	(12.53%)
	Nobs		3845			3838	
Finance	Mean	13.82%	19.11%	19.22%	13.70%	20.06%	20.20%
	Std	(11.41%)	(12.45%)	(12.53%)	(11.95%)	(14.33%)	(14.44%)
	Nobs		9856			9725	
Service	Mean	8.07%	9.69%	9.73%	8.76%	10.33%	10.36%
	Std	(7.72%)	(8.58%)	(8.61%)	(8.09%)	(8.81%)	(8.83%)
	Nobs		4870			4578	
Total	Mean	14.66%	16.56%	16.66%	15.56%	17.67%	17.79%
	Std	(12.90%)	(13.07%)	(13.16%)	(14.17%)	(14.44%)	(14.55%)
	Nobs		57541			56390	

Table A.2: Response of the Constituents of the S&P500 to Monetary Policy Shocks (measure FPB)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.2), v_t^2, the frequency of price adjustment, FPB, as well as their interactions. FPB treats missing values as not interrupting price spells if the price is the same before and after periods of missing values. Equally weighted frequencies of price adjustments are calculated at the establishment level using the microdata underlying the producer price index. Regressions (1) and (2) consider a 30 minutes event window, (3) and (4) add firm fixed effects, (5) and (6) firm and event fixed effects, whereas (7) and (8) focus on a 60 minutes event window. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	Tight Window		Firm FE		Firm & Event FE		Wide Window	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2	123.70***	73.33***	122.70***	72.99***			114.70***	89.34***
	(21.00)	(16.04)	(20.72)	(15.56)			(29.78)	(19.72)
$FPB \times v_t^2$	−121.90*	−41.67***	−119.90**	−41.32***	−117.60*	−16.88*	−86.00	−44.80**
	(62.13)	(6.23)	(59.23)	(6.41)	(60.94)	(9.12)	(58.62)	(21.77)
FPB	0.84**	0.48**					0.98	0.62*
	(0.34)	(0.24)					(0.69)	(0.32)
Event Fixed Effects	No	No	No	No	Yes	Yes	No	No
Firm Fixed Effects	No	No	Yes	Yes	Yes	Yes	No	No
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.11	0.09					0.03	0.08
Number of firms	760	760	760	760	760	760	760	760
Observations	57,541	57,438	57,541	57,437	57,541	57,411	57,541	55,018

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table A.3: Response of the Constituents of the S&P500 to Monetary Policy Shocks (measure FPC)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.2), v_t^2, the frequency of price adjustment, FPC, as well as their interactions. FPC forms the union of FPA and FPB. Equally weighted frequencies of price adjustments are calculated at the establishment level using the microdata underlying the producer price index. Regressions (1) and (2) consider a 30 minutes event window, (3) and (4) add firm fixed effects, (5) and (6) firm and event fixed effects, whereas (7) and (8) focus on a 60 minutes event window. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	Tight Window		Firm FE		Firm & Event FE		Wide Window	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2	123.60***	73.66***	122.50***	73.47***			114.60***	89.26***
	(20.98)	(15.71)	(20.70)	(15.39)			(29.76)	(19.74)
$FPC \times v_t^2$	−120.30*	−38.05***	−118.30**	−38.30***	−116.20*	−16.69*	−84.77	−44.10**
	(61.34)	(5.83)	(58.46)	(5.91)	(60.10)	(8.90)	(57.84)	(21.31)
FPC	0.83**	0.47*					0.98	0.61*
	(0.33)	(0.24)					(0.69)	(0.32)
Event Fixed Effects	No	No	No	No	Yes	Yes	No	No
Firm Fixed Effects	No	No	Yes	Yes	Yes	Yes	No	No
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.11	0.09					0.03	0.08
Number of firms	760	760	760	760	760	760	760	760
Observations	57,541	57,441	57,541	57,439	57,541	57,411	57,541	55,018

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table A.4: Response of the Constituents of the S&P500 to Monetary Policy Shocks (measure FPAW)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.2), v_t^2, the frequency of price adjustment, FPAW, as well as their interactions. FPAW treats missing values as interrupting price spells. Value of shipments weighted frequencies of price adjustments are calculated at the establishment level using the microdata underlying the producer price index. Regressions (1) and (2) consider a 30 minutes event window, (3) and (4) add firm fixed effects, (5) and (6) firm and event fixed effects, whereas (7) and (8) focus on a 60 minutes event window. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	Tight Window		Firm FE		Firm & Event FE		Wide Window	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2	127.90***	79.08***	126.80***	78.78***			119.40***	96.34***
	(23.20)	(14.68)	(22.94)	(14.16)			(30.64)	(21.00)
$FPAW \times v_t^2$	−160.00**	−66.92***	−157.30**	−66.32***	−156.30**	−39.24***	−126.00*	−84.80***
	(79.28)	(4.93)	(76.70)	(4.62)	(76.73)	(7.89)	(67.36)	(21.58)
$FPAW$	0.22	0.05					0.01	−0.08
	(0.28)	(0.16)					(0.31)	(0.12)
Event Fixed Effects	No	No	No	No	Yes	Yes	No	No
Firm Fixed Effects	No	No	Yes	Yes	Yes	Yes	No	No
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.12	0.11					0.03	0.09
Number of firms	740	740	740	740	740	740	740	740
Observations	56,390	56,295	56,390	56,296	56,390	56,276	56,390	53,885

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table A.5: Response of the Constituents of the S&P500 to Monetary Policy Shocks (measure FPBW)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.2), v_t^2, the frequency of price adjustment, FPBW, as well as their interactions. FPBW treats missing values as not interrupting price spells if the price is the same before and after periods of missing values. Value of shipments weighted frequencies of price adjustments are calculated at the establishment level using the microdata underlying the producer price index. Regressions (1) and (2) consider a 30 minutes event window, (3) and (4) add firm fixed effects, (5) and (6) firm and event fixed effects, whereas (7) and (8) focus on a 60 minutes event window. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	Tight Window		Firm FE		Firm & Event FE		Wide Window	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2	123.40***	75.24***	122.30***	74.69***			114.60***	91.68***
	(21.31)	(15.23)	(21.02)	(14.55)			(29.62)	(20.16)
$FPBW \times v_t^2$	−116.10*	−37.30***	−113.50*	−35.13***	−111.40*	−17.87**	−83.55	−52.25**
	(65.59)	(5.95)	(63.08)	(5.88)	(64.42)	(8.51)	(59.01)	(21.88)
$FPBW$	0.67***	0.52**					0.42	0.576**
	(0.24)	(0.25)					(0.28)	(0.28)
Event Fixed Effects	No	No	No	No	Yes	Yes	No	No
Firm Fixed Effects	No	No	Yes	Yes	Yes	Yes	No	No
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.12	0.11					0.03	0.04
Number of firms	740	740	740	740	740	740	740	740
Observations	56,390	56,295	56,390	56,294	56,390	56,265	56,390	53,882

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table A.6: Response of the Constituents of the S&P500 to Monetary Policy Shocks (measure FPCW)

This table reports the results of regressing squared percentage returns of the constituents of the S&P500 in a 30 minutes window bracketing the FOMC press releases on the federal funds futures based measure of monetary policy surprises calculated according to equation (1.2), v_t^2, the frequency of price adjustment, FPCW, as well as their interactions. FPCW forms the union of FPAW and FPBW. Value of shipments weighted frequencies of price adjustments are calculated at the establishment level using the microdata underlying the producer price index. Regressions (1) and (2) consider a 30 minutes event window, (3) and (4) add firm fixed effects, (5) and (6) firm and event fixed effects, whereas (7) and (8) focus on a 60 minutes event window. The full sample ranges from February 1994 through December 2009, excluding the release of September 17th 2001, for a total of 137 observations. Driscoll-Kraay standard errors are reported in parentheses.

	Tight Window		Firm FE		Firm & Event FE		Wide Window	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v_t^2	123.40***	75.08***	122.20***	74.52***			114.50***	91.58***
	(21.30)	(15.08)	(21.01)	(14.55)			(29.62)	(20.19)
$FPCW \times v_t^2$	−114.90*	−38.10***	−112.30*	−34.39***	−110.30*	−16.23**	−82.55	−51.22**
	(64.71)	(5.62)	(62.24)	(5.51)	(63.50)	(8.06)	(58.16)	(21.53)
$FPCW$	0.66***	0.52**					0.40	0.567**
	(0.23)	(0.24)					(0.28)	(0.28)
Event Fixed Effects	No	No	No	No	Yes	Yes	No	No
Firm Fixed Effects	No	No	Yes	Yes	Yes	Yes	No	No
Correction for outliers	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.12	0.11					0.03	0.04
Number of firms	740	740	740	740	740	740	740	740
Observations	56,390	56,296	56,390	56,294	56,390	56,266	56,390	53,883

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Appendix B

Nominal Rigidities and Asset Pricing

B.1 Model Derivations

Households

The representative household has additively separable utility in consumption and leisure and maximizes

$$\mathbb{E}_t \sum_{s=0}^{\infty} \left[\beta^s \frac{(C_{t+s} - bC_{t+s-1})^{1-\gamma}}{1-\gamma} - \psi_L \int_0^1 \frac{h_{i,t+s}^{1+\sigma}}{1+\sigma} di \right]$$

$$\text{s.t.} \qquad P_t C_t = \int_0^1 W_{i,t} h_{i,t} di + R_{t-1} B_{t-1} - B_t + D_t,$$

where $\mathbb{E}_t$ is the expectation operator conditional on the time t information set of the representative household, β is the discount factor, C is the composite consumption good, b ≥ 0 is a habit persistence parameter in consumption, $h_{i,t}$ denotes hours worked of type i, $\psi_L \geq 0$ is a parameter, P is the composite price index defined below, $W_{i,t}$ time t nominal wage for labor type i, R_t is the gross nominal interest rate, B_t denotes nominal bond holdings and D_t are aggregate dividends by the firm sector. Profits are redistributed via lump-sum transfer at the end of each period. The parameters γ and σ denote, respectively, the coefficient of relative risk aversion and the inverse of the Frisch elasticity of labor supply.

The first order conditions for the representative household for consumption and bond holdings are given by:

$$(C_t - bC_{t-1})^{-\gamma} = \Lambda_t P_t = \lambda_t$$
$$\mathbb{E}_t(\beta \Lambda_{t+1} R_t) = \Lambda_t.$$

Hence,

$$\frac{1}{P_t}(C_t - bC_{t-1})^{-\gamma} = \beta R_t\,\mathbb{E}_t\left[\frac{1}{P_{t+1}}(C_{t+1} - bC_t)^{-\gamma}\right]$$
$$1 = \beta R_t\,\mathbb{E}_t\left[\frac{1}{\pi_{t+1}}\left(\frac{C_{t+1} - bC_t}{C_t - bC_{t-1}}\right)^{-\gamma}\right].$$

Optimal Consumption Allocation

The composite consumption good is given by:

$$C_t \equiv \left[\int_0^1 f(k)^{\frac{1}{\varepsilon_c}} C_{k,t}^{\frac{\varepsilon_c - 1}{\varepsilon_c}} dk\right]^{\frac{\varepsilon_c}{\varepsilon_c - 1}}, \tag{B.1}$$

$$C_{k,t} \equiv f(k)\left[\int_0^1 C_{kj,t}^{\frac{\varepsilon_{ck} - 1}{\varepsilon_{ck}}} dj\right]^{\frac{\varepsilon_{ck}}{\varepsilon_{ck} - 1}}. \tag{B.2}$$

Let $P_{kj,t}$ denote the price charged by firm j in sector k for the consumption good C_{kj} in period t. The consumption price index is then given by:

$$P_t = \left[\int_0^1 f(k) P_{k,t}^{1-\varepsilon_c} dk\right]^{\frac{1}{1-\varepsilon_c}}, \tag{B.3}$$

$$P_{k,t} = \left[\int_0^1 P_{kj,t}^{1-\varepsilon_{ck}} dj\right]^{\frac{1}{1-\varepsilon_{ck}}}. \tag{B.4}$$

Assume that the representative household maximizes equation (B.2) for any given expenditure level Q_t:

$$\int_0^1 P_{kj,t} C_{kj,t} dj = Q_t. \tag{B.5}$$

The Lagrangian associated with this problem is given by:

$$\mathfrak{L} = f(k)\left(\int_0^1 C_{kj,t}^{\frac{\varepsilon_{ck} - 1}{\varepsilon_{ck}}} dj\right)^{\frac{\varepsilon_{ck}}{\varepsilon_{ck} - 1}} - \Omega_t\left(\int_0^1 P_{kj,t} C_{kj,t} dj - Q_t\right),$$

where Ω_t is the associated Lagrange multiplier.
The first-order conditions are:

$$f(k)\frac{\varepsilon_{ck}}{\varepsilon_{ck} - 1}\left(\int_0^1 C_{kj,t}^{\frac{\varepsilon_{ck} - 1}{\varepsilon_{ck}}} dj\right)^{\frac{1}{\varepsilon_{ck} - 1}} \frac{\varepsilon_{ck} - 1}{\varepsilon_{ck}} C_{kj,t}^{-\frac{1}{\varepsilon_{ck}}} = \Omega_t P_{kj,t} \quad \forall j \in [0, 1].$$

Rearranging and dividing by the expression for subcomposite $C_{ki,t}$:

$$C_{kj,t} = C_{ki,t}\left(\frac{P_{kj,t}}{P_{ki,t}}\right)^{-\varepsilon_{ck}}.$$

Substituting this expression into equation (B.5) we get:

$$\int_0^1 P_{kj,t}C_{ki,t}\left(\frac{P_{kj,t}}{P_{ki,t}}\right)^{-\varepsilon_{ck}} dj = Q_t$$
$$\Longleftrightarrow$$
$$C_{ki,t}P_{ki,t}^{\varepsilon_{ck}}\int_0^1 P_{kj,t}^{1-\varepsilon_{ck}} dj = Q_t.$$

Substituting for $\int_0^1 P_{kj,t}^{1-\varepsilon_{ck}} dj$ using equation (B.4):

$$C_{ki,t}P_{ki,t}^{\varepsilon_{ck}}P_{k,t}^{1-\varepsilon_{ck}} = Q_t \tag{B.6}$$
$$\Longleftrightarrow$$
$$C_{ki,t} = \frac{Q_t}{P_{k,t}}\left(\frac{P_{ki,t}}{P_{k,t}}\right)^{-\varepsilon_{ck}}.$$

Substituting the last expression for subcomposite kj in equation (B.2):

$$C_{k,t} = f(k)\left\{\int_0^1\left[\frac{Q_t}{P_{k,t}}\left(\frac{P_{kj,t}}{P_{k,t}}\right)^{-\varepsilon_{ck}}\right]^{\frac{\varepsilon_{ck}-1}{\varepsilon_{ck}}} dj\right\}^{\frac{\varepsilon_{ck}}{\varepsilon_{ck}-1}}.$$

Using the definition of the price index, equation (B.4), we get:

$$C_{k,t} = f(k)\frac{Q_t}{P_{k,t}}$$
$$\Longleftrightarrow$$
$$\frac{Q_t}{P_{k,t}} = C_{k,t}f(k)^{-1}. \tag{B.7}$$

Combining equation (B.7) with equation (B.6) for good kj:

$$C_{k,t}f(k)^{-1} = C_{kj,t}\left(\frac{P_{kj,t}}{P_{k,t}}\right)^{\varepsilon_{ck}}.$$

Solving for $C_{kj,t}$ we arrive at the demand for subcomposite kj:

$$C_{kj,t} = f(k)^{-1}C_{k,t}\left(\frac{P_{kj,t}}{P_{k,t}}\right)^{-\varepsilon_{ck}}.$$

Following the same logic as above we can derive the demand for the composite consumption good for a given expenditure level of Z_t:

$$\int_0^1 P_{k,t} C_{k,t} dk = Z_t. \tag{B.8}$$

The Lagrangian is given by:

$$\mathfrak{L} = \left(\int_0^1 f(k)^{\frac{1}{\varepsilon_c}} C_{k,t}^{\frac{\varepsilon_c - 1}{\varepsilon_c}} dk \right)^{\frac{\varepsilon_c}{\varepsilon_c - 1}} - \Theta_t \left(\int_0^1 P_{k,t} C_{k,t} dk - Z_t \right),$$

where Θ_t is the associated Lagrange multiplier. The first-order conditions are:

$$\frac{\varepsilon_c}{\varepsilon_c - 1} \left(\int_0^1 f(k)^{\frac{1}{\varepsilon_c}} C_{k,t}^{\frac{\varepsilon_c - 1}{\varepsilon_c}} dk \right)^{\frac{1}{\varepsilon_c - 1}} \frac{\varepsilon_c - 1}{\varepsilon_c} C_{k,t}^{-\frac{1}{\varepsilon_c}} f(k)^{\frac{1}{\varepsilon_c}} = \Theta_t P_{k,t} \quad \forall k \in [0, 1].$$

Rearranging and dividing by the expression for the consumption composite of sector l, $C_{l,t}$:

$$C_{k,t} = C_{l,t} \frac{f(k)}{f(l)} \left(\frac{P_{k,t}}{P_{l,t}} \right)^{-\varepsilon_c}.$$

Substituting this expression into equation (B.8) we get:

$$\int_0^1 P_{k,t} \frac{f(k)}{f(l)} C_{l,t} \left(\frac{P_{k,t}}{P_{l,t}} \right)^{-\varepsilon_c} dk = Z_t$$
$$\iff$$
$$C_{l,t} P_{l,t}^{\varepsilon_c} \frac{1}{f(l)} \int_0^1 f(k) P_{k,t}^{1-\varepsilon_c} dk = Z_t.$$

Substituting for $\int_0^1 f(k) P_{k,t}^{1-\varepsilon_c} dk$ using equation (B.3)

$$C_{l,t} P_{l,t}^{\varepsilon_c} \frac{1}{f(l)} P_t^{1-\varepsilon_c} = Z_t \tag{B.9}$$
$$\iff$$
$$C_{l,t} = f(l) \frac{Z_t}{P_t} \left(\frac{P_{l,t}}{P_t} \right)^{-\varepsilon_c}.$$

Substituting the last expression for the sector k consumption good in equation (B.1):

$$C_t = \left\{ \int_0^1 f(k)^{\frac{1}{\varepsilon_c}} \left[f(k) \frac{Z_t}{P_t} \left(\frac{P_{k,t}}{P_t} \right)^{-\varepsilon_c} \right]^{\frac{\varepsilon_c - 1}{\varepsilon_c}} dk \right\}^{\frac{\varepsilon_c}{\varepsilon_c - 1}}.$$

Using the definition of the price index, equation (B.3), we get:

$$C_t = \frac{Z_t}{P_t}. \tag{B.10}$$

Combining equation (B.10) with equation (B.9) for sector k:

$$\frac{Z_t}{P_t} = \frac{1}{f(k)} C_{k,t} \left(\frac{P_{k,t}}{P_t} \right)^{\varepsilon_c}.$$

Solving for $C_{k,t}$ we arrive at the demand for sector k composite consumption good:

$$C_{k,t} = f(k) C_t \left(\frac{P_{k,t}}{P_t} \right)^{-\varepsilon_c}.$$

Demand for Different Labor Types

The competitive labor contractor demands labor of different types i to maximize:

$$W_t H_t - \int_0^1 W_{i,t} h_{i,t} \mathrm{d}i$$

$$\text{s.t.} \qquad H_t = \left[\int_0^1 h_{i,t}^{\frac{\varepsilon_w - 1}{\varepsilon_w}} di \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}},$$

where W is the aggregate wage rate, H homogeneous labor, W_i wage rate of labor type i, h_i and $\varepsilon_w \geq 1$ is the elasticity of substitution among different labor types.
Following similar steps as in the derivation for the optimal consumption allocation, we arrive at:

$$h_{i,t} = \left(\frac{W_{i,t}}{W_t} \right)^{-\varepsilon_w} H_t.$$

The resulting demand curves are identical to a setup without competitive labor contractor where firms directly demand different labor types.
Note that the aggregate wage rate, W can be simply derived from:

$$\begin{aligned} W_t H_t &= \int_0^1 W_{i,t} h_{i,t} \mathrm{d}i \\ &= \int_0^1 W_{i,t} \left(\frac{W_{i,t}}{W_t} \right)^{-\varepsilon_w} H_t \mathrm{d}i \\ W_t^{1-\varepsilon_w} &= \int_0^1 W_{i,t}^{1-\varepsilon_w} \mathrm{d}i. \end{aligned}$$

Optimal Reset Wage

Let U_t be the optimal reset wage. The optimizing problem of the union representing labor of type i, $h_{i,t}$ is given by:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left\{ -\psi_L \frac{h_{i,t+s}^{1+\sigma}}{1+\sigma} + \frac{\Lambda_{t+s}}{\Lambda_t} U_{i,t} h_{i,t+s} \right\}$$

$$\text{s.t.} \qquad h_{i,t+s} = \left(\frac{U_{i,t}}{W_{t+s}} \right)^{-\varepsilon_w} H_{t+s},$$

where θ_w is the probability that the union cannot reset the wage rate of labor type i, $W_{i,t}$, σ is the inverse of the Frisch labor supply elasticity, Λ is the Lagrange multiplier on the households budget constraint, ϵ_w is the elasticity of substitution among different labor types and ψ_L is a parameter.
The first order condition is given by:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left\{ -\psi_L h_{i,t+s}^{1+\sigma} \frac{1}{U_{i,t}} (-\varepsilon_w) + \Lambda_{t+s}(1-\varepsilon_w) h_{i,t+s} \right\} = 0$$

$\Longleftrightarrow$

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left\{ \lambda_{t+s} \left(\frac{U_{i,t}}{P_{t+s}} \right) \left(\frac{U_{i,t}}{W_{t+s}} \right)^{-\varepsilon_w} H_{t+s} - \frac{\varepsilon_w}{\varepsilon_w - 1} \psi_L \left(\frac{U_{i,t}}{W_{t+s}} \right)^{-\varepsilon_w(1+\sigma)} H_{t+s}^{1+\sigma} \right\}$$

$\Longleftrightarrow$

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left\{ \lambda_{t+s} \left(\frac{U_{i,t}}{P_t} \right) \left(\frac{P_t}{P_{t+s}} \right) \left(\frac{W_t}{W_{t+s}} \right)^{-\varepsilon_w} H_{t+s} \right\}$$
$$= \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left\{ \frac{\varepsilon_w}{\varepsilon_w - 1} \psi_L \left(\frac{U_{i,t}}{W_t} \right)^{-\varepsilon_w \sigma} \left(\frac{W_t}{W_{t+s}} \right)^{-\varepsilon_w(1+\sigma)} H_{t+s}^{1+\sigma} \right\}.$$

Then,

$$\frac{U_{i,t}}{P_t} = \frac{\varepsilon_w}{\varepsilon_w - 1} \psi_L \left(\frac{U_{i,t}}{W_t} \right)^{-\varepsilon_w \sigma} \frac{\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left\{ \left(\frac{W_t}{W_{t+s}} \right)^{-\varepsilon_w(1+\sigma)} H_{t+s}^{1+\sigma} \right\}}{\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left\{ \lambda_{t+s} \left(\frac{P_t}{P_{t+s}} \right) \left(\frac{W_t}{W_{t+s}} \right)^{-\varepsilon_w} H_{t+s} \right\}}.$$

Note that all unions resetting wages in period t face an identical problem and therefore choose the same reset wage, U_t. Therefore, we can write the optimal real reset wage as:

$$\left(\frac{U_t}{P_t} \right)^{1+\varepsilon_w \sigma} = \frac{\varepsilon_w}{\varepsilon_w - 1} \psi_L \left(\frac{W_t}{P_t} \right)^{\varepsilon_w \sigma} \frac{F_{w,t}}{K_{w,t}}, \tag{B.11}$$

where

$$\begin{aligned}
F_{w,t} &= \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left[\left(\frac{W_t}{W_{t+s}} \right)^{-\varepsilon_w(1+\sigma)} H_{t+s}^{1+\sigma} \right] \\
&= H_t^{1+\sigma} + \mathbb{E}_t \sum_{s=1}^{\infty} (\beta\theta_w)^s \left[\left(\frac{W_t}{W_{t+s}} \right)^{-\varepsilon_w(1+\sigma)} H_{t+s}^{1+\sigma} \right] \\
&= H_t^{1+\sigma} + \beta\theta_w \, \mathbb{E}_t \left(\frac{W_t}{W_{t+1}} \right)^{-\varepsilon_w(1+\sigma)} \sum_{s=0}^{\infty} (\beta\theta)^s \left[\left(\frac{W_{t+1}}{W_{t+1+s}} \right)^{-\varepsilon_w(1+\sigma)} H_{t+1+s}^{1+\sigma} \right] \\
&= H_t^{1+\sigma} + \beta\theta_w \, \mathbb{E}_t \left(\frac{W_t}{W_{t+1}} \right)^{-\varepsilon_w(1+\sigma)} F_{w,t+1} \\
&= H_t^{1+\sigma} + \beta\theta_w \, \mathbb{E}_t \, \pi_{w,t+1}^{\varepsilon_w(1+\sigma)} F_{w,t+1}
\end{aligned}$$

and

$$\begin{aligned}
K_{w,t} &= \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left[\lambda_{t+s} \left(\frac{P_t}{P_{t+s}} \right) \left(\frac{W_t}{W_{t+s}} \right)^{-\varepsilon_w} H_{t+s} \right] \\
&= \lambda_t H_t + \mathbb{E}_t \sum_{s=1}^{\infty} (\beta\theta_w)^s \left[\lambda_{t+s} \left(\frac{P_t}{P_{t+s}} \right) \left(\frac{W_t}{W_{t+s}} \right)^{-\varepsilon_w} H_{t+s} \right] \\
&= \lambda_t H_t \\
&+ \beta\theta_w \, \mathbb{E}_t \left(\frac{P_t}{P_{t+1}} \right) \left(\frac{W_t}{W_{t+1}} \right)^{-\varepsilon_w} \sum_{s=0}^{\infty} (\beta\theta_w)^s \left[\lambda_{t+1+s} \left(\frac{P_{t+1}}{P_{t+1+s}} \right) \left(\frac{W_{t+1}}{W_{t+1+s}} \right)^{-\varepsilon_w} H_{t+1+s} \right] \\
&= \lambda_t H_t + \beta\theta_w \, \mathbb{E}_t \left(\frac{P_t}{P_{t+1}} \right) \left(\frac{W_t}{W_{t+1}} \right)^{-\varepsilon_w} \sum_{s=0}^{\infty} (\beta\theta_w)^s K_{w,t+1} \\
&= \lambda_t H_t + \beta\theta_w \, \mathbb{E}_t \, \frac{\pi_{w,t+1}^{\varepsilon_w}}{\pi_{t+1}} K_{w,t+1}.
\end{aligned}$$

In case of frictionless labor markets, equation (B.11) simplifies to:

$$\begin{aligned}
\left(\frac{U_t}{P_t} \right) &= \frac{\varepsilon_w}{\varepsilon_w - 1} \psi_L \left(\frac{U_t}{W_t} \right)^{-\varepsilon_w \sigma} \frac{H_t^{1+\sigma}}{\lambda_t H_t} \\
&= \frac{\varepsilon_w}{\varepsilon_w - 1} \psi_L \left(\frac{U_t}{W_t} \right)^{-\varepsilon_w \sigma} \frac{h_{i,t}^{\sigma}}{\lambda_t} \left(\frac{U_t}{W_t} \right)^{-\varepsilon_w \sigma} \\
&= \frac{\varepsilon_w}{\varepsilon_w - 1} \frac{\psi_L h_{i,t}^{\sigma}}{\lambda_t},
\end{aligned}$$

where the second equality exploited the demand curve for labor type i, equation (2.10).

Exploiting the fact that all unions resetting wages in period t set the same wage and the Calvo (1983) assumption that the probability of being able to reset the wage rate is independent of time and across labor types, we can write the aggregate wage as a weighted average of the reset wage and last periods aggregate wage where the weights are given by the fraction (which equals the overall probability that a given union is able to reset the wage rate) of unions which adjust their wage in period t:

$$W_t^{1-\varepsilon_w} = (1-\theta_w)U_t^{1-\varepsilon_w} + \theta_w W_{t-1}^{1-\varepsilon_w}$$

and

$$\left(\frac{W_t}{P_t}\right)^{1-\varepsilon_w} := w_t^{1-\varepsilon_w} = (1-\theta_w)\left(\frac{U_t}{P_t}\right)^{1-\varepsilon_w} + \theta_w \left(\frac{W_{t-1}}{P_{t-1}}\right)^{1-\varepsilon_w}\left(\frac{P_t}{P_{t-1}}\right)^{\varepsilon_w - 1}$$

Wage inflation $\pi_{w,t+1}$ can be expressed as:

$$\frac{W_{t+1}}{W_t} := \pi_{w,t+1} = \frac{W_{t+1}/P_{t+1}}{W_t/P_t}\frac{P_{t+1}}{P_t} = \frac{w_{t+1}}{w_t}\pi_{t+1}$$

and

$$\pi_{t+1} := \frac{P_{t+1}}{P_t}$$

is price inflation.

Optimal Reset Price

Recall:

$$C_{kj,t} = f(k)^{-1}C_{k,t}\left(\frac{P_{kj,t}}{P_{k,t}}\right)^{-\varepsilon_{ck}},$$

$$C_{k,t} = f(k)C_t\left(\frac{P_{k,t}}{P_t}\right)^{-\varepsilon_c}.$$

Therefore, by imposing market clearing in the good markets, we can write:

$$Y_{kj,t} = \left(\frac{P_{kj,t}}{P_{k,t}}\right)^{-\varepsilon_{ck}}\left(\frac{P_{k,t}}{P_t}\right)^{-\varepsilon_c} Y_t.$$

The problem of a firm j in sector k which is able to reoptimize in period t is then to choose $X_{kj,t}$ to maximize:

$$\mathbb{E}_t \sum_{s=0}^{\infty}(\beta\theta_k)^s \frac{\Lambda_{t+s}}{\Lambda_t}\left(X_{kj,t}Y_{kj,t+s} - W_{t+s}H_{kj,t+s}\right)$$

$$\text{s.t.} \qquad Y_{kj,t+s} = \left(\frac{X_{kj,t}}{P_{k,t+s}}\right)^{-\varepsilon_{ck}}\left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} Y_{t+s}$$

$$Y_{kj,t+s} = A_{t+s}H_{kj,t+s},$$

where $Y_{kj,t}$ is the output of firm j in sector k, Λ is the Lagrange multiplier on the household budget constraint, θ_k the probability with which a firm in sector k is not able to reset its price, W is the aggregate wage rate of homogeneous labor H and ϵ_c and ϵ_{ck} are the elasticities of substitution in consumption between sectoral subcomposites and within sector varieties. Substituting the constraints into the objective function:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\Lambda_{t+s}}{\Lambda_t} \Bigg[X_{kj,t} \left(\frac{X_{kj,t}}{P_{k,t+s}}\right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} Y_{t+s} - W_{t+s}\left(\frac{1}{A_{t+s}}\right)\left(\frac{X_{kj,t}}{P_{k,t+s}}\right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} Y_{t+s}\Bigg] \iff$$

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} P_t \Bigg[\left(\frac{X_{kj,t}}{P_t}\right)^{1-\varepsilon_{ck}} \left(\frac{P_t}{P_{t+s}}\right)^{1-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} Y_{t+s} - \left(\frac{W_{t+s}}{P_{t+s}}\right)\left(\frac{1}{A_{t+s}}\right)\left(\frac{X_{kj,t}}{P_t}\right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} \left(\frac{P_t}{P_{t+s}}\right)^{-\varepsilon_{ck}} Y_{t+s}\Bigg].$$

The first order condition is given by:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} \Bigg[(1-\varepsilon_{ck}) \left(\frac{X_{kj,t}}{P_t}\right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} \left(\frac{P_t}{P_{t+s}}\right)^{1-\varepsilon_{ck}} Y_{t+s} + \varepsilon_{ck}\left(\frac{W_{t+s}}{P_{t+s}}\right)\left(\frac{1}{A_{t+s}}\right)\left(\frac{X_{kj,t}}{P_t}\right)^{-\varepsilon_{ck}-1} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} \left(\frac{P_t}{P_{t+s}}\right)^{-\varepsilon_{ck}} Y_{t+s}\Bigg] \iff$$

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} \left[\left(\frac{X_{kj,t}}{P_t}\right) \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} \left(\frac{P_t}{P_{t+s}}\right)^{1-\varepsilon_{ck}} Y_{t+s}\right]$$
$$= \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} \left[\frac{\varepsilon_{ck}}{1-\varepsilon_{ck}} \left(\frac{W_{t+s}}{P_{t+s}}\right)\left(\frac{1}{A_{t+s}}\right) \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} \left(\frac{P_t}{P_{t+s}}\right)^{-\varepsilon_{ck}} Y_{t+s}\right].$$

Rearranging, we get:

$$\frac{X_{kj,t}}{P_t} = \frac{\varepsilon_{ck}}{\varepsilon_{ck}-1} \times \frac{\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} \left[\left(\frac{W_{t+s}}{P_{t+s}}\right)\left(\frac{1}{A_{t+s}}\right) \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} \left(\frac{P_t}{P_{t+s}}\right)^{-\varepsilon_{ck}} Y_{t+s}\right]}{\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} \left[\left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} \left(\frac{P_t}{P_{t+s}}\right)^{1-\varepsilon_{ck}} Y_{t+s}\right]}.$$

As this expression is independent of firm specific variables all firms in sector k which are able to reset their prices in period t will choose the identical real price, $\frac{X_{k,t}}{P_t}$:

$$\frac{X_{k,t}}{P_t} := \frac{\varepsilon_{ck}}{1-\varepsilon_{ck}} \frac{F_{p,k,t}}{K_{p,k,t}},$$

where

$$F_{p,k,t} = \lambda_t \left(\frac{W_t}{P_t}\right)\left(\frac{1}{A_t}\right)\left(\frac{P_{k,t}}{P_t}\right)^{\varepsilon_{ck}}\left(\frac{P_{k,t}}{P_t}\right)^{-\varepsilon_c} Y_t + \beta\theta_k \, \mathbb{E}_t \left(\frac{P_{t+1}}{P_t}\right)^{\varepsilon_{ck}} F_{p,k,t+1},$$
$$K_{p,k,t} = \lambda_t \left(\frac{P_{k,t}}{P_t}\right)^{\varepsilon_{ck}}\left(\frac{P_{k,t}}{P_t}\right)^{-\varepsilon_c} Y_t + \beta\theta_k \, \mathbb{E}_t \left(\frac{P_{t+1}}{P_t}\right)^{\varepsilon_{ck}-1} K_{p,k,t+1}.$$

Aggregate Output

Technically, the model does not possess an aggregate production function in the sense that knowing the state of technology, A_t and the number of people working, L_t is not sufficient to determine aggregate output, Y_t. Frictions in the labor market and price frictions lead to distortions in the optimal allocation of resources implying that aggregate output will be generally lower than implied by a frictionless model, $Y_t \leq A_t L_t$. In the following, I derive the "aggregate production function" following the logic of Yun (1996).

Aggregate labor supply in period t is given by:

$$L_t = \int_0^1 h_{i,t} \mathrm{d}i = \int_0^1 \left(\frac{W_{i,t}}{W_t}\right)^{-\varepsilon_w} H_t \mathrm{d}i = H_t DS_{w,t},$$

where wage dispersion $DS_{w,t}$ is defined as:

$$\begin{aligned}
DS_{w,t} &= \int_0^1 \left(\frac{W_{i,t}}{W_t}\right)^{-\varepsilon_w} \mathrm{d}i \\
&= \int_{wage\ adjuster} \left(\frac{W_{i,t}}{W_t}\right)^{-\varepsilon_w} \mathrm{d}i + \int_{wage\ non-adjuster} \left(\frac{W_{i,t}}{W_t}\right)^{-\varepsilon_w} \mathrm{d}i \\
&= \left[(1-\theta_w)\left(\frac{U_t}{W_t}\right)^{-\varepsilon_w} + \int_{wage\ non-adjuster} \left(\frac{W_{i,t}}{W_t}\right)^{-\varepsilon_w} \mathrm{d}i\right] \\
&= \left[(1-\theta_w)\left(\frac{U_t}{W_t}\right)^{-\varepsilon_w} + \theta_w \left(\frac{W_{t-1}}{W_t}\right)^{-\epsilon_w} \int_0^1 \left(\frac{W_{i,t-1}}{W_{t-1}}\right)^{-\varepsilon_w} \mathrm{d}i\right] \\
&= \left[(1-\theta_w)\left(\frac{U_t}{W_t}\right)^{-\varepsilon_w} + \theta_w \left(\frac{W_{t-1}}{W_t}\right)^{-\varepsilon_w} DS_{w,t-1}\right] \\
&= \left[(1-\theta_w)\left(\frac{U_t}{P_t}\right)^{-\varepsilon_w}\left(\frac{W_t}{P_t}\right)^{\varepsilon_w} + \theta_w \pi_w^{\varepsilon_w} DS_{w,t-1}\right].
\end{aligned}$$

Aggregate labor demand in period t is given by:

$$\begin{aligned} H_t &= \int_0^1 \int_0^1 H_{kj,t} \mathrm{d}j \mathrm{d}k \\ &= \int_0^1 \int_0^1 \frac{Y_{kj,t}}{A_t} \mathrm{d}j \mathrm{d}k \\ &= \frac{1}{A_t} Y_t \int_0^1 \int_0^1 \left(\frac{P_{kj,t}}{P_{k,t}} \right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t}}{P_t} \right)^{-\varepsilon_c} \mathrm{d}j \mathrm{d}k \\ &= \frac{1}{A_t} Y_t \int_0^1 f(k) DS_{p,k,t} \left(\frac{P_{k,t}}{P_t} \right)^{-\varepsilon_c} \mathrm{d}k \\ &= \frac{1}{A_t} Y_t DS_{p,t}, \end{aligned}$$

where price dispersion in sector k $DS_{p,k,t}$ is given by:

$$\begin{aligned} DS_{p,k,t} &= \int_0^1 \left(\frac{P_{kj,t}}{P_{k,t}} \right)^{-\epsilon_{ck}} \mathrm{d}j \qquad \text{(B.12)} \\ &= \int_{price\ adjuster} \left(\frac{P_{kj,t}}{P_{k,t}} \right)^{-\epsilon_{ck}} \mathrm{d}j + \int_{price\ non-adjuster} \left(\frac{P_{kj,t}}{P_{k,t}} \right)^{-\epsilon_{ck}} \mathrm{d}j \\ &= \left[(1-\theta_k) \left(\frac{X_{k,t}}{P_{k,t}} \right)^{-\varepsilon_{ck}} + \theta_k \left(\frac{P_{k,t-1}}{P_{k,t}} \right)^{-\varepsilon_{ck}} DS_{p,k,t-1} \right] \\ &= \left[(1-\theta_k) \left(\frac{X_{k,t}}{P_t} \right)^{-\varepsilon_{ck}} \left(\frac{P_t}{P_{k,t}} \right)^{-\varepsilon_{ck}} + \theta_k \left(\frac{P_{k,t-1}}{P_{t-1}} \right)^{-\varepsilon_{ck}} \left(\frac{P_{t-1}}{P_t} \right)^{-\varepsilon_{ck}} \left(\frac{P_t}{P_{k,t}} \right)^{-\varepsilon_{ck}} DS_{p,k,t-1} \right] \end{aligned}$$

and aggregate price dispersion $DS_{p,t}$ by:

$$DS_{p,t} = \int_0^1 f(k) \left(\frac{P_{k,t}}{P_t} \right)^{-\varepsilon_c} DS_{p,k,t} \mathrm{d}k. \qquad \text{(B.13)}$$

Hence, aggregate output in period t is given by:

$$Y_t = \frac{A_t L_t}{DS_{p,t} DS_{w,t}}.$$

Price and wage dispersion, $DS_{p,t}$ and $DS_{w,t}$ will be larger than one away from the zero inflation steady state. For instance for wage dispersion:

$$
\begin{aligned}
DS_{w,t} &= \int_0^1 \left(\frac{W_{i,t}}{W_t}\right)^{-\varepsilon_w} \mathrm{d}i \\
&= \int_0^1 \left[\left(\frac{W_{i,t}}{W_t}\right)^{1-\varepsilon_w}\right]^{\frac{-\varepsilon_w}{1-\varepsilon_w}} \mathrm{d}i \\
&\geq \int_0^1 \left[\left(\frac{W_{i,t}}{W_t}\right)^{1-\varepsilon_w} \mathrm{d}i\right]^{\frac{-\varepsilon_w}{1-\varepsilon_w}} \\
&= 1^{\frac{-\varepsilon_w}{1-\varepsilon_w}} \\
&= 1,
\end{aligned}
$$

where the inequality follows from Jensen's inequality and the penultimate equality is due to the definition of the aggregate wage rate:

$$
W_t^{1-\varepsilon_w} = \left[\int_0^1 W_{i,t}^{1-\varepsilon_w} di\right].
$$

Hence, as stated at the beginning of this section, output will be generally inefficiently low due to distortions in the labor and product markets.

Price of Claim on Sector Dividends

Real dividends of sector k are given by:

$$
D_{k,t} = \frac{1}{P_t} \int_0^1 \left(P_{kj,t} Y_{kj,t} - H_{kj,t} W_t\right) dj.
$$

Recall that demand of firm j in sector k and the production function are given by:

$$
\begin{aligned}
Y_{kj,t} &= \left(\frac{P_{kj,t}}{P_{k,t}}\right)^{-\epsilon_{ck}} \left(\frac{P_{k,t}}{P_t}\right)^{-\epsilon_c} Y_t \\
H_{kj,t} &= \frac{Y_{kj,t}}{A_t}.
\end{aligned}
$$

Therefore,

$$\begin{aligned}
D_{k,t} &= \int_0^1 \left[\left(\frac{P_{kj,t}}{P_{k,t}}\right)^{1-\epsilon_{ck}} \left(\frac{P_{k,t}}{P_t}\right)^{1-\epsilon_c} Y_t - \left(\frac{W_t}{P_t}\right)\left(\frac{1}{A_t}\right)\left(\frac{P_{kj,t}}{P_{k,t}}\right)^{-\epsilon_{ck}} \left(\frac{P_{k,t}}{P_t}\right)^{-\epsilon_k} Y_t \right] dj \\
&= \left(\frac{P_{k,t}}{P_t}\right)^{1-\epsilon_c} Y_t \left[\int_0^1 \left(\frac{P_{kj,t}}{P_{k,t}}\right)^{1-\epsilon_{ck}} dj - \left(\frac{W_t}{P_t}\right)\left(\frac{1}{A_t}\right)\left(\frac{P_{k,t}}{P_t}\right)^{-1} \int_0^1 \left(\frac{P_{kj,t}}{P_{k,t}}\right)^{-\epsilon_{ck}} dj \right] \\
&= \left(\frac{P_{k,t}}{P_t}\right)^{1-\epsilon_c} Y_t \left[1 - \left(\frac{W_t}{P_t}\right)\left(\frac{1}{A_t}\right)\left(\frac{P_{k,t}}{P_t}\right)^{-1} DS_{p,k,t} \right] && \text{(B.14)} \\
&= \left(\frac{P_{k,t}}{P_t}\right)^{1-\epsilon_c} Y_t \left[1 - \frac{1}{\mu_{k,t}} \right], && \text{(B.15)}
\end{aligned}$$

where I made use of the definition of the sectoral price index, equation (B.4), the sectoral price dispersion, equation (B.12) and $\mu_{k,t}$ is the markup in sector k. Note that the terms in brackets can be interpreted as sector k profit margin.
Hence, we can write the price of a claim to sector k dividends as follows:

$$\begin{aligned}
P_{k,t} &= \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \frac{\lambda_{t+s}}{\lambda_t} D_{k,t+s} \\
&= D_{k,t} + \mathbb{E}_t \sum_{s=1}^{\infty} \beta^s \frac{\lambda_{t+s}}{\lambda_t} D_{k,t+s} \\
&= D_{k,t} + \mathbb{E}_t\, \beta \frac{\lambda_{t+1}}{\lambda_t} \sum_{s=0}^{\infty} \beta^s \frac{\lambda_{t+1+s}}{\lambda_{t+1}} D_{k,t+1+s} \\
&= D_{k,t} + \mathbb{E}_t\, \beta \frac{\lambda_{t+1}}{\lambda_t} P_{k,t+1}.
\end{aligned}$$

Cross Sectional Stock Returns at the Sector Level

Starting from the Euler equation or the "central asset pricing formula" (see Cochrane (2005), chapter 1) and assuming joint log-normality, I first derive the expected excess return of a generic asset and then the expected return and return difference across sectors of a claim to sector dividends which pays off only one period in the future to develop intuition for the key driving forces of the observed cross sectional return premium for sticky price firms.

$$1 = \mathbb{E}_t[M_{t,t+1} R_{t+1}],$$

where $M_{t,t+1}$ is the stochastic discount factor to price asset between periods t and $t+1$ and R_{t+1} is the gross return of any generic asset.
Exploiting the assumption of joint log-normality, I get

$$1 = \exp\left[\mathbb{E}_t\, m_{t,t+1} + \mathbb{E}_t\, r_{t+1} + \frac{1}{2} \operatorname{var}_t m_{t,t+1} + \frac{1}{2} \operatorname{var}_t r_{t+1} + \operatorname{cov}_t(m_{t,t+1}, r_{t+1}) \right],$$

where lower case variable correspond to the natural logarithm of upper case variables. Taking logs and subtracting the expression for the risk-free rate, r^f_{t+1}, I can write log expected excess returns as

$$\mathbb{E}_t\, r_{t+1} - r^f_{t+1} + \frac{1}{2}\operatorname{var} r_{t+1} = -\operatorname{cov}_t(m_{t+1}, r_{t+1}).$$

Consider the return to a claim to sector k dividends in period $t+1$ with current price $P_{k,t}$, $R_{k,t+1} = D_{k,t+1}/P_{k,t}$.
I can write the expected excess return of a claim to sector one dividends over the return of a claim to sector two dividends (plus Jensen's inequality terms) as

$$\begin{aligned}\mathbb{E}_t\, r_{1,t+1} - \mathbb{E}_t\, r_{2,t+1} + \left[\frac{1}{2}\operatorname{var} r_{1,t+1} - \frac{1}{2}\operatorname{var} r_{2,t+1}\right] &= -\operatorname{cov}_t(m_{t+1}, r_{1,t+1} - r_{2,t+1})\\ &= -\operatorname{cov}_t(m_{t+1}, d_{1,t+1} - d_{2,t+1}).\end{aligned}$$

Using equation (B.15), I can write the log difference in dividends as

$$d_{1,t+1} - d_{2,t+1} = (1-\varepsilon_c)(p_{1,t+1} - p_{2,t+1}) + \left[\log\left(1 - \frac{1}{\mu_{1,t+1}}\right) - \log\left(1 - \frac{1}{\mu_{2,t+1}}\right)\right].$$

Taking a first-order Taylor series approximation around the steady state markup, $\mu_1 = \mu_2 = \varepsilon_{ck}/(\varepsilon_{ck} - 1)$

$$\log\left(1 - \frac{1}{\mu_{k,t+1}}\right) \approx \log\left(1 - \frac{1}{\mu_k}\right) + \frac{1}{\mu_k - 1}\left(\log \mu_{k,t+1} - \mu_k\right).$$

Hence, I can write differences in log dividends as

$$d_{1,t+1} - d_{2,t+1} = (1-\varepsilon_c)(p_{1,t+1} - p_{2,t+1}) + (\varepsilon_{ck} - 1)(\log \mu_{1,t+1} - \log \mu_{2,t+1}).$$

Making use of equation (B.14), I can express this relation as

$$d_{1,t+1} - d_{2,t+1} = (1-\varepsilon_c)(p_{1,t+1} - p_{2,t+1}) + (\varepsilon_{ck} - 1)[(p_{1,t+1} - p_{2,t+1}) - (ds_{p,1,t+1} - ds_{p,2,t+1})].$$

Thus, expected excess returns are given by

$$\begin{aligned}\mathbb{E}_t\, r_{1,t+1} - \mathbb{E}_t\, r_{2,t+1} + \left[\frac{1}{2}\operatorname{var} r_{1,t+1} - \frac{1}{2}\operatorname{var} r_{2,t+1}\right] &= -(\varepsilon_{ck} - \varepsilon_c)\operatorname{cov}_t(m_{t,t+1}, (p_{1,t+1} - p_{2,t+1}))\\ &\quad - (1-\varepsilon_{ck})\operatorname{cov}_t(m_{t,t+1}, (ds_{p,1,t+1} - ds_{p,2,t+1})).\end{aligned}$$

Optimal Reset Price and Capital in a Model with Capital

This section briefly outlines a model with capital in the production function. Capital is typically introduced via economy wide rental markets for capital which makes the model highly

tractable and allows a solution similar to previous derivations in this appendix. Unfortunately, this assumption is not only empirically not justified but also has vastly counterfactual business cycle implications, a point forcefully made by Altig et al. (2011). Once one departs from this assumption and allows for firm specific capital, the solution becomes more involved, as the optimal reset price becomes history dependent, in particular, the optimal reset price will be a function of the firm specific capital stock and therefore firms resetting prices at time t will no longer face the same optimization problem and therefore will not choose identical reset prices which makes aggregation less straight forward.
In this sketch I follow Sveen and Weinke (2007) and introduce investment by revoking another time to the Calvo (1983) framework. In particular, each firm in the economy faces a constant probability, $1-\theta_I$, – independent of time and across firms – of being able to invest. The investment probability is equal across all firms in the economy. This setup captures the lumpiness of firm level investment observed in the data.
I assume that firms first set prices and then know whether they can reoptimize the capital stock. In addition, I assume that firms keep their capital constant in case they cannot invest, meaning a firm can always perform maintenance investments.

The problem of a firm is now to set the optimal price and capital stock to maximize:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \frac{\Lambda_{t+s}}{\Lambda_t} \left\{ P_{kj,t+s} Y_{kj,t+s} - W_{t+s} H_{kj,t+s} - P_{t+s} \left[K_{kj,t+s+1} - (1-\delta) K_{kj,t+s} \right] \right\}$$

$$\begin{aligned}
\text{s.t.} \qquad Y_{kj,t+s} &= \left(\frac{P_{kj,t+s}}{P_{k,t+s}} \right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}} \right)^{-\varepsilon_c} Y_{t+s} \\
Y_{kj,t+s} &= A_{t+s} H_{kj,t+s}^{1-\alpha} K_{kj,t+s}^{\alpha} \Longrightarrow H_{kj,t+s} = Y_{kj,t+s}^{\frac{1}{1-\alpha}} A_{t+s}^{-\frac{1}{1-\alpha}} K_{kj,t+s}^{-\frac{\alpha}{1-\alpha}} \\
P_{kj,t+s+1} &= \begin{cases} P^*_{kj,t+s+1} & \text{w/ prob.} \quad (1-\theta_k) \\ P_{kj,t+s} & \text{w/ prob.} \quad \theta_k \end{cases} \\
K_{kj,t+s+1} &= \begin{cases} K^*_{kj,t+s+1} & \text{w/ prob.} \quad (1-\theta_I) \\ K_{kj,t+s} & \text{w/ prob.} \quad \theta_I . \end{cases}
\end{aligned}$$

First, neglecting all terms independent of the reset price:

$$\begin{aligned}
&\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\Lambda_{t+s}}{\Lambda_t} \Bigg[X_{kj,t} \left(\frac{X_{kj,t}}{P_{k,t+s}} \right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}} \right)^{-\varepsilon_c} Y_{t+s} \\
&\quad - W_{t+s} A_{t+s}^{-\frac{1}{1-\alpha}} \left(\frac{X_{kj,t}}{P_{k,t+s}} \right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_{k,t+s}}{P_{t+s}} \right)^{-\frac{\varepsilon_c}{1-\alpha}} Y_{t+s}^{\frac{1}{1-\alpha}} K_{kj,t+s}^{-\frac{\alpha}{1-\alpha}} \Bigg]
\end{aligned}$$

$\Longleftrightarrow$

$$\begin{aligned}
&\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} P_t \Bigg[\left(\frac{X_{kj,t}}{P_t} \right)^{1-\varepsilon_{ck}} \left(\frac{P_t}{P_{t+s}} \right)^{1-\varepsilon_{ck}} \left(\frac{P_{t+s}}{P_{k,t+s}} \right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}} \right)^{-\varepsilon_c} Y_{t+s} \\
&\quad - W_{t+s} A_{t+s}^{-\frac{1}{1-\alpha}} \left(\frac{X_{kj,t}}{P_t} \right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_t}{P_{t+s}} \right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_{t+s}}{P_{k,t+s}} \right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_{k,t+s}}{P_{t+s}} \right)^{-\frac{\varepsilon_c}{1-\alpha}} Y_{t+s}^{\frac{1}{1-\alpha}} K_{kj,t+s}^{-\frac{\alpha}{1-\alpha}} \Bigg].
\end{aligned}$$

The first order condition with respect to $X_{kj,t}$ is then given by:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \frac{\lambda_{t+s}}{\lambda_t} \Bigg[(1-\varepsilon_{ck}) \left(\frac{X_{kj,t}}{P_t}\right)^{-\varepsilon_{ck}} \left(\frac{P_t}{P_{t+s}}\right)^{1-\varepsilon_{ck}} \left(\frac{P_{t+s}}{P_{k,t+s}}\right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} Y_{t+s}$$

$$+ \varepsilon_{ck} \frac{1}{1-\alpha} \frac{W_{t+s}}{P_{t+s}} A_{t+s}^{-\frac{1}{1-\alpha}} \left(\frac{X_{kj,t}}{P_t}\right)^{-\frac{\varepsilon_{ck}+1-\alpha}{1-\alpha}} \left(\frac{P_t}{P_{t+s}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_{t+s}}{P_{k,t+s}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\frac{\varepsilon_c}{1-\alpha}}$$

$$Y_{t+s}^{\frac{1}{1-\alpha}} K_{kj,t+s}^{-\frac{\alpha}{1-\alpha}} \Bigg] = 0$$

$$\Longleftrightarrow$$

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \lambda_{t+s} \Bigg[(\varepsilon_{ck}-1) \left(\frac{X_{kj,t}}{P_t}\right)^{1+\frac{\varepsilon_{ck}\alpha}{1-\alpha}} \left(\frac{P_t}{P_{t+s}}\right)^{1-\varepsilon_{ck}} \left(\frac{P_{t+s}}{P_{k,t+s}}\right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} Y_{t+s}$$

$$- \varepsilon_{ck} \frac{1}{1-\alpha} \frac{W_{t+s}}{P_{t+s}} A_{t+s}^{-\frac{1}{1-\alpha}} \left(\frac{P_t}{P_{t+s}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_{t+s}}{P_{k,t+s}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\frac{\varepsilon_c}{1-\alpha}} Y_{t+s}^{\frac{1}{1-\alpha}} K_{kj,t+s}^{-\frac{\alpha}{1-\alpha}} \Bigg] = 0$$

$$\Longleftrightarrow$$

$$\left(\frac{X_{kj,t}}{P_t}\right)^{1+\frac{\varepsilon_{ck}\alpha}{1-\alpha}} = \frac{\varepsilon_{ck}}{\varepsilon_{ck-1}} \frac{1}{1-\alpha} \times$$

$$\frac{\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \lambda_{t+s} \frac{W_{t+s}}{P_{t+s}} A_{t+s}^{-\frac{1}{1-\alpha}} \left(\frac{P_t}{P_{t+s}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_{t+s}}{P_{k,t+s}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\frac{\varepsilon_c}{1-\alpha}} Y_{t+s}^{\frac{1}{1-\alpha}} K_{kj,t+s}^{-\frac{\alpha}{1-\alpha}}}{\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_k)^s \lambda_{t+s} \left(\frac{P_t}{P_{t+s}}\right)^{1-\varepsilon_{ck}} \left(\frac{P_{t+s}}{P_{k,t+s}}\right)^{-\varepsilon_{ck}} \left(\frac{P_{k,t+s}}{P_{t+s}}\right)^{-\varepsilon_c} Y_{t+s}}.$$

Then, we can write the optimal reset price as:

$$\left(\frac{X_{kj,t}}{P_t}\right)^{1+\frac{\varepsilon_{ck}\alpha}{1-\alpha}} = \frac{\varepsilon_{ck}}{\varepsilon_{ck}-1} \frac{1}{1-\alpha} \frac{F_{P,kj,t}}{K_{P,k,t}},$$

where

$$K_{P,k,t} = \lambda_t p_{k,t}^{\varepsilon_{ck}} p_{k,t}^{-\varepsilon_c} Y_t + \beta\theta_k \, \mathbb{E}_t \, \pi_{t+1}^{\varepsilon_{ck}-1} K_{P,k,t+1}$$

$$F_{P,kj,t} = \theta_I K_{kj,t}^{-\frac{\alpha}{1-\alpha}} FS_{P,k,t} \, \mathbb{E}_t + \left[\frac{\alpha}{1-\alpha} \beta \frac{X_{kj,t}}{P_t}^{-\frac{\varepsilon_{ck}}{1-\alpha}} p_{k,t+1}^{\frac{\varepsilon_{ck}}{1-\alpha}} p_{k,t+1}^{\frac{-\varepsilon_c}{1-\alpha}} \pi_{t+1}^{\frac{\varepsilon_{ck}}{1-\alpha}} \right]^{-\alpha} \pi_{t+1}^{\frac{\varepsilon_{ck}}{1-\alpha}} \beta FF_{P,k,t}$$

$$FS_{P,k,t} = \lambda_t \frac{W_t}{P_t} A_t^{-\frac{1}{1-\alpha}} Y_t^{\frac{1}{1-\alpha}} p_{k,t}^{\frac{\varepsilon_{ck}}{1-\alpha}} p_{k,t}^{\frac{-\varepsilon_c}{1-\alpha}} + \beta\theta_k\theta_I \, \mathbb{E}_t \, \pi_{t+1}^{\frac{\varepsilon_{ck}}{1-\alpha}} FS_{P,k,t+1}$$

$$FF_{P,k,t} = (1-\theta_I) \left(\frac{FSS_{K,k,t}}{K_{K,k,t}}\right)^{-\alpha} \mathbb{E}_t \, FS_{P,k,t+1} + \beta\theta_k \, \mathbb{E}_t \, \pi_{t+2}^{\frac{\varepsilon_{ck}}{1-\alpha}} p_{k,t+2}^{\frac{-\varepsilon_{ck}\alpha}{1-\alpha}} p_{k,t+2}^{\frac{\varepsilon_c\alpha}{1-\alpha}} \pi_{t+2}^{\frac{-\varepsilon_{ck}\alpha}{1-\alpha}} FF_{P,k,t+1}.$$

The optimal reset price conditional on never adjusting the capital stock is given by:

$$\frac{\overline{X}_{kj,t}}{P_t}^{1+\frac{\varepsilon_{ck}\alpha}{1-\alpha}} = \frac{\varepsilon_{ck}}{\varepsilon_{ck}-1}\frac{1}{1-\alpha}K_{kj,t}^{-\frac{\alpha}{1-\alpha}}\frac{FSS_{P,k,t}}{K_{P,k,t}},$$

where

$$FSS_{P,k,t} = \lambda_t \frac{W_t}{P_t} A_t^{-\frac{1}{1-\alpha}} Y_t^{\frac{1}{1-\alpha}} p_{k,t}^{\frac{\varepsilon_{ck}}{1-\alpha}} p_{k,t}^{\frac{-\varepsilon_c}{1-\alpha}} + \beta\theta_k \, \mathbb{E}_t \, \pi_{t+1}^{\frac{\varepsilon_{ck}}{1-\alpha}} FSS_{P,k,t+1}.$$

The first order condition with respect to $K_{kj,t+1}$ is given by:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_I)^s \frac{\Lambda_{t+s}}{\Lambda_t}\left[P_{t+s} - \beta\frac{\Lambda_{t+s+1}}{\Lambda_{t+s}}P_{t+s+1}\left(\frac{\alpha}{1-\alpha}\frac{W_{t+s+1}}{P_{t+s+1}}\frac{H_{kj,t+s+1}}{K_{kj,t+1}} + (1-\delta)\right)\right] = 0$$

$$\iff$$

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_I)^s \frac{\Lambda_{t+s}}{\Lambda_t}\left[P_{t+s} - \beta\frac{\Lambda_{t+s+1}}{\Lambda_{t+s}}P_{t+s+1}\left(\frac{\alpha}{1-\alpha}\frac{W_{t+s+1}}{P_{t+s+1}}Y_{kj,t+s+1}^{\frac{1}{1-\alpha}}A_{t+s+1}^{-\frac{1}{1-\alpha}}K_{kj,t+1}^{-\frac{1}{1-\alpha}} + (1-\delta)\right)\right].$$

Hence,

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_I)^s \frac{\lambda_{t+s}}{\lambda_t}\frac{P_t}{P_{t+s}}\left[K_{kj,t+1}^{\frac{1}{1-\alpha}}\left(P_{t+s} - \beta\frac{\lambda_{t+s+1}}{\lambda_{t+s}}\frac{P_{t+s}}{P_{t+s+1}}P_{t+s+1}(1-\delta)\right)\right]$$
$$= \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_I)^s \frac{\lambda_{t+s}}{\lambda_t}\frac{P_t}{P_{t+s}}\left[\beta\frac{\alpha}{1-\alpha}\frac{\lambda_{t+s+1}}{\lambda_{t+s}}\frac{P_{t+s}}{P_{t+s+1}}P_{t+s+1}\left(\frac{W_{t+s+1}}{P_{t+s+1}}\right)\right.$$
$$\left.\left(\frac{P_{kj,t+s+1}}{P_{k,t+s+1}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}}\left(\frac{P_{k,t+s+1}}{P_{t+s+1}}\right)^{-\frac{\varepsilon_c}{1-\alpha}}Y_{t+s+1}^{\frac{1}{1-\alpha}}A_{t+s+1}^{-\frac{1}{1-\alpha}}\right]$$

$$\iff$$

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_I)^s \lambda_{t+s}\left[K_{kj,t+1}^{\frac{1}{1-\alpha}}\left(1 - \beta\frac{\lambda_{t+s+1}}{\lambda_{t+s}}(1-\delta)\right)\right]$$
$$= \mathbb{E}_t \sum_{s=0}^{\infty} \beta(\beta\theta_I)^s \lambda_{t+s+1}\frac{\alpha}{1-\alpha}\times$$
$$\left[\left(\frac{W_{t+s+1}}{P_{t+s+1}}\right)\left(\frac{P_{kj,t+s+1}}{P_{k,t+s+1}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}}\left(\frac{P_{k,t+s+1}}{P_{t+s+1}}\right)^{-\frac{\varepsilon_c}{1-\alpha}}Y_{t+s+1}^{\frac{1}{1-\alpha}}A_{t+s+1}^{-\frac{1}{1-\alpha}}\right].$$

Therefore,

$$K^{*\frac{1}{1-\alpha}}_{k,t+1} = \frac{\alpha}{1-\alpha}\times \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \beta(\beta\theta_I)^s \lambda_{t+s+1}\left[\frac{W_{t+s+1}}{P_{t+s+1}}\left(\frac{P_{kj,t+s+1}}{P_{k,t+s+1}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}}\left(\frac{P_{k,t+s+1}}{P_{t+s+1}}\right)^{-\frac{\varepsilon_c}{1-\alpha}} Y^{\frac{1}{1-\alpha}}_{t+s+1} A^{\frac{1}{1-\alpha}}_{t+s+1}\right]}{\mathbb{E}_t \sum_{s=0}^{\infty}\left[(\beta\theta_I)^s\lambda_{t+s} - \beta(\beta\theta_I)^s \lambda_{t+s+1}(1-\delta)\right]}$$

$$:= \frac{\alpha}{1-\alpha}\frac{F_{K,kj,t}}{K_{K,k,t}},$$

where

$$\begin{aligned}
K_{K,k,t} &= \lambda_t - \beta\lambda_{t+1}(1-\delta) + \beta\theta_I\,\mathbb{E}_t\, K_{K,k,t+1} \\
F_{K,kj,t} &= \beta\theta_k \left(\frac{P_{kj,t}}{P_t}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} \times \\
&\qquad \mathbb{E}_t\, p^{\frac{\varepsilon_{ck}}{1-\alpha}}_{k,t+1} p^{\frac{-\varepsilon_c}{1-\alpha}}_{k,t+1} \pi^{\frac{\varepsilon_{ck}}{1-\alpha}}_{t+1} FS_{K,k,t} + \beta\,\mathbb{E}_t \left(\frac{\varepsilon_{ck}}{\varepsilon_{ck}-1}\frac{1}{1-\alpha} K^{*-\frac{\alpha}{1-\alpha}}_{kj,t+1}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha+\varepsilon_{ck}\alpha}} FF_{K,k,t} \\
FS_{K,k,t} &= \mathbb{E}_t\,\lambda_{t+1}\frac{W_{t+1}}{P_{t+1}} Y^{\frac{1}{1-\alpha}}_{t+1} A^{-\frac{1}{1-\alpha}}_{t+1} + \beta\theta_k\theta_I\,\mathbb{E}_t\, p^{\frac{\varepsilon_{ck}}{1-\alpha}}_{k,t+2} p^{\frac{-\varepsilon_c}{1-\alpha}}_{k,t+2} \pi^{\frac{\varepsilon_{ck}}{1-\alpha}}_{t+2} FS_{K,k,t+1} \\
FF_{K,k,t} &= (1-\theta_k)\,\mathbb{E}_t\left(\frac{FSS_{P,k,t+1}}{K_{P,k,t+1}}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha+\varepsilon_{ck}\alpha}} p^{\frac{\varepsilon_{ck}}{1-\alpha}}_{k,t+1} p^{\frac{-\varepsilon_c}{1-\alpha}}_{k,t+1} FS_{K,k,t} + \beta\theta_I\,\mathbb{E}_t\, FF_{K,k,t+1}.
\end{aligned}$$

The optimal capital stock conditional on never adjusting the reset price is given by:

$$\overline{K}^{*\frac{1}{1-\alpha}}_{kj,t+1} = \frac{\alpha}{1-\alpha}\frac{\beta\left(\frac{P_{kj,t}}{P_t}\right)^{-\frac{\varepsilon_{ck}}{1-\alpha}} p^{\frac{\varepsilon_{ck}}{1-\alpha}}_{k,t+1} p^{\frac{-\varepsilon_c}{1-\alpha}}_{k,t+1} \pi^{\frac{\varepsilon_{ck}}{1-\alpha}}_{t+1} FSS_{K,k,t}}{K_{K,k,t}},$$

where

$$FSS_{K,k,t} = \mathbb{E}_t\,\lambda_{t+1}\frac{W_{t+1}}{P_{t+1}} Y^{\frac{1}{1-\alpha}}_{t+1} A^{-\frac{1}{1-\alpha}}_{t+1} + \beta\theta_I\,\mathbb{E}_t\, p^{\frac{\varepsilon_{ck}}{1-\alpha}}_{k,t+2} p^{\frac{-\varepsilon_c}{1-\alpha}}_{k,t+2} \pi^{\frac{\varepsilon_{ck}}{1-\alpha}}_{t+2} FSS_{K,k,t+1}.$$

B.2 Summary of Equilibrium Conditions

Sector Specific Conditions

Reset Price

$$\frac{X_{k,t}}{P_t} = \frac{\varepsilon_{ck}}{\varepsilon_{ck}-1}\frac{F_{p,k,t}}{K_{p,k,t}}$$

$$F_{p,k,t} = \lambda_t\left(\frac{W_t}{P_t}\right)\left(\frac{1}{A_t}\right)\left(\frac{P_{k,t}}{P_t}\right)^{\varepsilon_{ck}}\left(\frac{P_{k,t}}{P_t}\right)^{-\varepsilon_c} Y_t + \beta\theta_k\left(\frac{P_{t+1}}{P_t}\right)^{\varepsilon_{ck}} F_{p,k,t+1}$$

$$K_{p,k,t} = \lambda_t\left(\frac{P_{k,t}}{P_t}\right)^{\varepsilon_{ck}}\left(\frac{P_{k,t}}{P_t}\right)^{-\varepsilon_c} Y_t + \beta\theta_k\left(\frac{P_{t+1}}{P_t}\right)^{\varepsilon_{ck}-1} K_{p,k,t+1}$$

Relative Price

$$P_{k,t} = \left[(1-\theta_k)X_{k,t}^{1-\varepsilon_{ck}} + \theta_k P_{k,t-1}^{1-\varepsilon_{ck}}\right]^{\frac{1}{1-\varepsilon_{ck}}}$$

Price Dispersion

$$DS_{p,k,t} = \left[(1-\theta_k)\left(\frac{X_{k,t}}{P_t}\right)^{-\varepsilon_{ck}}\left(\frac{P_t}{P_{k,t}}\right)^{-\varepsilon_{ck}} + \theta_k\left(\frac{P_{k,t-1}}{P_{t-1}}\right)^{-\varepsilon_{ck}}\left(\frac{P_{t-1}}{P_t}\right)^{-\varepsilon_{ck}}\left(\frac{P_t}{P_{k,t}}\right)^{-\varepsilon_{ck}} DS_{p,k,t-1}\right]$$

Aggregate Conditions

Law of Motion for Price Level

$$1 = \int_0^1 f(k)\left[(1-\theta_k)\left(\frac{X_{k,t}}{P_t}\right)^{(1-\varepsilon_c)} + \theta_k\left(\frac{P_{k,t-1}}{P_{t-1}}\right)^{(1-\varepsilon_c)}\left(\frac{P_{t-1}}{P_t}\right)^{(1-\varepsilon_c)}\right]\mathrm{d}k$$

Aggregate Price dispersion

$$DS_{p,t} = \int_0^1 f(k)\left(\frac{P_{k,t}}{P_t}\right)^{-\varepsilon_c} DS_{p,k,t}\mathrm{d}k.$$

Reset Wage

$$\left(\frac{U_t}{P_t}\right)^{1+\varepsilon_w\sigma} = \frac{\varepsilon_w}{\varepsilon_w-1}\psi_L\left(\frac{W_t}{P_t}\right)^{\varepsilon_w\sigma}\frac{F_{w,t}}{K_{w,t}}$$

$$F_{w,t} = H_t^{1+\sigma} + \beta\theta_w\,\mathbb{E}_t\,\pi_{w,t+1}^{\varepsilon_w(1+\sigma)}F_{w,t+1}$$

$$K_{w,t} = \lambda_t H_t + \beta\theta_w\,\mathbb{E}_t\,\frac{\pi_{w,t+1}^{\varepsilon_w}}{\pi_{t+1}}K_{w,t+1}.$$

Wage Dispersion

$$DS_{w,t} = \left[(1-\theta_w)\left(\frac{U_t}{P_t}\right)^{-\varepsilon_w}\left(\frac{W_t}{P_t}\right)^{\varepsilon_w} + \theta_w \pi_w^{\varepsilon_w} DS_{w,t-1}\right]$$

Aggregate Real Wage

$$\frac{W_t}{P_t} = \left[(1-\theta_w)\left(\frac{U_t}{P_t}\right)^{1-\varepsilon_w} + \theta_w\left(\frac{W_{t-1}}{P_{t-1}}\right)^{1-\varepsilon_w}\left(\frac{P_{t-1}}{P_t}\right)^{1-\varepsilon_w}\right]^{\frac{1}{1-\varepsilon_w}}$$

Wage Inflation

$$\frac{W_{t+1}}{W_t} = \pi_{w,t+1} = \frac{W_{t+1}/P_{t+1}}{W_t/P_t}\frac{P_{t+1}}{P_t} = \frac{w_{t+1}}{w_t}\pi_{t+1}$$

Consumption Euler Equation

$$1 = \beta R_t \, \mathbb{E}_t\left[\frac{1}{\pi_{t+1}}\left(\frac{C_{t+1}-bC_t}{C_t-bC_{t-1}}\right)^{-\gamma}\right]$$

Aggregate Output

$$Y_t = \frac{A_t L_t}{DS_{p,t}DS_{w,t}}$$

Monetary Policy

$$i_t = \phi_\pi \pi_t + \phi_x x_t + \log\left(\frac{1}{\beta}\right) + u_{m,t}$$
$$u_{m,t} = \rho_m u_{m,t-1} + \sigma_{mp}\varepsilon_{mp,t+1}$$

Technology

$$a_{t+1} = \rho_a a_t + \sigma_a \varepsilon_{a,t+1},$$

B.3 Aggregation of good-based Frequencies of Price Adjustment

In this section I discuss in more detail how I aggregate good-based frequencies of price adjustment to the firm level in a two stage procedure.

I first aggregate good based frequencies to the establishment level via internal identifiers of the BLS. To perform the firm level aggregation, I check whether establishments with the same or similar names are part of the same company. In addition, I use publicly available data to search for names of subsidiaries and name changes e.g. due to mergers, acquisitions or restructuring occurring during the sample period for all firms in the dataset.

I discuss the fictitious case of the company Milkwell Inc, to illustrate aggregation to the firm level. Assume I observe product prices of items for the establishments Milkwell Advanced Circuit, Milkwell Aerospace, Milkwell Automation and Control, Milkwell Mint and Bier Good. In the first step, I calculate the frequency of product price adjustment at the item level and aggregate this measure at the establishment level for all of the above mentioned establishments. I calculate both equally weighted frequencies, U and frequencies weighted by values of shipments associated with items/establishments, W, say for establishment Milkwell Aerospace. I then use publicly available information to check whether the individual establishments are part of the same company. Let's assume that I find that all of the above mentioned establishments with Milkwell in the establishment name but Milkwell Mint are part of Milkwell Inc. Looking at the company structure, I also find that Milkwell has several subsidiaries, Honeymoon, Pears and Bier Good. Using this information, I then aggregate the establishment level frequencies of Milkwell Advanced Circuit, Milkwell Aerospace, Milkwell Automation and Control and Bier Good to the company level, again calculating equally weighted and value of shipments weighted frequencies.

B.4 Cash Flow and Discount Rate Betas

In this section I derive the key equations of the Campbell and Vuolteenaho (2004) decomposition of CAPM β into cash flow and discount rate β.

Following Campbell and Shiller (1988a) and Campbell (1991), I use a loglinear approximation for the one period log return and iterate the resulting relationship forward to obtain an accounting identity expressing unexpected returns, $r_{t+1} - \mathbb{E}_t\, r_{t+1}$, as a function of revisions in future dividend growth, Δd_{t+1+s}, and returns

$$\begin{aligned} r_{t+1} - \mathbb{E}_t\, r_{t+1} &= (\mathbb{E}_{t+1} - \mathbb{E}_t) \sum_{s=0}^{\infty} \rho^s \Delta d_{t+1+s} - (\mathbb{E}_{t+1} - \mathbb{E}_t) \sum_{s=1}^{\infty} \rho^s r_{t+1+s} \\ &= N_{CF,t+1} - N_{DR,t+1}, \end{aligned}$$

where ρ is a discount coefficient slightly below one, $N_{CF,t+1}$ denotes news about future dividends and $N_{DR,t+1}$ news about future expected returns.[1]

To obtain the news terms, I estimate a first-order VAR

$$z_{t+1} = a + \Gamma z_t + u_{t+1}$$

[1]See Campbell and Vuolteenaho (2004) for an interpretation of ρ. I follow them and set ρ to a value of 0.95 at an annual frequency.

where z_{t+1} is a $m \times 1$ state vector with r_{t+1} as its first element, a and Γ are a $m \times 1$ vector and a $m \times m$ matrix of coefficients and u_{t+1} is a $m \times 1$ vector of one-step ahead forecast errors.[2]

Cash flow and discount rate news are then functions of $t+1$ shocks

$$N_{CF,t+1} = (e1' + e1'\lambda)u_{t+1} \tag{B.16}$$

$$N_{DR,t+1} = e1'\lambda u_{t+1}, \tag{B.17}$$

where $e1$ is a $m \times 1$ selection vector whose first element is one and whose other elements are zero, λ is defined as $\lambda \equiv \rho\Gamma(I - \rho\Gamma)^{-1}$ and I is a $m \times m$ identity matrix.

I follow Campbell and Vuolteenaho (2004) and estimate a VAR(1) over the full sample period at a monthly frequency using four state variables: the log excess return on the CRSP value weighted index, the yield spread between the 10-year constant maturity bonds (Global Financial Data (GFD) symbol IGUSA10D) and the 1-year constant maturity notes (GFD symbol IGUSA1D), the 10-year smoothed price-earnings ratio of Shiller (2000) as well as the small stock value spread calculated as in Campbell and Vuolteenaho (2004).[3]

I define cash flow and discount rate betas as

$$\beta_{p,CF} \equiv \frac{Cov(r^e_{p,t}, N_{CF,t})}{Var(r^e_{m,t} - \mathbb{E}_{t-1}\, r^e_{m,t})}$$

$$\beta_{p,DR} \equiv \frac{Cov(r^e_{p,t}, -N_{DR,t})}{Var(r^e_{m,t} - \mathbb{E}_{t-1}\, r^e_{m,t})},$$

where $r^e_{p,t}$ is the log excess return of portfolio p and $r^e_{m,t}$ is the log excess return of the market. $\beta_{p,CF}$ and $\beta_{p,DR}$ add up to the CAPM beta, β_p. I estimate these betas using the VAR-fitted news series to construct sample variances and covariances allowing for one additional lag of the news terms. I calculate GMM standard errors conditional on the realized news series from the VAR.[4]

B.5 Additional Results

This section contains several robustness checks and results for alternative measures of the frequency of price adjustment.

Table B.1 runs panel regressions with my measure of price stickiness as left hand side variable. Individually, we see that book to market, beta, leverage and the price to cost

[2]This formulation is not restrictive as any higher-order VAR can be written in its companion form as a VAR(1) by suitably augmenting the state vector.

[3]This is the VAR specification as in the original contribution of Campbell and Vuolteenaho (2004). Other reasonable specifications of the state vector might potentially lead to different results, see Chen and Zhao (2009).

[4]Specifically, I write the covariances and variances as functions of sample means and apply the Delta method as advocated in chapter 11 of Cochrane (2005).

margin are most strongly related with price stickiness. Firms with more flexible prices have lower CAPM beta and price to cost margins but higher book to market ratios and leverage. Jointly, these firm characteristics can explain up to 13% of the variation in SAU across firms.

As discussed in the main body of the paper, I calculate the frequency of price adjustment as the mean fraction of months with price changes during the sample period of an item. Because the collected data may have missing values, I construct different measures of the frequency of price adjustment, S. In the first approach, labeled A, I treat missing values as interrupting price spells. For example, if a price was \$4 for two months, then misses for a month, and is again observed at \$5 for another three months, I treat the data as reporting two price spells with durations of two and three months where none of the spells has a price change and hence the frequency is zero. In the second approach, labeled B, missing values do not interrupt price histories. In the previous example, approach B concatenates spells of \$4 and \$5 prices and yields one price change in five months so that the frequency is 1/5. Approach C takes the union of A and B, that is, there is a price change if either A or B identify a price change. I employ approach SA in the main paper weighting item based frequencies equally. Results are very similar if I make use of these alternative measures.

Table B.2 reports mean frequencies, standard deviations and the number of firm-months observations for these different measures of the frequency of price adjustment, both for the total sample and for different industries separately.

Table B.3 contains times series means of portfolio average firm characteristics. Column 1 shows that the frequency of price adjustment is by construction monotonically increasing from as low as 0.01 per month for portfolio 1 to 0.35 for the flexible price portfolio. The following columns document similar facts as the correlations in Table 2.2: firms with flexible prices are on average larger and have a slightly higher book to market ratio but lower systematic risk as measured by beta and leverage. There is no difference in cash flows, turnover or bid-ask spreads. The last two columns document that part of the difference in the frequency of price adjustment could reflect market power as the portfolio with flexible price firms has a lower price to cost margin and Herfindahl - Hirschman index than the portfolio containing sticky price firms.

Table B.4 and Table B.5 repeat the baseline regression of annual stock returns on firm characteristics, return predictors and year fixed effects only. The individual coefficients generally have the expected signs and most of them are individually statistically significant. Adding year fixed effects in Table B.5 effects reduces the explanatory power of some characteristics.

Table B.6 to Table B.8 repeat the baseline exercise for the benchmark period for overlapping annual returns at the monthly frequency, annualized monthly returns and the latter specification with month fixed effects. Results are quantitatively as well as statistically very similar to my benchmark analysis. None of these variations has a material impact on the coefficient on the frequency of price adjustment; the return premium for sticky price firms varies between 2.2% per annum when looking at monthly returns, the full set of controls and month fixed effects in column (12) of Table B.8 and 7.5% in the specification with monthly overlapping annual returns and only controlling for book to market in column (2) of Table

B.6.

Table B.9 and Table B.10 add the durability of output from Bils et al. (2012) and the number of products in my dataset at the firm level as additional covariates. Controlling for the variation in durability actually slightly increases the premium for sticky price firms, while adding the number of products marginally reduces the coefficient on the frequency of price adjustment which stays however highly statistically significant. The latter effect is expected given that larger firms with more products in sample tend to change prices more frequently (see Goldberg and Hellerstein (2011) and Bhattarai and Schoenle (2012)).

In Table B.11, I add a specification in which I cluster standard errors along the time and firm dimensions. While the statistical significance of the coefficient on the frequency of price adjustment only slightly decreases, some other standard return predictors lose their explanatory power. Table B.12 repeats my within industry results but adds finer defined industry dummies. In particular, I add dummies at the Fama & French 10 and 17 industry level. As expected, the more I restrict the variation in the data by adding additional fixed effects, the smaller the coefficient on the frequency of price adjustment.

Table B.13 reports descriptive statistics for the firm characteristics and return predictors for the benchmark sample period from July 1982 to June 2007 for all firms independent of missing data on the frequency of price adjustment. The full and merged (Table 2.2) sample are virtually identical based on observables which is expected given the probabilistic sampling underlying the construction of the producer price index.

Table B.14 reports descriptive statistics for the firm characteristics and return predictors for the full sample period from July 1963 to June 2011 and Table B.15 the corresponding results of panel regressions of annual stock returns on the measure for the frequency of price adjustment, SAU, and controls according to equation (2.1). Results are very similar to the benchmark sample period and the regression coefficients imply a premium in returns moving from firms with low frequencies of price adjustment to firms with high frequencies of price adjustment between 2.5% in column (3) and 6.6% in column (4).[5]

Table B.16 repeats the baseline panel specifications on unwinsorized variables. The coefficient on SAU tends to be larger in absolute value at continuously high statistical significance while the explanatory power of the model somewhat decreases. The premium for price stickiness increases from 4.5% when adding all controls to 7.9% when only controlling for the book to market ratio.

Table B.17 and Table B.18 report results at the portfolio level for alternative measures of the frequency of price adjustment, both for raw returns and for characteristic adjusted returns. Return premia for the L-H portfolio range between 2.3% (SCW, 1963-2011) and 5.6% (SCU, 1982-1998) per annum for raw returns and 2.2% (SAW, 1963-2011) and 5.5% (SBW, 1982-1998) for characteristic-adjusted returns similar in magnitude to the numbers reported in Table 2.3.

[5]These and subsequent premia are calculated by multiplying the regression coefficient on the frequency of price adjustment by 0.6, the differential in the frequency of price adjustment between firms which most infrequently change their product prices and firms which are most flexible in adjusting prices (see Table B.2).

Table B.19 reports results at the portfolio level for a subset of firms which have been part of the S&P500 at the end of June 1994 in Panel A, while Panel B chooses 2006 as cutoff year. Results are very similar to my baseline finding and show that overall premium for sticky price firms is not due to attrition or selection.

Table B.20, Table B.21, Table B.22, Table B.23 and Table B.24 repeat the baseline panel regressions for the measures SAW, SBU, SBW, SCU and SCW. Results are very similar to the baseline results in Table 2.4. The coefficient on the measure of price stickiness is always negative and statistically significant while the absolute size tends to be somewhat smaller. This however is driven by the fact that the alternative measures imply on average a slightly higher frequency of price adjustment and a larger spread between firms with most sticky and flexibly prices during my sample period (see Table B.2). Overall, the estimates imply premia ranging from 2.7% for the measure SCW when controlling for size in column (3) of Table B.24 and 6.7% per year for measure SBU when adding the book to market ratio as a control in Table B.21.

Table B.25, Table B.26, and Table B.27 repeat the unconditional and conditional CAPM regressions, the decomposition in cash flow and discount rate β and the long-horizon predictability for the whole sample ranging from July 1963 to June 2011. Again, I find that neither the unconditional nor the conditional CAPM can rationalize the level of the returns for the 5 portfolios of stocks sorted on their frequency of product price adjustment while both models have explanatory power for the cross-sectional dispersion in returns driving the α of the L-H portfolio to statistically insignificant and economically small excess returns of 0.10% and 0.03% per month, respectively. In addition, cash flow and discount rate βs also contribute equally to the overall βs of the individual portfolios and are monotonic in the portfolio number. Regarding the long-horizon predictability, I again find predictability for the L-H portfolio at long horizons of up to 5 years when I adjust the log dividend price ratio for changes in the steady state of the economy following the methodology of Lettau and Van Nieuwerburgh (2008) in Panel B and strong predictability at all horizons ranging from 1 to 60 months when I employ the Lettau and Ludvigson (2001) proxy for the consumption-wealth ratio, cay, in Panel C.

Table B.28 report results for long-horizon forecasting regressions of log excess returns of the zero-cost portfolio of going long the portfolio of stocks with high book to market value of equity and shorting the portfolio of stocks with low book to market value of equity of Fama and French (1993), HML, in Panel A, and the CRSP value weighted excess return in Panel B on the proxy for the consumption wealth ratio of Lettau and Ludvigson (2001). cay has a marginally statistically significant forecasting power the log excess return of the CRSP value weighted index. The maximal R^2 is 35% at a four year horizon. cay negatively predicts the HML factor of Fama and French (1993) with a maximum explanatory power of 21% at a five year forecasting horizon; again barely statistically significant though.

Table B.29 repeats the benchmark estimation at the portfolio level using portfolio mean firm characteristics as control variables. This exercise obviously leaves a lot of cross-sectional variation in the frequency of price change unused and is biased against finding an effect of the frequency of price adjustment as it is (almost) constant over time at the portfolios level.

This table nevertheless shows that the coefficient on price stickiness is always negative and for almost all specification highly statistically significant with point estimates in the ballpark of previous estimates.

The higher riskiness of firms with lower frequencies of price adjustment might potentially also be reflected in higher realized volatilities at the firm level. I construct this measure by taking the square root of the sum of daily squared returns over one year. Table B.30 documents a similar pattern for realized volatilities as we have seen for returns: across specifications – controlling for firm characteristics both individually and jointly – price flexibility is associated with lower realized volatilities which is highly statistically significant for most estimations. Going from firms with most flexible product prices in sample to firms with stickiest prices is associated with an increase in realized volatility of 5.95% per annum in column (1) for the regression without additional controls and varies between 4.09% in column (6) when I only control for leverage and 6.46% in column (9) when the bid-ask spread is the sole additional control. The specification controlling for β in column (5) is an exception as β drives out the measure of price stickiness. This might indicate that β to some extent already captures the higher riskiness of sticky price firms.[6] Once I add all controls, though, the coefficient on SAU is again highly statistically significant.

Figures B.1 and B.2 show why there is only a small risk premium associated with technology shocks. The mean reversion in technology has it that aggregate output moves only little in reaction to the shock, translating into a small reaction in marginal utility and finally dividends, stock prices and returns.

Figure B.3 to Figure B.6 show why variations in the within sector elasticity of substitutions are quantitatively more important than variations in the elasticity of substitution between sectoral consumption aggregates.[7] We know from equation (2.5) that sector price indexes are independent of ε_c and therefore the variation in relative sector price indexes we see in Figure B.3 is driven by the effect of ε_c on the aggregate price level when aggregating sector prices. Once we look at differences across sectors, this effect cancels out and hence variation in ε_c has no effect on the price margin in equation (2.12). Equation (B.12) shows that sector price dispersion is independent of the across sector elasticity of substitution in consumption and therefore also the inefficiency margin is not impacted by changes ε_c. Hence, ε_c only affects the quantity margin $(\check{Y}_{1,t}-\check{Y}_{2,t})$. Real sector output is determined by aggregate output times the relative sector price $P_{k,t}/P_t$ to the power of $(1-\varepsilon_c)$. Increasing the across sector elasticity of substitution in consumption translate into more negative differences in dividends between the sticky and flexible price sector and therefore increase the cross sectional return difference. This channel, however, is quantitatively small and of second order

[6]This result is somewhat expected as I look at total realized volatilities and not at idiosyncratic realized volatilities controlling for exposure to market risk.

[7]ε_c low, medium, and high correspond to values of between sectoral consumption aggregates of 4, 8, and 12, respectively. The return of the zero cost portfolio of going long the portfolio of stocks with low frequencies of price adjustment and shorting the flexible price portfolio increases from 2.34% per year to 3.69%.

compared the effects of the within sector elasticity of substitution.[8]

Figure B.7 depicts the actual sensitivities of the portfolios to monetary policy surprises on the y-axis against the CAPM predicted sensitivities on the x-axis. All portfolios line up fairly closely along the 45 degree line resulting in a correlation between actual and predicted sensitivity of 75%.

Figure B.8 plots standardized consumption surplus at the end of the quarter and the standardized cumulative two year excess returns of the sticky minus flexible price portfolio at an annual frequency for model simulated data. Times of consumption close to habit, bad times, generally coincide with high expected returns going forward, resulting in an unconditional correlation of close to 50%.

Table B.31 further investigates the effects of differences in the frequency of price adjustment on stock returns in a two sector version of the model. The parameters of the baseline calibration are identical to the five sector model with the Calvo (1983) rates being the only exception. I calibrate θ_1 to 0.895 and θ_2 to 0.015, the two extreme values of my 5 sector calibration, implying average durations of price spells of 9.1 and 0.24 quarters respectively. In the left panel of the line (1), we see that this calibration implies only a moderate cross-sectional dispersion in returns of 0.76% while the equity premium is slightly higher compared to the five sector version of the model with 7.71% per annum. Instead of simulating dividends and valuations at the firm level, I report returns for the claim on aggregate dividends at the sector level in the right half of the table.

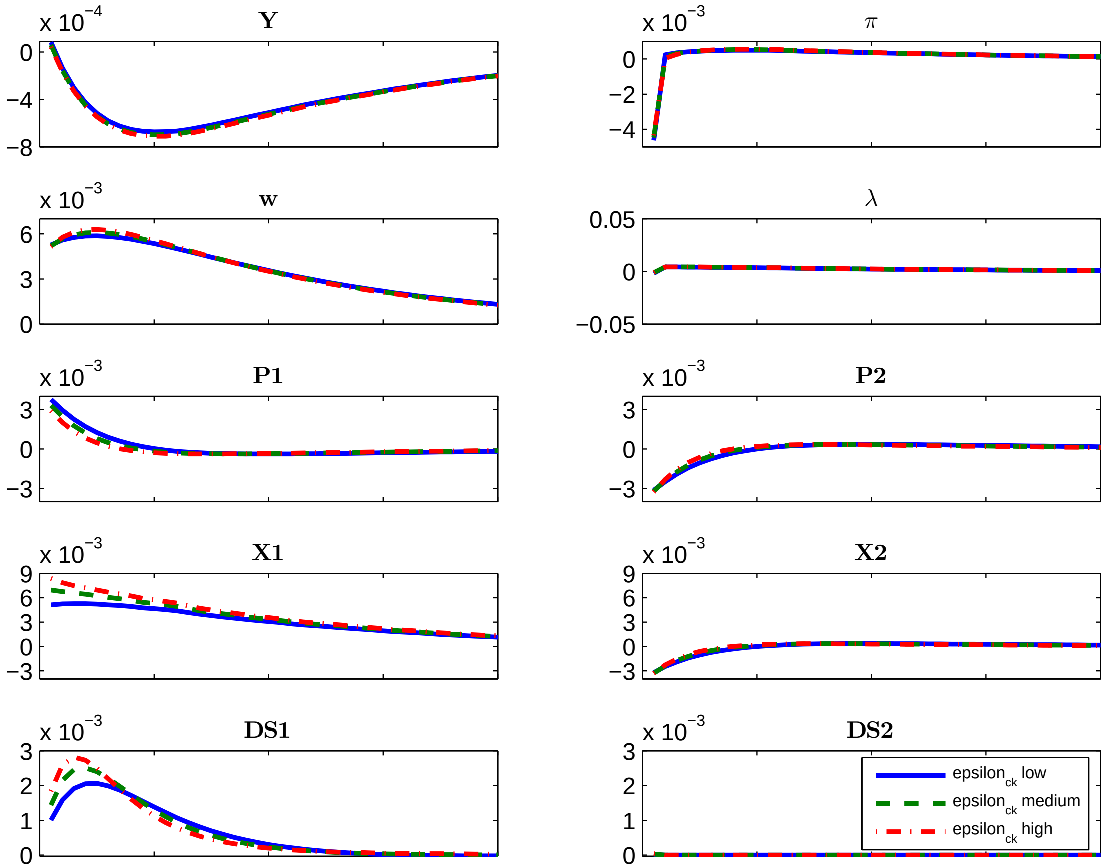
The calibration leads to returns which are almost identical across sectors and an overall equity premium of 6.9%. In the next line I increase the price rigidity in the first sector to $\theta_1 = 0.905$ implying that prices are reset every 10.02 quarters on average. This leads to a large increase in the cross sectional return premium for the sticky price sector resulting in a spread of almost 2.5% per year and raising the equity premium by almost 1% in the firm level simulation. In the right half of the table, on the contrary, we see that solving the model at the industry level leaves out a lot of real effects of nominal rigidities: the equity premium stays almost identical and the spread in returns increase from 0.07% to only 0.09% per year. The following lines perform the same sensitivity analysis as for the five sector version of the model discussed in the main body of the paper leaving the difference in the frequency of price adjustment at this increased level. The fact that a two sector version of the model leads to a lower spread in returns across sectors compared to the five sector version even though the average duration of price spells is higher is similar to the findings for the effects of monetary policy shocks on real output and inflation in the presence of differences in the frequencies of price adjustment. Carvalho (2006) shows that a model with identical frequencies of price adjustment across sectors requires a substantially larger degree of nominal rigidities to match the aggregate effects of a model with heterogeneity in Calvo (1983)-rates calibrated to micro evidence. Lines (3) and (4) underline this point: an economy with equal rigidities across sectors has an identical equity premium in an economy with two and five sectors and an

[8] As Figure B.3 shows, changes in ε_c also barely affect aggregate quantities and therefore also have no indirect effects on stock returns via a valuation channel.

economy with flexible prices has again a slightly higher equity premium. The other model robustness checks and alternative specifications lead to qualitatively and quantitatively very similar results compared to the five sector economy. In the right half of the table we see that none of the model variation has a material impact on the equity premium or leads to a substantial increase of the spread in returns between flexible and sticky price sector.

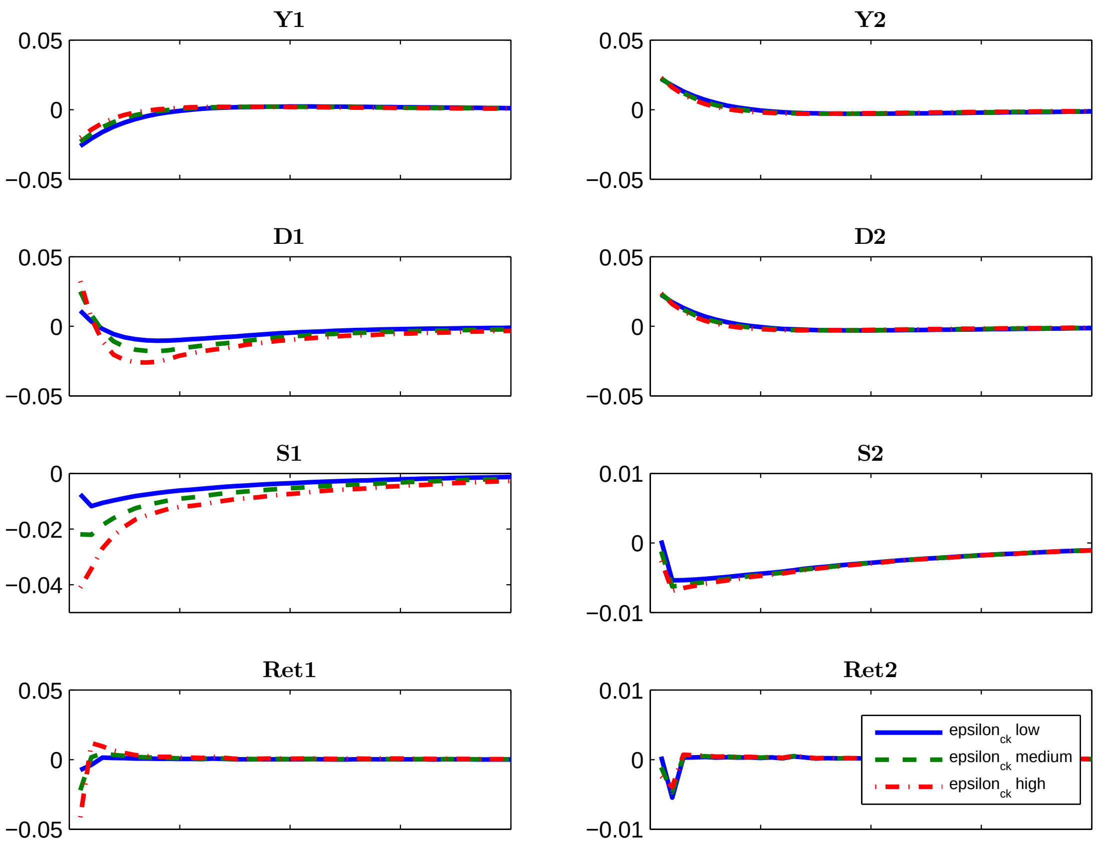
Lines (21) and (22) offer an interesting additional insight: the penultimate line of the table again shows that an unpruned model approximated to second order leads to a larger spread in returns across sectors and a lower equity risk premium for the simulated economy and an even slightly negative spread in returns between sticky and flexible sector for the model solved at the industry level. Raising the order of approximation to third order on the contrary now also leads to a significant cross sectional spread in return at the sector level with the sticky price sector commanding a return premium of almost 3% per year.

Figure B.1: Impulse Response Functions to Technology Shock (varying ε_{ck})



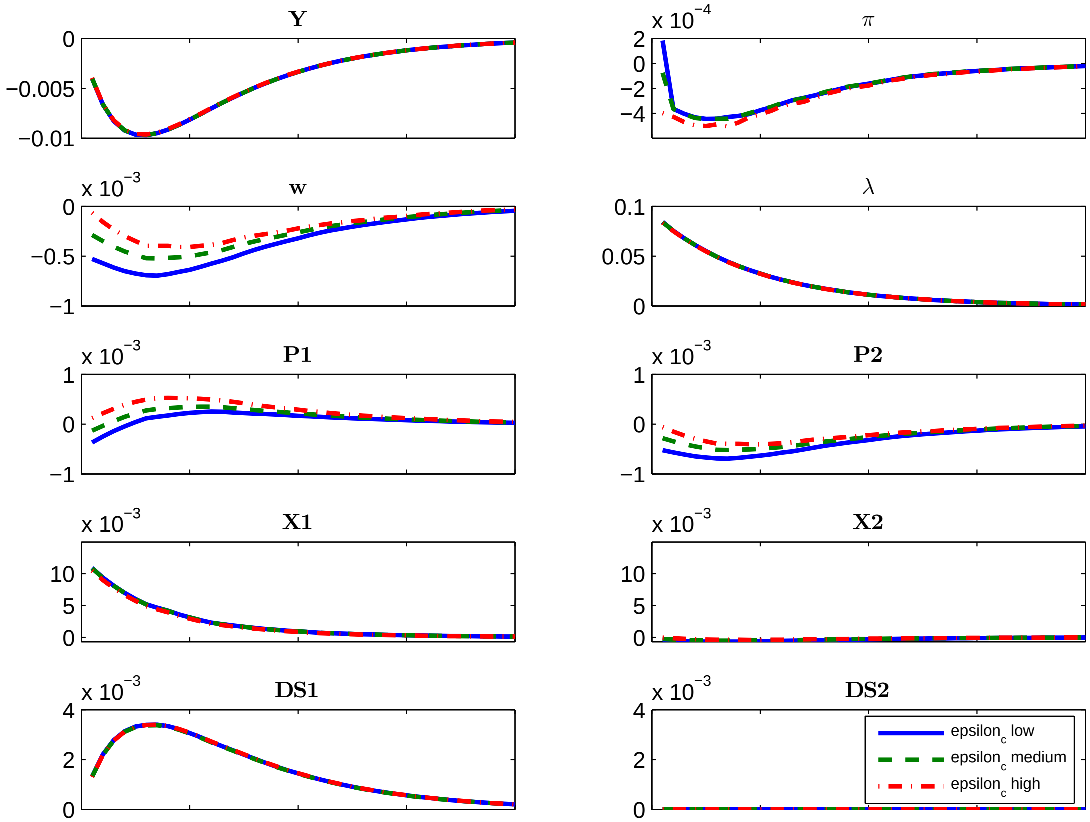
This figure plots the impulse response functions of several macroeconomic variables of a two sector version of the model of Section 2.4 to a one standard deviation technology shock for different values of the elasticity of substitution of within sector consumption varieties, ε_{ck}. ε_{ck} low, medium, and high correspond to values of 8, 12, and 16, respectively. Y is output, π inflation, w aggregate real wage, λ the marginal utility of consumption, P1 and P2 the relative prices of sectors one and two, X1 and X2 the optimal real reset prices, and DS1 and DS2 the price dispersion in the two sectors.

Figure B.2: Impulse Response Functions to Technology Shock (varying ε_{ck})



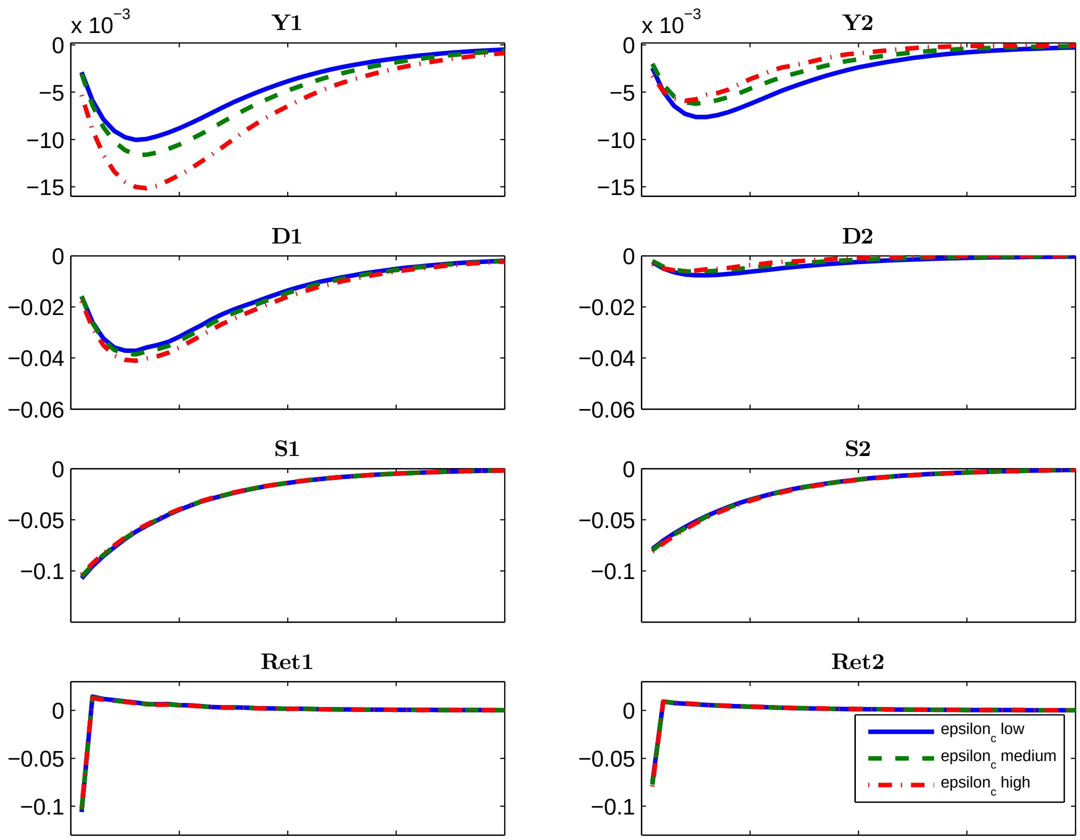
This figure plots the impulse response functions of several macroeconomic variables and asset returns of a two sector version of the model of Section 2.4 to a one standard deviation technology shock for different values of the elasticity of substitution of within sector consumption varieties, ε_{ck}. ε_{ck} low, medium, and high correspond to values of 8, 12, and 16, respectively. Y1 and Y2 are the output of sectors one and two, D1 and D2 sector level dividends, S1 and S2 the prices of claims to aggregate sector dividends and Ret1 and Ret2 the returns of these claims.

Figure B.3: Impulse Response Functions to Monetary Policy Shock (varying ε_c)



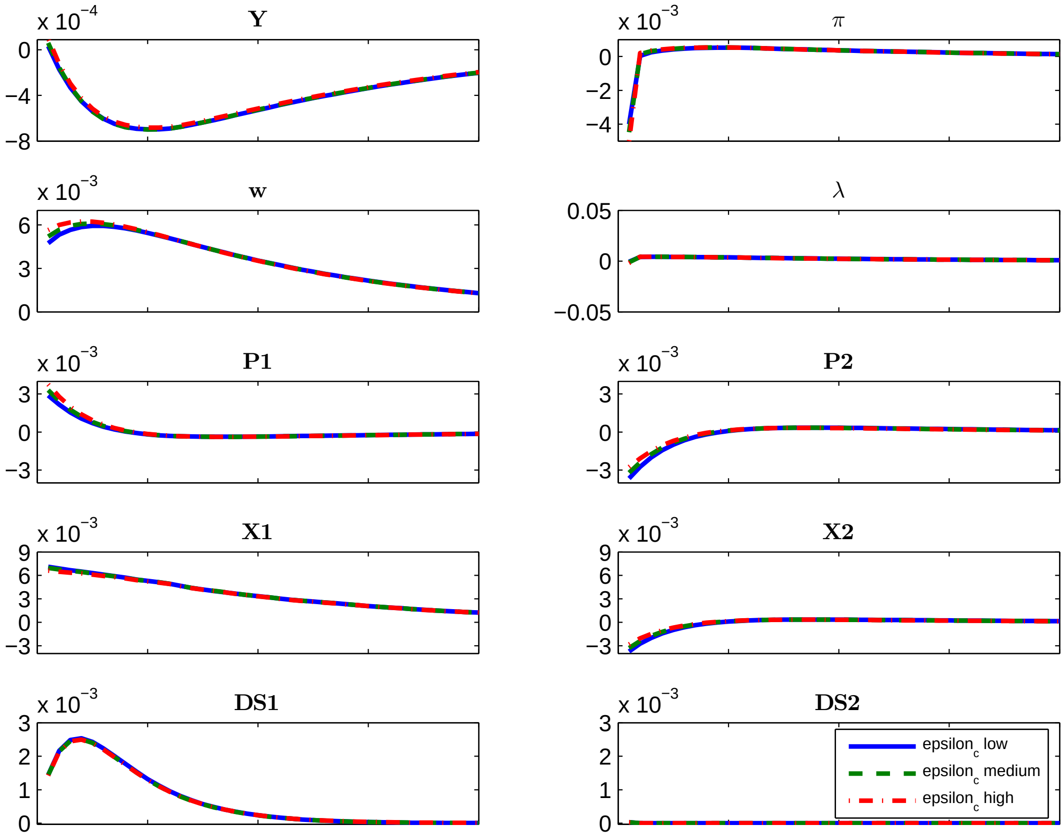
This figure plots the impulse response functions of several macroeconomic variables of the model of Section 2.4 to a one standard deviation contractionary monetary policy shock for different values of the elasticity of substitution of across sector consumption varieties, ε_c. ε_c low, medium, and high correspond to values of 4, 8, and 12, respectively. Y is output, π inflation, w aggregate real wage, λ the marginal utility of consumption, P1 and P2 the relative prices of sectors one and two, X1 and X2 the optimal real reset prices, and DS1 and DS2 the price dispersion in the two sectors.

Figure B.4: Impulse Response Functions to Monetary Policy Shock (varying ε_c)



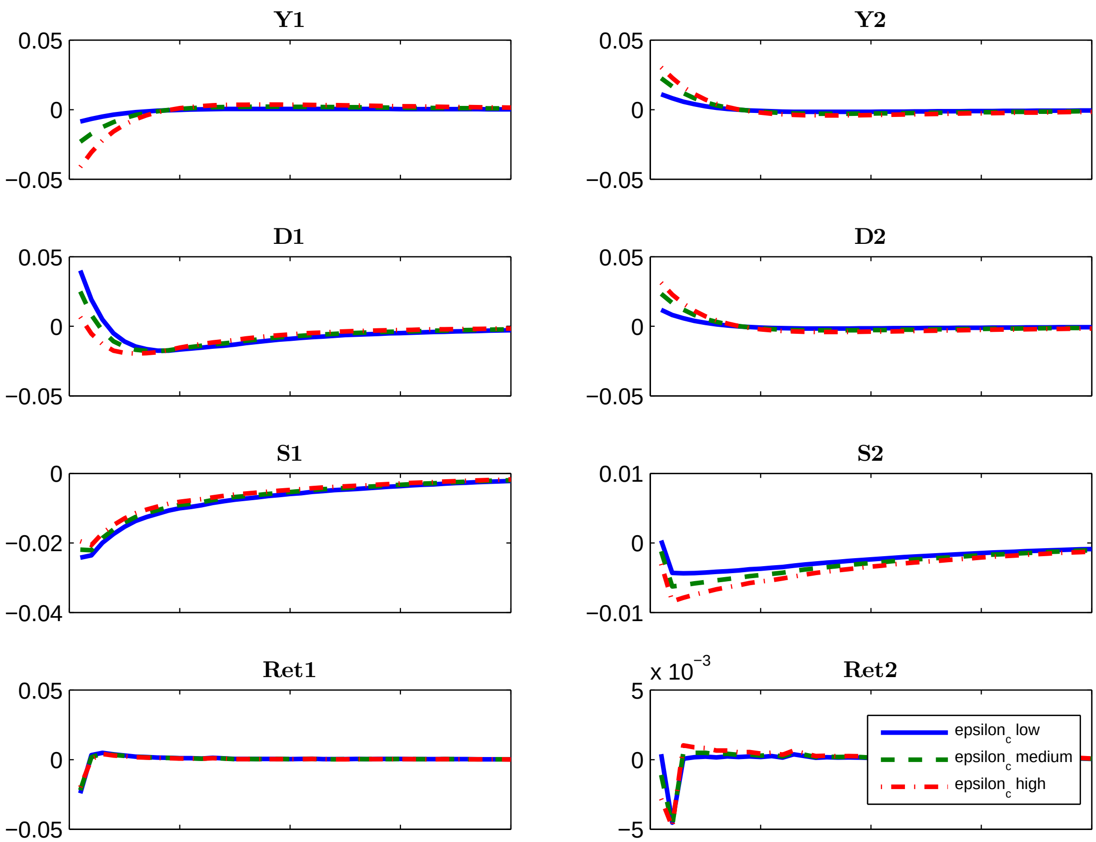
This figure plots the impulse response functions of several macroeconomic variables of the model of Section 2.4 to a one standard deviation contractionary monetary policy shock for different values of the elasticity of substitution of across sector consumption varieties, ε_c. ε_c low, medium, and high correspond to values of 4, 8, and 12, respectively. Y1 and Y2 are the output of sector one and two, D1 and D2 sector level dividends, S1 and S2 the prices of claims to aggregate sector dividends and Ret1 and Ret2 the returns of these claims.

Figure B.5: Impulse Response Functions to Technology Shock (varying ε_c)



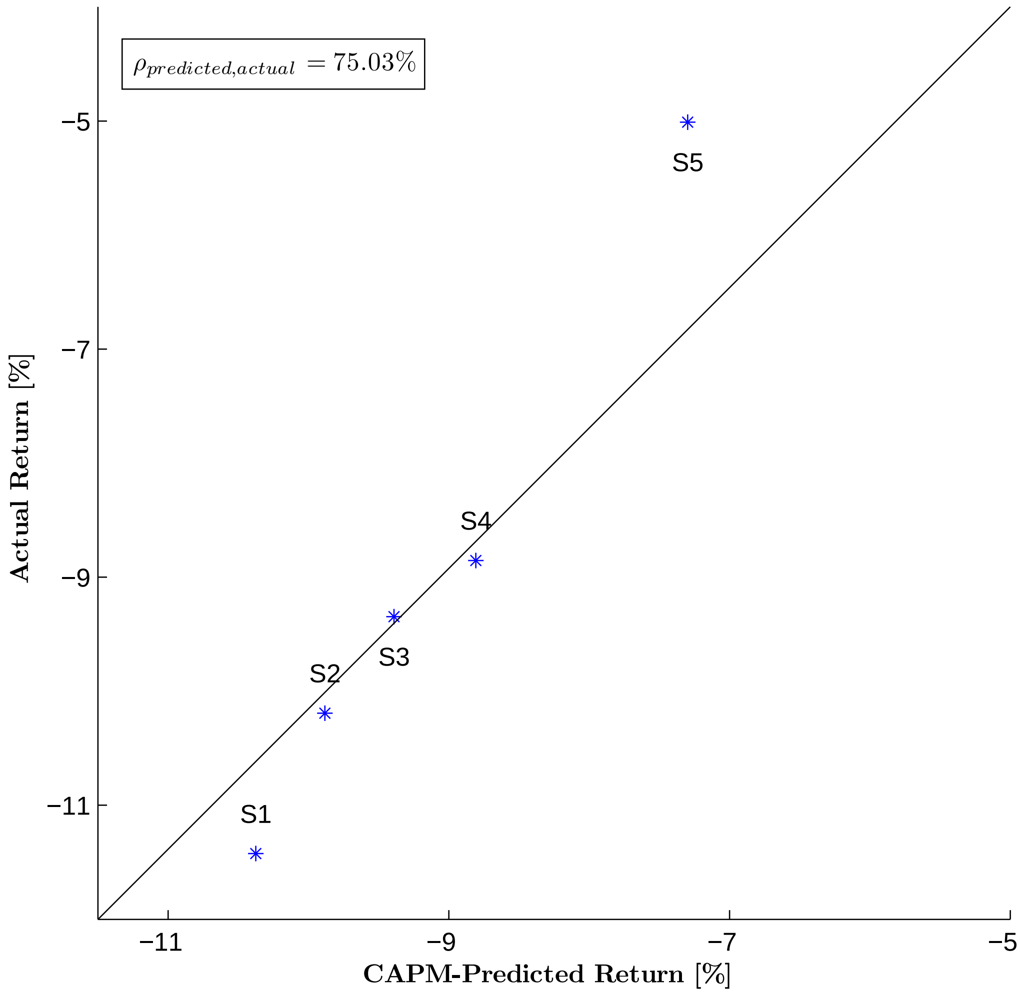
This figure plots the impulse response functions of several macroeconomic variables of the model of Section 2.4 to a one standard deviation technology shock for different values of the elasticity of substitution of across sector consumption varieties, ε_c. ε_c low, medium, and high correspond to values of 4, 8, and 12, respectively. Y is output, π inflation, w aggregate real wage, λ the marginal utility of consumption, P1 and P2 the relative prices of sectors one and two, X1 and X2 the optimal real reset prices, and DS1 and DS2 the price dispersion in the two sectors.

Figure B.6: Impulse Response Functions to Technology Shock (varying ε_c)



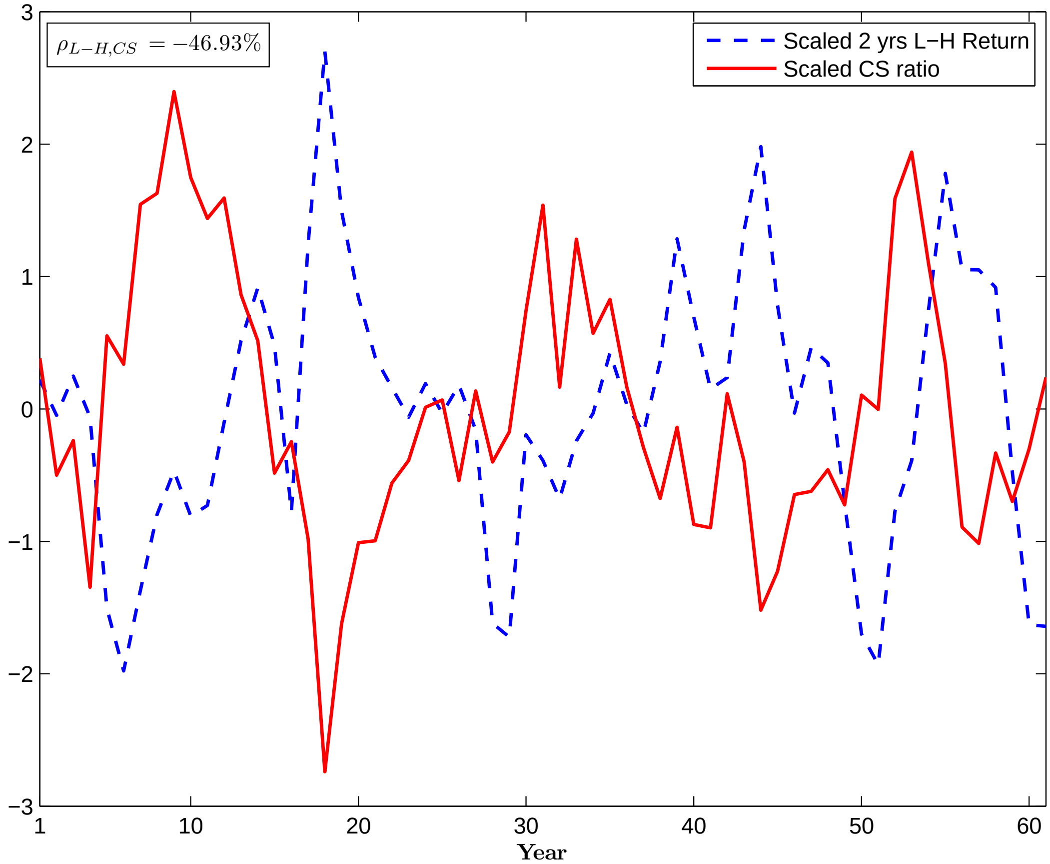
This figure plots the impulse response functions of several macroeconomic variables of the model of Section 2.4 to a one standard deviation technology shocks for different values of the elasticity of substitution of across sector consumption varieties, ε_c. ε_c low, medium, and high correspond to values of 4, 8, and 12, respectively. Y1 and Y2 are the output of sectors one and two, D1 and D2 sector level dividends, S1 and S2 the prices of claims to aggregate sector dividends and Ret1 and Ret2 the returns of these claims.

Figure B.7: Actual vs. Predicted Response to 1% Federal Funds Rate Surprise



This figure plots the actual response of monthly percentage excess returns to a one percentage point surprise increase in the Federal Funds rate versus the CAPM-predicted response for five portfolios sorted on increasing frequency of price adjustment (S1-S5). Stocks are assigned to one of five baskets based on the frequency of price adjustment. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is June 1989 to June 2007.

Figure B.8: Model Implied Consumption Surplus (CS) and Following 2 Year Returns



This figure plots standardized consumption surplus from the calibrated model of Section 2.4 and the subsequent standardized two year return of the zero cost portfolio of going long the claim to dividends of the sector with low frequencies of price adjustment and shorting the claim to dividends of the sector with high frequencies of price adjustment, L-H. The sampling frequency is annual with consumption surplus measured at the end of year t and returns measured from the beginning of year t+1 to the end of year t+2.

Table B.1: Panel Regressions of Price Stickiness on Firm Characteristics (Benchmark Sample)

This table reports the results of regressing the frequency of price adjustment, SAU, on various firm characteristics and return predictors. Standard errors are clustered at the firms level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Size	0.42*									1.04***
	(0.23)									(0.29)
BM		7.11***								7.74***
		(0.80)								(0.89)
Beta			−4.59***							−2.05*
			(1.00)							(1.06)
Lev				9.17***						10.92***
				(1.59)						(1.73)
CF					−8.02					38.03***
					(5.65)					(6.50)
Turnover						−4.26				10.73***
						(3.14)				(3.10)
Spread							0.35			0.45*
							(0.22)			(0.26)
PCM								−10.33***		−8.19***
								(2.33)		(2.43)
HHI									−2.02**	−2.35***
									(0.92)	(0.89)
#	13,841	13,613	13,350	13,766	13,777	13,840	13,840	13,775	13,241	13,059
R^2	0.24%	5.37%	2.45%	2.89%	0.15%	0.11%	0.08%	2.29%	0.29%	12.98%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.2: Frequency of Price Adjustment by Industry

This table reports average frequencies of price adjustment at the industry and aggregate levels with standard deviations in parentheses for different measures of the frequency of price adjustment. SA treats missing values as interrupting price spells, for SB, missing values do not interrupt price spells if the price is the same before and after periods of missing values and SC forms the union of the two. Columns (1) to (3) use equally weighted frequencies of price adjustments, U, whereas columns (4) to (6) weight frequencies with associated values of shipments, W. Frequencies of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is July 1963 to June 2011

		SAU	SBU	SCU	SAW	SBW	SCW
		(1)	(2)	(3)	(4)	(5)	(6)
Agriculture	Mean	22.75%	24.31%	24.50%	25.03%	26.70%	26.96%
	Std	(17.49%)	(17.44%)	(17.69%)	(19.11%)	(19.00%)	(19.30%)
	Max	59.39%	64.83%	65.17%	59.39%	64.83%	65.17%
	Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	#		16,754			16,082	
Manufacturing	Mean	12.03%	13.01%	13.07%	13.12%	14.16%	14.25%
	Std	(11.35%)	(11.40%)	(11.48%)	(13.41%)	(13.39%)	(13.49%)
	Max	60.00%	60.32%	60.32%	60.00%	60.32%	60.32%
	Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	#		139,235			136,667	
Utilities	Mean	22.66%	23.79%	23.90%	23.03%	24.06%	24.15%
	Std	(12.79%)	(12.58%)	(12.62%)	(13.52%)	(13.42%)	(13.46%)
	Max	53.89%	53.29%	53.29%	55.83%	55.83%	55.83%
	Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	#		42,425			41,948	
Trade	Mean	20.41%	22.14%	22.24%	20.75%	22.57%	22.66%
	Std	(13.74%)	(13.48%)	(13.55%)	(13.80%)	(13.45%)	(13.52%)
	Max	60.00%	60.00%	60.00%	60.00%	60.00%	60.00%
	Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	#		19,124			19,124	
Finance	Mean	13.14%	18.78%	18.90%	13.65%	20.67%	20.81%
	Std	(11.31%)	(12.70%)	(12.79%)	(12.61%)	(15.10%)	(15.21%)
	Max	45.65%	45.65%	45.65%	46.84%	51.67%	51.67%
	Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	#		40,380			39,737	
Service	Mean	8.13%	9.67%	9.72%	9.20%	10.68%	10.73%
	Std	(9.19%)	(9.55%)	(9.60%)	(9.94%)	(10.12%)	(10.15%)
	Max	60.00%	60.00%	60.00%	60.00%	60.00%	60.00%
	Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	#		15,618			14,823	
Total	Mean	14.86%	16.67%	16.76%	15.79%	17.83%	17.94%
	Std	(13.00%)	(13.23%)	(13.32%)	(14.37%)	(14.72%)	(14.83%)
	Max	60.00%	64.83%	65.17%	60.00%	64.83%	65.17%
	Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	#		273,536			268,381	

Table B.3: Summary Statistics of Firm Characteristics and Return Predictors at the Portfolio Level (Benchmark Sample)

This table reports time series averages of annual mean firm characteristics and return predictors used in the subsequent analysis at the portfolio level. Stocks are assigned to one of five basket based on the frequency of price adjustment, SAU. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

Portfolio	SAU (1)	Size (2)	BM (3)	Beta (4)	Lev (5)	CF (6)	Turnover (7)	Spread (8)	PCM (9)	HHI (10)
Sticky	0.01	13.84	0.65	1.18	0.39	0.09	8.89	1.54	0.39	0.27
S2	0.05	14.06	0.58	1.16	0.33	0.11	8.21	1.57	0.38	0.30
S3	0.10	14.09	0.64	1.16	0.38	0.10	8.19	1.57	0.36	0.29
S4	0.19	14.15	0.75	1.07	0.45	0.09	7.87	1.48	0.35	0.24
Flexible	0.35	14.32	0.83	0.98	0.46	0.09	8.10	1.51	0.32	0.14
S1-S5	0.34	0.48	0.18	-0.20	0.06	0.00	-0.79	-0.03	-0.06	-0.13

Table B.4: Panel Regressions of Annual Stock Returns on Firm Characteristics (Benchmark Sample)

This table reports the results of regressing annual percentage returns on firm characteristics and return predictors. Standard errors are clustered at the firm level and reported in parentheses. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Size	−5.09***									−6.56***
	(0.25)									(0.34)
BM		8.06***								8.82***
		(0.83)								(1.12)
Beta			5.38***							3.11***
			(0.76)							(1.11)
Lev				−3.04**						2.36
				(1.37)						(2.03)
CF					−1.31					32.06***
					(5.32)					(7.88)
Turnover						26.56***				14.62***
						(3.53)				(4.54)
Spread							−1.51***			−5.96***
							(0.36)			(0.46)
PCM								2.28		9.62***
								(1.59)		(2.18)
HHI									1.60*	2.39*
									(0.84)	(1.23)
Year FE	N	N	N	N	N	N	N	N	N	N
#	13,810	13,582	13,319	13,735	13,746	13,810	13,810	13,744	13,210	13,029
R^2	3.88%	0.76%	0.36%	0.03%	0.00%	0.48%	0.16%	0.01%	0.02%	6.95%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.5: Panel Regressions of Annual Stock Returns on Firm Characteristics (Benchmark Sample, Fixed Effects)

This table reports the results of regressing annual percentage returns on firm characteristics, return predictors and year fixed effects. Standard errors are clustered at the firm level and reported in parentheses. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Size	−4.44***									−5.04***
	(0.29)									(0.33)
BM		2.13***								2.62 **
		(0.82)								(1.08)
Beta			4.52***							0.25
			(0.73)							(1.05)
Lev				0.03						3.57 **
				(1.39)						(1.82)
CF					−10.03*					0.94
					(5.56)					(7.37)
Turnover						52.81***				36.13***
						(3.90)				(4.94)
Spread							−5.50***			−7.41***
							(0.55)			(0.58)
PCM								6.60***		8.42***
								(1.64)		(1.97)
HHI									0.45	1.95 **
									(0.70)	(0.99)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,810	13,582	13,319	13,735	13,746	13,810	13,810	13,744	13,210	13,029
R^2	21.92%	19.90%	20.29%	19.73%	19.75%	21.35%	20.88%	19.83%	19.67%	24.88%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.6: Panel Regression of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, Monthly Overlapping)

This table reports the results of regressing overlapping annual percentage returns at the monthly frequency on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
SAU	−7.61***	−5.91***	−12.46***	−4.04**	−7.54***	−7.78***	−8.09***	−7.25***	−7.78***	−7.55***	−4.96**
	(1.72)	(1.83)	(2.10)	(1.63)	(1.77)	(1.75)	(1.71)	(1.75)	(1.78)	(1.81)	(2.18)
Size		−2.93***									−4.13***
		(0.13)									(0.23)
BM			6.81***								6.81***
			(0.55)								(0.74)
Beta				6.94***							7.24***
				(0.55)							(0.84)
Lev					0.40						2.09
					(1.01)						(1.38)
CF						−9.23**					19.62***
						(4.17)					(6.00)
Turnover							0.11				−6.15*
							(2.45)				(3.19)
Spread								−1.87***			−5.78***
								(0.18)			(0.26)
PCM									−1.05		6.76***
									(1.39)		(1.71)
HHI										0.92**	0.17
										(0.39)	(0.53)
#	264,662	264,662	260,096	256,393	261,913	262,757	256,941	264,657	262,636	247,781	239,309
R^2	0.06%	1.84%	0.83%	0.63%	0.06%	0.08%	0.07%	0.43%	0.06%	0.08%	4.81%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.7: Panel Regressions of Annualized Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, Monthly Returns)

This table reports the results of regressing annualized monthly percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SAU	−7.52***	−8.03***	−5.77***	−8.73***	−5.47***	−7.13***	−8.02***	−6.67***	−8.57***	−6.76***	−7.93***	−4.11*
	(1.91)	(1.98)	(2.10)	(2.10)	(1.97)	(1.99)	(2.00)	(1.92)	(2.07)	(1.94)	(2.05)	(2.27)
Size			−3.44***									−2.84***
			(0.24)									(0.26)
BM				1.74***								1.88 * *
				(0.67)								(0.90)
Beta					4.67***							−0.62
					(0.59)							(0.81)
Lev						−2.31 * *						−0.34
						(1.15)						(1.56)
CF							−2.88					3.13
							(4.35)					(6.23)
Turnover								40.31***				35.41***
								(3.49)				(4.33)
Spread									3.28***			3.02***
									(0.35)			(0.39)
PCM										5.45***		8.25***
										(1.40)		(1.61)
HHI											0.30	1.36*
											(0.60)	(0.74)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	167,115	167,115	167,115	164,338	161,243	166,208	166,348	166,707	167,110	166,324	159,870	157,399
R^2	0.01%	1.51%	1.66%	1.51%	1.55%	1.50%	1.50%	1.51%	1.58%	1.51%	1.50%	1.71%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.8: Panel Regressions of Annualized Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, Month Fixed Effect)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors and month fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SAU	−7.52***	−8.15***	−5.96***	−8.89***	−5.70***	−7.58***	−8.18***	−6.98***	−8.33***	−6.85***	−8.13***	−3.71*
	(1.91)	(1.99)	(2.09)	(2.10)	(1.98)	(2.01)	(2.01)	(1.92)	(2.01)	(1.94)	(2.06)	(2.17)
Size			−3.35***									−3.19***
			(0.24)									(0.25)
BM				1.76***								1.85 * *
				(0.67)								(0.88)
Beta					4.47***							0.56
					(0.58)							(0.80)
Lev						−1.21						0.52
						(1.14)						(1.49)
CF							−5.96					0.25
							(4.38)					(6.11)
Turnover								34.45***				25.92***
								(3.45)				(4.24)
Spread									1.01***			0.45
									(0.36)			(0.41)
PCM										5.50***		8.17***
										(1.40)		(1.57)
HHI											−0.01	1.05
											(0.56)	(0.71)
Month FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	167,115	167,115	167,115	164,338	161,243	166,208	166,348	166,707	167,110	166,324	159,870	157,399
R^2	0.01%	24.17%	24.31%	24.23%	24.46%	24.17%	24.16%	24.18%	24.17%	24.17%	24.37%	24.64%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.9: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, Durability)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin, HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level and Dur the durability measure of Bils et al. (2012). Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
SAU	−10.04***	−10.97***	−8.04***	−12.94***	−8.54***	−10.99***	−10.98***	−9.83***	−10.16***	−9.52***	−10.79***	−11.47***	−8.98***
	(2.16)	(2.28)	(2.44)	(2.50)	(2.29)	(2.32)	(2.31)	(2.27)	(2.34)	(2.25)	(2.36)	(2.50)	(3.00)
Size			−4.38***										−5.07***
			(0.29)										(0.35)
BM				3.22***									3.26***
				(0.84)									(1.22)
Beta					4.12***								0.69
					(0.75)								(1.20)
Lev						1.06							4.06 **
						(1.38)							(1.94)
CF							−10.97 **						9.08
							(5.55)						(8.15)
Turnover								52.39***					36.79***
								(3.87)					(5.19)
Spread									−5.45***				−7.69***
									(0.54)				(0.61)
PCM										5.61***			6.38***
										(1.66)			(2.17)
HHI											0.23		2.15*
											(0.70)		(1.19)
Dur												0.06	−1.08***
												(0.32)	(0.40)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,810	13,810	13,810	13,582	13,319	13,735	13,746	13,810	13,810	13,744	13,210	12,055	11,593
R^2	0.11%	19.96%	21.99%	20.07%	20.37%	19.86%	19.88%	21.45%	20.99%	19.93%	19.80%	18.87%	24.02%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.10: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, # Products)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin, HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level and # Prod is the number of goods in the micro data underlying the Producer Price Index. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
SAU	−10.04***	−10.97***	−8.04***	−12.94***	−8.54***	−10.99***	−10.98***	−9.83***	−10.16***	−9.52***	−10.79***	−8.13***	−6.10**
	(2.16)	(2.28)	(2.44)	(2.50)	(2.29)	(2.32)	(2.31)	(2.27)	(2.34)	(2.25)	(2.36)	(2.34)	(2.80)
Size			−4.38***										−4.91***
			(0.29)										(0.33)
BM				3.22***									3.52***
				(0.84)									(1.13)
Beta					4.12***								−0.21
					(0.75)								(1.08)
Lev						1.06							4.53**
						(1.38)							(1.84)
CF							−10.97**						5.44
							(5.55)						(7.67)
Turnover								52.39***					37.28***
								(3.87)					(4.91)
Spread									−5.45***				−7.37***
									(0.54)				(0.58)
PCM										5.61***			7.69***
										(1.66)			(1.99)
HHI											0.23		1.66*
											(0.70)		(1.00)
# Prod												−0.06***	−0.03*
												(0.01)	(0.02)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,810	13,810	13,810	13,582	13,319	13,735	13,746	13,810	13,810	13,744	13,210	13,810	13,004
R^2	0.11%	19.96%	21.99%	20.07%	20.37%	19.86%	19.88%	21.45%	20.99%	19.93%	19.80%	20.04%	24.97%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.11: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level or firm-year level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SAU	−10.97***	−8.04***	−12.94***	−8.54***	−10.99***	−10.98***	−9.83***	−10.16***	−9.52***	−10.79***	−7.07***	−7.07 * *
	(2.28)	(2.44)	(2.50)	(2.29)	(2.32)	(2.31)	(2.27)	(2.34)	(2.25)	(2.36)	(2.73)	(3.49)
Size		−4.38***									−4.97***	−4.97***
		(0.29)									(0.33)	(1.03)
BM			3.22***								3.21***	3.21
			(0.84)								(1.11)	(2.70)
Beta				4.12***							0.10	0.10
				(0.75)							(1.06)	(3.57)
Lev					1.06						4.35 * *	4.35
					(1.38)						(1.84)	(3.43)
CF						−10.97 * *					3.76	3.76
						(5.55)					(7.49)	(11.30)
Turnover							52.39***				37.00***	37.00*
							(3.87)				(4.94)	(19.00)
Spread								−5.45***			−7.37***	−7.37***
								(0.54)			(0.57)	(1.21)
PCM									5.61***		7.84***	7.84*
									(1.66)		(1.98)	(4.12)
HHI										0.23	1.79*	1.79
										(0.70)	(0.99)	(1.24)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm-Year
#	13,810	13,810	13,582	13,319	13,735	13,746	13,810	13,810	13,744	13,210	13,029	13,029
R^2	19.96%	21.99%	20.07%	20.37%	19.86%	19.88%	21.45%	20.99%	19.93%	19.80%	24.93%	24.93%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.12: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, Within Industry)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors, year fixed effects and industry fixed effects, where indicated. FF10 and FF17 indicate industry dummies according to the Fama & French 10 and 17 industry definition. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is July 1982 to June 2007.

	Baseline (1)	Agriculture (2)	Manufacturing (3)	Utilities (4)	Trade (5)	Finance (6)	Services (7)	Dummies (8)	Dummies (9)	Dummies (10)
SAU	−10.97***	−15.28**	−7.34*	−9.13**	−9.35	−2.32	−11.38	−7.80***	−5.57**	−4.66*
	(2.28)	(6.96)	(4.17)	(4.18)	(8.92)	(4.89)	(19.63)	(2.44)	(2.61)	(2.56)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry FE	N	N	N	N	N	N	N	Y	FF10	FF17
#	13,810	753	6,811	2,029	1,051	2,249	917	13,810	13,792	13,792
R^2	19.96%	27.15%	20.50%	25.51%	38.89%	44.58%	21.07%	20.24%	20.25%	20.08%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.13: Summary Statistics and Correlations for Firm Characteristics and Return Predictors (Benchmark Sample, all firms)

This table reports time series averages of annual cross-sectional means and standard deviations for firm characteristics and return predictors used in the subsequent analysis in Panel A and contemporaneous correlations of these variables in Panel B for all firms which have been part of the S&P500 between 1994 and 2009 independent of whether they have missing data on the frequency of price adjustment. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	Size (1)	BM (2)	Beta (3)	Lev (4)	CF (5)	Turnover (6)	Spread (7)	PCM (8)	HHI (9)
	Panel A. Means and Standard Deviations								
Mean	14.64	0.62	1.12	0.39	0.09	0.11	0.01	0.37	0.00
Std	1.29	0.38	0.45	0.24	0.06	0.09	0.01	0.19	0.00
N	678	664	649	673	674	678	678	673	642
	Panel B. Contemporaneous Correlations								
BM	−0.14								
Beta	−0.19	−0.23							
Lev	0.01	0.28	−0.20						
CF	0.17	−0.44	−0.01	−0.49					
Turnover	−0.19	−0.10	0.46	−0.17	0.03				
Spread	−0.33	0.14	0.10	0.07	−0.13	−0.02			
PCM	0.10	−0.33	0.10	−0.08	0.27	0.08	−0.13		
HHI	0.05	−0.05	−0.05	0.01	0.09	−0.06	0.01	0.00	

Table B.14: Summary Statistics and Correlations for Firm Characteristics and Return Predictors (Full Sample)

This table reports time series averages of annual cross-sectional means and standard deviations for firm characteristics and return predictors used in the subsequent analysis in Panel A and contemporaneous correlations of these variables in Panel B. SAU measures the frequency of price adjustment. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1963 to June 2011.

	SAU (1)	Size (2)	BM (3)	Beta (4)	Lev (5)	CF (6)	Turnover (7)	Spread (8)	PCM (9)	HHI (10)
	Panel A. Means and Standard Deviations									
Mean	0.15	14.11	0.69	1.10	0.40	0.10	8.76	1.54	0.36	0.24
Std	0.13	1.32	0.42	0.43	0.24	0.06	6.65	0.73	0.17	0.49
N	472	472	463	457	466	468	457	472	468	440
	Panel B. Contemporaneous Correlations									
Size	0.10									
BM	0.22	−0.20								
Beta	−0.15	−0.22	−0.17							
Lev	0.17	−0.07	0.25	−0.12						
CF	−0.06	0.21	−0.46	0.04	−0.50					
Turnover	−0.03	−0.23	−0.04	0.45	−0.04	0.01				
Spread	−0.01	−0.32	0.10	0.22	0.10	−0.13	0.26			
PCM	−0.14	0.13	−0.35	0.03	−0.08	0.25	0.01	−0.10		
HHI	−0.08	0.00	−0.06	0.00	0.02	0.06	−0.03	0.00	0.04	

Table B.15: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Full Sample)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. SAU treats missing values as interrupting price spells. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is regression the coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1963 to June 2011.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SAU	−7.87∗∗∗	−8.16∗∗∗	−4.16 ∗ ∗	−11.03∗∗∗	−5.35∗∗∗	−8.68∗∗∗	−8.24∗∗∗	−8.51∗∗∗	−8.21∗∗∗	−7.83∗∗∗	−8.11∗∗∗	−5.17∗∗∗
	(1.68)	(1.71)	(1.87)	(1.94)	(1.63)	(1.78)	(1.74)	(1.67)	(1.81)	(1.74)	(1.77)	(2.17)
Size			−4.29∗∗∗									−4.66∗∗∗
			(0.21)									(0.25)
BM				4.25∗∗∗								4.04∗∗∗
				(0.56)								(0.72)
Beta					5.13∗∗∗							2.77∗∗∗
					(0.54)							(0.81)
Lev						2.05 ∗ ∗						5.34∗∗∗
						(1.03)						(1.42)
CF							−3.71					25.59∗∗∗
							(4.25)					(6.06)
Turnover								32.05∗∗∗				18.28∗∗∗
								(3.21)				(3.92)
Spread									−2.68∗∗∗			−5.24∗∗∗
									(0.34)			(0.44)
PCM										1.52		5.24∗∗∗
										(1.37)		(1.67)
HHI											1.48∗∗∗	1.49∗∗∗
											(0.39)	(0.52)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	22,602	22,602	22,602	22,169	21,889	22,30 1	22,400	21,909	22,602	22,389	21,046	20,291
R^2	0.07%	25.29%	27.53%	25.52%	25.75%	25.29%	25.19%	26.00%	25.63%	25.18%	25.23%	29.29%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.16: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, Unwinsorized)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SAU	−11.25∗∗∗	−12.17∗∗∗	−8.75∗∗∗	−13.21∗∗∗	−8.29∗∗∗	−12.60∗∗∗	−12.13∗∗∗	−10.80∗∗∗	−11.68∗∗∗	−11.71∗∗∗	−11.69∗∗∗	−7.43 ∗ ∗
	(2.89)	(3.02)	(3.18)	(3.20)	(2.98)	(3.05)	(3.03)	(2.88)	(3.07)	(2.97)	(3.08)	(3.35)
Size			−5.77∗∗∗									−5.95∗∗∗
			(0.47)									(0.47)
BM				1.85∗								1.39
				(0.97)								(1.14)
Beta					7.42∗∗∗							0.27
					(1.19)							(1.45)
Lev						2.92						3.82
						(2.03)						(2.34)
CF							−23.70∗					−0.72
							(14.32)					(9.79)
Turnover								62.50∗∗∗				48.29∗∗∗
								(7.19)				(7.55)
Spread									−2.13∗∗∗			−4.82∗∗∗
									(0.82)			(1.09)
PCM										0.65		2.99∗∗∗
										(0.65)		(0.73)
HHI											0.11	0.71 ∗ ∗
											(0.22)	(0.28)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,810	13,810	13,810	13,582	13,319	13,735	13,746	13,810	13,810	13,744	13,210	13,029
R^2	0.10%	13.89%	16.51%	14.49%	14.52%	13.82%	13.95%	16.32%	14.28%	13.78%	13.66%	20.03%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.17: Mean Portfolio Returns (Alternative Measures of Price Stickiness)

This table reports time series averages of annual equally weighted portfolio raw returns for various sample periods with Newey and West (1987) standard errors in parentheses. Stocks are assigned to one of five baskets based on the frequency of price adjustment. SA treats missing values as interrupting price spells, for SB, missing values do not interrupt price spells if the price is the same before and after periods of missing values, and SC forms the union of the two. Equally (U) and value of shipment weighted (W) probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics.

	Sticky (1)	S2 (2)	S3 (3)	S4 (4)	Flexible (5)	S1-S5 (6)
			Panel A. Annual Mean Returns (SBU)			
07/1963 - 06/2011	18.98***	17.87***	18.23***	17.19***	16.07***	2.91***
	(2.66)	(1.98)	(1.98)	(2.29)	(2.11)	(1.05)
07/1982 - 06/2007	23.88***	21.40***	21.71***	21.51***	20.36***	3.52**
	(2.85)	(2.66)	(2.53)	(2.44)	(2.40)	(1.61)
07/1982 - 06/1998	28.23***	24.93***	24.81***	25.04***	22.74***	5.50***
	(3.25)	(2.96)	(3.15)	(2.68)	(2.98)	(1.25)
			Panel B. Annual Mean Returns (SCU)			
07/1963 - 06/2011	19.03***	17.89***	18.15***	17.25***	16.03***	3.00***
	(2.70)	(1.98)	(1.95)	(2.27)	(2.14)	(1.09)
07/1982 - 06/2007	24.00***	21.42***	21.58***	21.52***	20.34***	3.66**
	(2.87)	(2.62)	(2.54)	(2.36)	(2.50)	(1.65)
07/1982 - 06/1998	28.40***	24.97***	24.67***	24.88***	22.83***	5.57***
	(3.22)	(2.96)	(3.14)	(2.68)	(3.03)	(1.33)
			Panel C. Annual Mean Returns (SAW)			
07/1963 - 06/2011	18.66***	17.88***	18.13***	17.27***	16.00***	2.66*
	(2.58)	(2.05)	(2.05)	(2.23)	(1.89)	(1.43)
07/1982 - 06/2007	23.80***	21.14***	21.97***	21.44***	19.61***	4.19**
	(2.49)	(2.90)	(2.51)	(2.30)	(2.58)	(1.82)
07/1982 - 06/1998	27.49***	25.10***	25.28***	24.69***	22.02***	5.47***
	(3.13)	(3.22)	(3.15)	(2.79)	(2.79)	(1.72)

Standard errors in parentheses continued on next page

$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.17: Continued from Previous Page

	Sticky (1)	S2 (2)	S3 (3)	S4 (4)	Flexible (5)	S1-S5 (6)
			Panel D. Annual Mean Returns (SBW)			
07/1963 - 06/2011	19.04***	17.23***	17.87***	17.11***	16.54***	2.49*
	(2.69)	(1.95)	(1.88)	(2.43)	(1.93)	(1.30)
07/1982 - 06/2007	23.94***	20.24***	21.80***	21.37***	20.57***	3.38*
	(2.55)	(2.80)	(2.42)	(2.37)	(2.68)	(2.01)
07/1982 - 06/1998	27.92***	23.91***	24.78***	25.12***	22.71***	5.22***
	(2.82)	(3.15)	(2.93)	(2.85)	(3.25)	(1.85)
			Panel E. Annual Mean Returns (SCW)			
07/1963 - 06/2011	18.89***	17.34***	17.87***	17.09***	16.56***	2.33*
	(2.70)	(1.94)	(1.88)	(2.44)	(1.93)	(1.31)
07/1982 - 06/2007	23.89***	20.25***	21.80***	21.34***	20.59***	3.29**
	(2.51)	(2.82)	(2.42)	(2.38)	(2.68)	(1.99)
07/1982 - 06/1998	27.79***	24.00***	24.78***	25.12***	22.71***	5.08***
	(2.79)	(3.18)	(2.93)	(2.85)	(3.25)	(1.83)

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.18: Mean Portfolio DGTW adjusted Returns (Alternative Measures of Price Stickiness)

This table reports time series averages of annual equally weighted characteristic adjusted (DGTW) portfolio returns following Daniel et al. (1997) returns for various sample periods with Newey and West (1987) standard errors in parentheses. Stocks are assigned to one of five baskets based on the frequency of price adjustment. SA treats missing values as interrupting price spells, for SB, missing values do not interrupt price spells if the price is the same before and after periods of missing values, and SC forms the union of the two. Equally (U) and value of shipment weighted (W) probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics.

	Sticky (1)	S2 (2)	S3 (3)	S4 (4)	Flexible (5)	S1-S5 (6)
	Panel A. Annual Mean DGTW adj Returns (SBU)					
07/1963 - 06/2011	4.89***	4.10***	4.10***	3.36***	2.04***	2.85***
	(1.23)	(0.32)	(0.40)	(0.64)	(0.84)	(0.94)
07/1982 - 06/2007	6.94***	4.47***	4.57***	4.57***	3.20***	3.74**
	(0.91)	(0.25)	(0.59)	(0.79)	(1.18)	(1.45)
07/1982 - 06/1998	6.97***	4.17***	3.66***	3.50***	1.52***	5.44***
	(0.39)	(0.40)	(0.49)	(0.36)	(0.39)	(0.56)
	Panel B. Annual Mean DGTW adj Returns (SCU)					
07/1963 - 06/2011	4.95***	4.09***	4.06***	3.37***	2.04***	2.91***
	(1.26)	(0.33)	(0.41)	(0.61)	(0.85)	(0.96)
07/1982 - 06/2007	7.07***	4.46***	4.49***	4.48***	3.26***	3.80***
	(0.91)	(0.24)	(0.62)	(0.80)	(1.15)	(1.47)
07/1982 - 06/1998	7.10***	4.24***	3.52***	3.36***	1.62***	5.48***
	(0.40)	(0.30)	(0.54)	(0.34)	(0.40)	(0.58)
	Panel C. Annual Mean DGTW adj Returns (SAW)					
07/1963 - 06/2011	4.67***	3.62***	4.06***	3.33***	2.34***	2.32*
	(1.30)	(0.31)	(0.43)	(0.58)	(0.81)	(1.23)
07/1982 - 06/2007	6.92***	4.12***	4.36***	4.50***	3.04***	3.88**
	(1.17)	(0.33)	(0.71)	(0.69)	(1.16)	(1.52)
07/1982 - 06/1998	6.35***	4.18***	3.44***	3.51***	1.26***	5.10***
	(0.56)	(0.43)	(0.37)	(0.22)	(0.59)	(0.99)

Standard errors in parentheses continued on next page

$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.18: Continued from Previous Page

	Sticky (1)	S2 (2)	S3 (3)	S4 (4)	Flexible (5)	S1-S5 (6)
	Panel D. Annual Mean DGTW adj Returns (SBW)					
07/1963 - 06/2011	5.16***	3.43***	3.66***	3.33***	2.53***	2.63 * *
	(1.32)	(0.30)	(0.51)	(0.70)	(0.93)	(1.19)
07/1982 - 06/2007	7.28***	3.24***	4.25***	4.51***	3.69***	3.59 * *
	(0.96)	(0.29)	(0.65)	(0.78)	(1.39)	(1.75)
07/1982 - 06/1998	7.05***	3.03***	3.30***	3.86***	1.53***	5.53***
	(0.44)	(0.37)	(0.28)	(0.36)	(0.62)	(0.89)
	Panel E. Annual Mean DGTW adj Returns (SCW)					
07/1963 - 06/2011	5.04***	3.57***	3.66***	3.31***	2.55***	2.49 * *
	(1.31)	(0.33)	(0.51)	(0.70)	(0.94)	(1.18)
07/1982 - 06/2007	7.18***	3.29***	4.25***	4.48***	3.72***	3.46 * *
	(0.93)	(0.29)	(0.65)	(0.78)	(1.41)	(1.72)
07/1982 - 06/1998	6.91***	3.12***	3.30***	3.86***	1.53***	5.38***
	(0.45)	(0.38)	(0.28)	(0.36)	(0.62)	(0.90)

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.19: Mean Portfolio Returns (SAU, S&P500)

This table reports time series averages of annual equally weighted portfolio raw returns for various sample periods with Newey and West (1987) standard errors in parentheses. Stocks are assigned to one of five baskets based on the frequency of price adjustment, SAU. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Panel A includes only firms which have been part of the S&P500 index at the end of June 1994 whereas Panel B focuses on firms which have been part of the S&P500 index at the end of June 2006.

	Sticky (1)	S2 (2)	S3 (3)	S4 (4)	Flexible (5)	S1-S5 (6)
	Panel A. S&P500 Constituents as of 06/30/1994					
07/1963 - 06/2011	16.55***	16.53***	17.32***	16.18***	14.74***	1.81
	(2.40)	(2.16)	(1.82)	(2.10)	(1.87)	(1.28)
07/1982 - 06/2007	20.30***	19.39***	19.87***	18.86***	17.26***	3.04**
	(3.33)	(3.16)	(2.88)	(2.99)	(3.12)	(1.38)
07/1982 - 06/1998	24.45***	23.66***	22.83***	22.53***	19.72***	4.73***
	(3.76)	(3.23)	(3.72)	(3.11)	(3.41)	(1.21)
	Panel B. S&P500 Constituents as of 06/30/2006					
07/1963 - 06/2011	20.44***	18.15***	17.96***	17.83***	16.28***	4.16**
	(3.04)	(2.44)	(2.28)	(2.62)	(2.04)	(1.66)
07/1982 - 06/2007	25.67***	22.57***	22.44***	22.32***	20.50***	5.17**
	(3.56)	(3.01)	(2.41)	(2.70)	(2.15)	(2.12)
07/1982 - 06/1998	30.91***	27.05***	26.45***	26.80***	23.04***	7.87***
	(3.30)	(2.63)	(3.05)	(2.63)	(2.37)	(1.31)

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.20: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, SAW)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SAW, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. SAW treats missing values as interrupting price spells. Value of shipments weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SAW	−8.08***	−8.93***	−6.35***	−10.52***	−6.91***	−9.10***	−8.96***	−8.02***	−8.55***	−7.60***	−8.78***	−5.67**
	(1.90)	(2.01)	(2.17)	(2.16)	(2.02)	(2.04)	(2.03)	(2.00)	(2.07)	(1.98)	(2.08)	(2.40)
Size			−4.30***									−4.93***
			(0.30)									(0.33)
BM				3.09***								3.25***
				(0.84)								(1.10)
Beta					4.03***							0.32
					(0.75)							(1.07)
Lev						1.23						4.69**
						(1.38)						(1.86)
CF							−9.82*					5.02
							(5.75)					(7.74)
Turnover								51.82***				35.97***
								(3.94)				(5.03)
Spread									−5.38***			−7.29***
									(0.54)			(0.58)
PCM										6.00***		8.42***
										(1.69)		(2.01)
HHI											0.21	1.65
											(0.70)	(1.01)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,507	13,507	13,507	13,302	13,016	13,446	13,450	13,507	13,507	13,450	12,920	12,754
R^2	0.09%	20.16%	22.13%	20.33%	20.58%	20.13%	20.15%	21.61%	21.18%	20.21%	20.07%	25.06%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.21: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, SBU)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SBU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firms level and reported in parentheses. SBU treats missing values as not interrupting price spells if the price is the same before and after periods of missing values. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SBU	−7.50***	−8.47***	−5.91**	−10.28***	−6.33***	−8.51***	−8.82***	−7.90***	−7.77***	−7.06***	−8.62***	−5.97**
	(2.16)	(2.27)	(2.44)	(2.49)	(2.26)	(2.32)	(2.32)	(1.32)	(2.25)	(2.23)	(2.35)	(2.71)
Size			−4.40***									−4.98***
			(0.29)									(0.33)
BM				3.04***								3.10***
				(0.85)								(1.10)
Beta					4.26***							0.15
					(0.74)							(1.05)
Lev						0.98						4.26**
						(1.40)						(1.84)
CF							−11.93**					2.45
							(5.59)					(7.38)
Turnover								12.01***				36.97***
								(1.32)				(4.92)
Spread									−5.47***			−7.38***
									(0.02)			(0.57)
PCM										5.89***		8.00***
										(1.65)		(1.96)
HHI											0.20	1.78*
											(0.70)	(0.99)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,810	13,810	13,810	13,582	13,319	13,735	13,746	13,810	13,810	13,744	13,210	13,029
R^2	0.06%	19.91%	21.96%	20.02%	20.34%	19.81%	19.84%	21.42%	20.95%	19.89%	19.76%	24.92%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.22: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, SBW)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SBW, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. SBW treats missing values as not interrupting price spells if the price is the same before and after periods of missing values. Value of shipments weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SBW	−5.45***	−6.42***	−4.14*	−7.90***	−4.66 **	−6.63***	−6.75***	−5.91***	−6.16***	−5.19***	−6.59***	−4.61 **
	(1.90)	(1.99)	(2.15)	(2.15)	(1.97)	(2.03)	(2.02)	(1.97)	(2.07)	(1.94)	(2.03)	(2.34)
Size			−4.32***									−4.94***
			(0.30)									(0.33)
BM				2.92***								3.15***
				(0.84)								(1.10)
Beta					4.18***							0.37
					(0.75)							(1.07)
Lev						1.17						4.61 **
						(1.40)						(1.86)
CF							−10.85*					3.68
							(5.79)					(7.62)
Turnover								52.02***				35.90***
								(3.94)				(5.02)
Spread									−5.39***			−7.30***
									(0.54)			(0.58)
PCM										6.35***		8.63***
										(1.68)		(1.99)
HHI											0.17	1.63
											(0.70)	(1.01)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,507	13,507	13,507	13,302	13,016	13,446	13,450	13,507	13,507	13,450	12,920	12,754
R^2	0.04%	20.11%	22.10%	20.27%	20.55%	20.08%	20.11%	21.57%	21.13%	20.17%	20.03%	25.05%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.23: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, SCU)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SCU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. SCU forms the union of SAU and SBU. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SCU	−7.41∗∗∗	−8.37∗∗∗	−5.80∗∗	−10.15∗∗∗	−6.25∗∗∗	−8.40∗∗∗	−8.71∗∗∗	−7.77∗∗∗	−7.69∗∗∗	−6.98∗∗∗	−8.52∗∗∗	−5.86∗∗
	(2.15)	(2.26)	(2.42)	(2.48)	(2.24)	(2.31)	(2.31)	(2.23)	(2.34)	(2.22)	(2.33)	(2.69)
Size			−4.40∗∗∗									−4.98∗∗∗
			(0.29)									(0.33)
BM				3.03∗∗∗								3.10∗∗∗
				(0.85)								(1.10)
Beta					4.27∗∗∗							0.15
					(0.74)							(1.05)
Lev						0.98						4.25∗∗
						(1.40)						(1.84)
CF							−11.91∗∗					2.43
							(5.60)					(7.38)
Turnover								52.63∗∗∗				36.95∗∗∗
								(3.87)				(4.92)
Spread									−5.47∗∗∗			−7.38∗∗∗
									(0.55)			(0.57)
PCM										5.90∗∗∗		8.02∗∗∗
										(1.65)		(1.96)
HHI											0.20	1.78∗
											(0.70)	(0.99)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,810	13,810	13,810	13,582	13,319	13,735	13,746	13,810	13,810	13,744	13,210	13,029
R^2	0.06%	19.91%	21.96%	20.01%	20.33%	19.81%	19.84%	21.42%	20.95%	19.89%	19.76%	24.91%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.24: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics (Benchmark Sample, SCW)

This table reports the results of regressing annual percentage returns on the frequency of price adjustment, SCW, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. SCW forms the union of SAW and SBW. Value of shipments weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SCW	−5.38∗∗∗	−6.35∗∗∗	−4.08∗	−7.80∗∗∗	−4.63 ∗ ∗	−6.56∗∗∗	−6.68∗∗∗	−5.82∗∗∗	−6.10∗∗∗	−5.14∗∗∗	−6.53∗∗∗	−4.54∗
	(1.88)	(1.98)	(2.13)	(2.13)	(1.95)	(2.01)	(2.00)	(1.96)	(2.06)	(1.93)	(2.02)	(2.32)
Size			−4.32∗∗∗									−4.94∗∗∗
			(0.30)									(0.33)
BM				2.91∗∗∗								3.15∗∗∗
				(0.84)								(1.10)
Beta					4.18∗∗∗							0.38
					(0.75)							(1.07)
Lev						1.17						4.61 ∗ ∗
						(1.40)						(1.86)
CF							−10.84∗					3.66
							(5.79)					(7.62)
Turnover								52.02∗∗∗				35.88∗∗∗
								(3.94)				(5.02)
Spread									−5.39∗∗∗			−7.30∗∗∗
									(0.54)			(0.58)
PCM										6.36∗∗∗		8.64∗∗∗
										(1.68)		(1.99)
HHI											0.18	1.63
											(0.70)	(1.01)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,507	13,507	13,507	13,302	13,016	13,446	13,450	13,507	13,507	13,450	12,920	12,754
R^2	0.04%	20.11%	22.10%	20.27%	20.55%	20.08%	20.11%	21.57%	21.13%	20.17%	20.03%	25.05%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.25: CAPM Regressions (Full Sample)

This table reports results for the unconditional CAPM in Panel A and the conditional CAPM in Panel B. Stocks are assigned to one of five baskets based on the frequency of price adjustment, SAU and returns are equally weighted at the portfolio level. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. α is the intercept and β the slope of times series regressions of monthly portfolio excess returns on a constant and the excess return of the CRSP value weighted index. OLS and Fama and MacBeth (1973) standard errors are reported in parentheses and Newey and West (1987) standard errors in brackets. The conditional CAPM is monthly estimated on a rolling basis over the last twelve months following the methodology of Lewellen and Nagel (2006). The sample period is July 1963 to June 2011.

	Sticky	S2	S3	S4	Flexible	S1-S5
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A. Unconditional CAPM			
α_p	0.50	0.48	0.47	0.42	0.40	0.10
SE_{OLS}	(0.08)∗∗∗	(0.07)∗∗∗	(0.08)∗∗∗	(0.07)∗∗∗	(0.08)∗∗∗	(0.09)
SE_{NW}	[0.13]∗∗∗	[0.08]∗∗∗	[0.11]∗∗∗	[0.09]∗∗∗	[0.10]∗∗∗	[0.10]
β_p	1.14	1.14	1.13	1.04	0.95	0.19
SE_{OLS}	(0.02)∗∗∗	(0.01)∗∗∗	(0.02)∗∗∗	(0.02)∗∗∗	(0.02)∗∗∗	(0.02)∗∗∗
SE_{NW}	[0.03]∗∗∗	[0.03]∗∗∗	[0.05]∗∗∗	[0.04]∗∗∗	[0.05]∗∗∗	[0.03]∗∗∗
			Panel B. Conditional CAPM			
α_p	0.44	0.45	0.45	0.41	0.41	0.03
SE_{FMB}	(0.03)∗∗∗	(0.02)∗∗∗	(0.03)∗∗∗	(0.02)∗∗∗	(0.03)∗∗∗	(0.03)
SE_{NW}	[0.11]∗∗∗	[0.08]∗∗∗	[0.09]∗∗∗	[0.08]∗∗∗	[0.08]∗∗∗	[0.09]
β_p	1.25	1.22	1.20	1.11	0.99	0.27
SE_{FMB}	(0.01)∗∗∗	(0.01)∗∗∗	(0.01)∗∗∗	(0.01)∗∗∗	(0.01)∗∗∗	(0.01)∗∗∗
SE_{NW}	[0.04]∗∗∗	[0.03]∗∗∗	[0.04]∗∗∗	[0.03]∗∗∗	[0.04]∗∗∗	[0.04]∗∗∗

Standard errors in parentheses

$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.26: Cash Flow and Discount Rate Betas (Full Sample)

This table reports results for a beta decomposition into cash-flow β, β_{CF}, and discount-rate β, β_{DR}, following Campbell and Vuolteenaho (2004) as well as their sum. GMM (Hansen (1982)) standard errors conditional on the estimated news series are reported in parentheses. Stocks are assigned to one of five baskets based on the frequency of price adjustment, SAU and returns are equally weighted at the portfolio level. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is from July 1963 to June 2011.

	Sticky	S2	S3	S4	Flexible	S1-S5
	(1)	(2)	(3)	(4)	(5)	(6)
$\beta_{p,CF}$	0.70∗∗∗	0.69∗∗∗	0.70∗∗∗	0.64∗∗∗	0.57∗∗∗	0.12∗∗∗
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.02)
$\beta_{p,DR}$	0.60∗∗∗	0.59∗∗∗	0.58∗∗∗	0.52∗∗∗	0.47∗∗∗	0.12∗∗∗
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.02)
β_p	1.29	1.28	1.28	1.16	1.04	0.24

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.27: Long-Horizon Predictability (Full Sample)

This table reports results for m-month forecasting regressions of log excess returns on the zero-cost portfolio of going long the portfolio of stocks with low frequencies of price adjustment, SAU, and shorting the portfolio of stocks with high frequencies of price adjustment on the log dividend-price ratio in Panel A, the break adjusted log dividend-price ratio in Panel B following the methodology of Lettau and Van Nieuwerburgh (2008) and the proxy for the consumption-wealth ratio of Lettau and Ludvigson (2001) in Panel C. For each regression the table reports OLS standard errors in parentheses, Newey and West (1987) standard errors in brackets, Hansen and Hodrick (1980) standard errors in curly brackets and Hodrick (1992) standard errors in angle brackets. Stocks are assigned to one of five baskets based on the frequency of price adjustment, SAU and returns are equally weighted at the portfolio level. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. The sample period is July 1963 to June 2011.

Horizon m (Months)	1	6	12	24	36	48	60
				Panel A. Dividend Price Ratio			
$b_{lh}^{(m)}$	0.00	0.01	0.01	0.03	0.05	0.09	0.13
SE_{NW}	[0.00]	[0.01]	[0.02]	[0.05]	[0.08]	[0.11]	[0.13]
SE_{HH}	{0.00}	{0.01}	{0.03}	{0.06}	{0.10}	{0.12}	{0.13}
SE_H	⟨0.00⟩	⟨0.02⟩	⟨0.03⟩	⟨0.07⟩	⟨0.10⟩	⟨0.12⟩	⟨0.15⟩
R^2	0.04%	0.20%	0.33%	0.57%	1.41%	2.92%	4.64%
				Panel B. Break Adjusted Dividend Price Ratio			
$b_{lh}^{(m)}$	0.00	0.03	0.05	0.11	0.21	0.31	0.45
SE_{NW}	[0.01]	[0.02]	[0.05]	[0.09]	[0.13]	[0.16] **	[0.16]***
SE_{HH}	{0.01}	{0.03}	{0.06}	{0.11}	{0.15}	{0.16}*	{0.14}***
SE_H	⟨0.01⟩	⟨0.03⟩	⟨0.06⟩	⟨0.10⟩	⟨0.15⟩	⟨0.18⟩*	⟨0.21⟩ **
R^2	0.16%	1.01%	1.79%	3.15%	6.63%	10.38%	16.27%
				Panel C. Consumption Wealth Ratio			
$b_{lh}^{(m)}$	0.20	1.28	2.62	4.99	6.82	8.36	10.14
SE_{OLS}	(0.05)***	(0.13)***	(0.18)***	(0.26)***	(0.34)***	(0.43)***	(0.52)***
SE_{NW}	[0.05]***	[0.23]***	[0.45]***	[0.81]***	[1.09]***	[1.24]***	[1.50]***
SE_{HH}	{0.05}***	{0.27}***	{0.54}***	{0.95}***	{1.09}***	{1.08}***	{1.41}***
SE_H	⟨0.05⟩***	⟨0.29⟩***	⟨0.58⟩***	⟨1.19⟩***	⟨1.66⟩***	⟨2.16⟩***	⟨2.92⟩***
R^2	2.52%	15.19%	28.36%	40.37%	43.27%	41.74%	42.72%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.28: Long Horizon Predictability: HML and Market (Benchmark Sample)

This table reports results for m-month forecasting regressions of log excess returns on the zero-cost portfolio of going long the portfolio of stocks with high book to market values of equity and shorting the portfolio of stocks with low book to market values of equity of Fama and French (1993), HML, in Panel A, and the CRSP value weighted excess return in Panel B on the proxy for the consumption wealth ratio of Lettau and Ludvigson (2001). For each regression the table reports OLS standard errors in parentheses, Newey and West (1987) standard errors in brackets, Hansen and Hodrick (1980) standard errors in curly brackets and Hodrick (1992) standard errors in angle brackets. The sample period is July 1982 to June 2007.

Horizon m (Months)	1	6	12	24	36	48	60
				Panel A. HML			
$b_{lh}^{(m)}$	−0.13	−0.89	−1.82	−4.09	−6.35	−7.18	−8.11
SE_{NW}	[0.07]*	[0.35] **	[0.84] **	[1.52]***	[2.35]***	[3.84]*	[4.40]*
SE_{HH}	{0.07}*	{0.40} **	{0.94}*	{1.38}***	{2.47} **	{4.74}	{4.66}*
SE_H	⟨0.07⟩*	⟨0.44⟩ **	⟨0.94⟩*	⟨2.08⟩ **	⟨3.54⟩*	⟨5.06⟩	⟨5.21⟩
R^2	0.56%	3.10%	5.22%	10.95%	20.40%	20.82%	20.97%
				Panel B. Market Excess Return			
$b_{lh}^{(m)}$	0.05	0.61	1.67	4.77	9.67	14.30	14.71
SE_{NW}	[0.10]	[0.49]	[1.01]*	[2.64]*	[4.69] **	[5.10]***	[5.01]***
SE_{HH}	{0.10}	{0.56}	{1.17}	{3.18}	{5.38}*	{5.37}***	{5.37}***
SE_H	⟨0.10⟩	⟨0.61⟩	⟨1.27⟩	⟨2.80⟩*	⟨4.97⟩*	⟨8.26⟩*	⟨9.10⟩
R^2	0.04%	0.99%	3.51%	11.91%	25.00%	34.99%	32.31%

Standard errors in parentheses

$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.29: Panel Regressions of Annual Stock Returns on Price Stickiness and Firm Characteristics at the Portfolio Level (Benchmark Sample)

This table reports the results of regressing annual percentage returns at the portfolio level on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects, where indicated. Stocks are assigned to one of five basket based on their frequency of price adjustment, SAU, and returns and firm characteristics equally weighted at the portfolio level. Standard errors are clustered at the portfolio level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SAU	−10.94***	−10.62***	−4.54*	−25.79***	−32.27***	−15.19***	−12.03***	−7.71***	−10.65***	−16.34	−10.42***	−29.99**
	(2.30)	(2.77)	(2.75)	(9.91)	(6.16)	(3.05)	(2.02)	(0.61)	(3.02)	(11.41)	(2.89)	(14.66)
Size			−7.11***									−13.42***
			(1.57)									(0.67)
BM				19.83								43.17
				(12.16)								(26.54)
Beta					−35.69***							−29.70
					(9.96)							(20.62)
Lev						13.86						−10.70
						(8.59)						(38.54)
CF							−87.68					166.61
							(55.86)					(156.07)
Turnover								75.59**				97.57
								(36.83)				(100.68)
Spread									−3.63			−7.34
									(6.80)			(5.18)
PCM										−27.00		21.26
										(40.34)		(58.26)
HHI											1.45	43.51***
											(8.54)	(12.93)
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	125	125	125	125	125	125	125	125	125	125	125	125
R^2	0.51%	93.28%	93.57%	93.50%	93.67%	93.35%	93.40%	93.39%	93.30%	93.31%	93.28%	94.49%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.30: Panel Regressions of Annual Realized Volatilities on Price Stickiness and Firm Characteristics (Benchmark Sample)

This table reports the results of regressing annual realized volatilities on the frequency of price adjustment, SAU, firm characteristics, return predictors and year fixed effects, where indicated. Standard errors are clustered at the firm level and reported in parentheses. Equally weighted probabilities of price adjustments are calculated at the firm level using the micro data underlying the Producer Price Index constructed by the Bureau of Labor Statistics. Realized volatilities are calculated as the square root of the sum of daily squared returns. Size is the natural logarithm of the market capitalization in thousands, BM is the book to market ratio, Beta is the regression coefficient on the market excess return in rolling times series regressions, Lev is financial leverage, CF measures cash flows, Turnover the fraction of shares traded to shares outstanding, Spread is the mean bid - ask spread, PCM is the price to cost margin and HHI the Herfindahl - Hirschman index of sales at the Fama & French 48 industry level. Stock level data are from CRSP and financial statement data from Compustat. The sample period is July 1982 to June 2007.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SAU	−9.92***	−9.81***	−7.44 * *	−7.76 * *	−0.54	−6.81 * *	−9.81***	−7.97	−10.76***	−8.70***	−10.36***	−7.07***
	(3.23)	(3.17)	(2.92)	(3.12)	(2.19)	(3.09)	(3.20)	(84.64)	(2.88)	(3.13)	(3.21)	(2.73)
Size			−3.55***									−4.97***
			(0.28)									(0.33)
BM				−3.56***								3.21***
				(0.89)								(1.11)
Beta					18.40***							0.10
					(0.65)							(1.06)
Lev						−8.79***						4.35 * *
						(1.55)						(1.84)
CF							−10.71*					3.76
							(5.74)					(7.49)
Turnover								2.18				37.00***
								(2.71)				(4.94)
Spread									6.31***			−7.37***
									(0.53)			(0.57)
PCM										4.07*		7.84***
										(2.13)		(1.98)
HHI											−2.00***	1.79*
											(0.57)	(0.99)
											(0.00)	
Year FE	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#	13,839	13,839	13,839	13,611	13,348	13,764	13,775	13,839	13,839	13,773	13,239	13,029
R^2	0.58%	23.11%	30.37%	24.52%	46.14%	24.76%	23.35%	44.34%	30.69%	23.40%	24.29%	24.93%

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table B.31: Model Implied Stock Returns (2 Sectors)

This table reports annualized mean excess returns for simulated data of the model of Section 2.4, the model implied equity risk premium (ERP), the Sharpe ratio (SR) as well as the sensitivity (β_{SAU}) of annualized returns on the monthly frequency of price adjustment: $R_{jk,t} = \alpha + \beta_{SAU} \times (1 - \theta_k)$. A two sector version of the model is calibrated using standard parameter values reported in Table 2.11 and the empirical distribution of the frequency of price adjustment of Nakamura and Steinsson (2008). The model is solved using a second order approximation as implemented in dynare employing the pruning package of Andreasen et al. (2013), calibrated at a quarterly frequency and simulated for 400 firms in each sector for 500 periods discarding the first 250 periods as burn in in the left half of the table. The right half reports results for a claim on industry dividends directly.

		Firm Level						Sector Level				
		Sticky	Flexible	S1-S2	ERP	SR	β_{SAU}	Sticky	Flexible	S1 - S2	ERP	SR
(1)	Baseline	8.08	7.33	0.76	7.71	0.36	−0.86***	6.90	6.82	0.08	6.86	0.49
(2)	Large spread in θ_k	9.74	7.30	2.44	8.52	0.33	−2.74***	6.92	6.82	0.09	6.87	0.49
(3)	Equal Frequencies	7.09	7.09	0.00	7.09	0.49		6.83	6.83	0.00	6.83	0.49
(4)	Flexible Prices	7.49	7.49	0.00	7.49	0.50		6.78	6.78	0.00	6.78	0.47
(5)	$\epsilon_c = \epsilon_{ck} = 12$	10.41	7.25	3.16	8.83	0.33	−3.55***	6.90	6.85	0.05	6.87	0.49
(6)	$\epsilon_c = \epsilon_{ck} = 8$	6.91	7.34	-0.43	7.13	0.45	0.48***	6.84	6.82	0.02	6.83	0.49
(7)	$\epsilon_{ck} = 13$	11.66	7.29	4.37	9.47	0.31	−4.91***	6.94	6.83	0.11	6.88	0.49
(8)	$\epsilon_{ck} = 11$	8.42	7.31	1.11	7.87	0.35	−1.25***	6.90	6.82	0.07	6.86	0.49
(9)	$\epsilon_c = 10$	10.04	7.27	2.77	8.66	0.33	−3.11***	6.91	6.83	0.07	6.87	0.49
(10)	$\epsilon_c = 6$	9.50	7.33	2.17	8.42	0.33	−2.43***	6.92	6.81	0.11	6.87	0.49
(11)	$\epsilon_w = 6$	9.31	7.27	2.04	8.29	0.36	−2.29***	6.92	6.80	0.11	6.86	0.50
(12)	$\sigma = 1$	9.36	7.15	2.21	8.25	0.37	2.48***	6.75	6.64	0.11	6.70	0.51
(13)	Shock std = 0.009	13.93	8.17	5.76	11.05	0.32	−6.47***	7.79	7.70	0.10	7.74	0.52
(14)	$\theta_w = 8$	9.40	7.26	2.14	8.33	0.35	−2.40***	6.92	6.80	0.11	6.86	0.50
(15)	$\phi_\pi = 1.3$	6.23	6.11	0.12	6.17	0.35	−0.14	5.70	5.60	0.09	5.65	0.41
(16)	$\phi_\pi = 0.5/4$	9.72	7.29	2.43	8.51	0.33	−2.73***	6.91	6.82	0.09	6.87	0.49
(17)	MP shocks only	8.74	6.58	2.16	7.66	0.29	−2.43***	6.49	6.50	-0.01	6.50	0.48
(18)	Technol shocks only	1.12	0.84	0.29	0.98	0.42	−0.32***	0.44	0.34	0.10	0.39	0.15
(19)	Interest Rate Smoothing	11.26	8.76	2.51	10.01	0.33	2.82***	8.61	8.60	0.01	8.60	0.42
(20)	$\phi_x = 0.975$	11.15	8.12	3.02	9.64	0.37	−3.40***	7.29	7.20	0.09	7.25	0.50
(21)	Unpruned 2^{nd} order	7.15	3.18	3.97	5.16	0.17	−4.46***	6.06	6.61	-0.55	6.33	0.39
(22)	Unpruned 3^{rd} order	9.98	3.75	6.23	6.87	0.19	−7.00***	9.37	6.39	2.98	7.88	0.36

$*p < 0.10, **p < 0.05, ***p < 0.01$