How Rigid Are Producer Prices?

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Abstract

How rigid are producer prices? Conventional wisdom is that producer prices are more rigid than and so play less of an allocative role than do consumer prices. In the 1987-2008 micro data collected by the U.S. Bureau of Labor Statistics for the PPI, we find that producer prices for finished goods and services in fact exhibit roughly the same rigidity as do consumer prices that include sales, and substantially less rigidity than do consumer prices that exclude sales. Large firms change prices two to three times more frequently than do small firms, and by smaller amounts, particularly for price decreases. Longer price durations are associated with larger price changes, though there is considerable heterogeneity in this relationship. Long-term contracts are associated with somewhat greater price rigidity for goods and services, though the differences are not dramatic. The size of price decreases plays a key role in inflation dynamics, while the size of price increases does not. The frequencies of price increases and decreases tend to move together, and so cancel one another out.

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1 Introduction

Prices are one of the classical objects of inquiry in economics. Their adjustment is thought to be the key to the efficiency of the market over other ways to organize the production and allocation of goods, such as central planning. At the same time, one of the established facts in the economics literature, starting with the first generation of pricing studies in the 1920s and 1930s, has been the apparent rigidity of prices which raises the question of other mechanisms that may be used to allocate goods efficiently.

A more recent literature, notably Barro (1977) and Carlton (1986), emphasizes how long-term relationships between buyers and sellers (formalized perhaps by an explicit contract) may substantially reduce the allocative role of prices in producer-to-producer transactions. This follows because quantities are also specified in the contract (Barro, 1977), the price specified in the contract is not available to other buyers (Carlton, 1986), or variations in a product's quality (via delivery delays and the like) alter its price (Carlton, 1983). From these papers, the conventional wisdom in the literature has come to be that producer prices are more rigid than and so play less of an allocative role than do consumer prices. Due to data availability constraints, there have traditionally been no direct measures enabling researchers to compare, say, the frequency of price change or other similar summary statistics for producer and consumer prices.

For the current macroeconomics literature, one of the most important measurement challenges remains characterizing the microeconomic sources of inflation. Since the seminal studies by Frederick Mills (1927) and Gardiner Means (1935), surprisingly few authors have looked at patterns of producer pricing behavior and the implications for aggregate price movements.[1] These types of studies are important as they deepen our understanding of monetary policy's impact on the real economy and as economists' assumptions about the nature and sources of aggregate price rigidities shape their policy recommendations on basic issues in monetary policy. In a June 2008 speech on, "Outstanding Issues in the Analysis of Inflation" Ben Bernanke noted that a better understanding of the factors that determine the pricing behavior of "price-setters themselves, namely businesses" is one of the major unresolved issues for monetary policymakers – while there are surveys available of house-

[1] Notable exceptions include Carlton (1986), Blinder, Canetti, Lebow, and Rudd (1998), and Stigler and Kindahl (1970).

holds, economists, and from markets of inflation-indexed securities, there is only very limited information about the determinants of firms' pricing behavior.

This paper uses confidential microeconomic data collected by the Producer Price Program of the U.S. Bureau of Labor Statistics to establish a new set of stylized facts about the patterns and determinants of firms' pricing behavior. The data are available on a monthly basis for a comprehensive set of industries from 1987 to the present.

We find, first, that price rigidity in finished goods producers prices is roughly comparable to the rigidity of consumer prices including sales, and substantially more flexible than the rigidity of consumer prices excluding sales. Second, we find strikingly different patterns of price adjustment for large and small firms. Across industries, large firms change prices much more frequently than do small firms, and by smaller amounts. Third, the size of price changes is positively related to the time since the last price change, though there is considerable heterogeneity in this relationship. The relationship is strengthened by weighting large firms appropriately in the data. Fourth, long-term contracts are associated with somewhat greater price rigidity for goods, but not as much for services. Finally, the size of price decreases plays a key role in inflation dynamics: The size of price increases is constant over the business cycle, but the size of price decreases varies with inflation. The frequencies of price increases and decreases tend to move together, and so cancel one another out.

Our paper relates to a rapidly growing literature that uses the microeconomic data underlying national CPIs and PPIs to catalogue stylized facts about the behavior of prices. This literature is surveyed by Klenow and Malin (2009). We find a somewhat higher frequency of price change for the U.S. PPI than found for most Euro-Area PPI's, as surveyed in Vermeuelen et al (2007), which is consistent with the differences found for CPI's between the two economies, as discussed in Dhyne et al (2006). We also find a somewhat higher frequency of price change than do Nakamura and Steinsson (2008) (hereafter, NS) for the U.S. PPI due to our use of firm-level weights in aggregating the data.

2 Data Description

The Producer Price Index is a set of indexes that measure the average change over time in the prices received by domestic producers of goods and services. To construct the PPI, the BLS surveys the prices of about 100,000 items each month to produce over 10,000 PPI's for individual products and groups of products.

The PPI program seeks to measure the "entire marketed output of U.S. producers."[2] Its main purpose is to capture price movements prior to the retail level, to "foreshadow subsequent price changes for businesses and consumers", to deflate GDP and other economic time series, and as the basis for contract escalation clauses in purchase and sales contracts. Sales and excise taxes are not included in the price data collected by the BLS, as they do not measure revenue going to the producer.[3]

Producers are selected for the PPI survey via a sampling of all the firms on file with the Unemployment Insurance System. A firm's probability of being chosen for inclusion in the PPI survey is related to its size measured by employment. After a firm has been selected and has agreed to participate in the survey (participation is voluntary), a probability sampling procedure is used to determine which of the firm's items will be included in the PPI. This procedure, known formally as disaggregation, iteratively selects items based on their share of the firm's total revenue. The BLS's need for coverage across broad product categories also guides the sampling selection process. The items produced by the firm are broken down by the field economist into categories, and each of those categories are broken down further by various price-determining characteristics, which may include item characteristics, such as color or size, and transaction characteristics, such as the nature of the buyer or the type of discount used. The final item chosen for inclusion in the PPI survey is defined as a specific product sold under particular contractual terms to a particular buyer. After this initial visit by the BLS field economist, the firm reports prices for the selected items on a monthly basis on a form provided by the BLS via the mail.

The BLS asks firms to report prices as of the Tuesday of the week containing the 13th of the month. Each month, roughly prices are collected from 30,000 establishments. If a firm fails to return its form in a given month, a BLS economist will generally follow up with a phone call. A firm will generally continue to report prices for a given item for 7 years, when a new sample is selected for the industry.

The price information provided by firms are aggregated into two classification systems,

[2] See PPI FAQ's: http://www.bls.gov/ppi/ppifaq.htm.

[3] These prices are also adjusted as necessary (using a producer-cost valuation) for changes in the quality associated with any given product. In addition, the *PPI* program has wholesale and retail "prices" that are trade margins, not actual prices.

one based on commodity classifications, and the second industry classifications. The commodity classification organizes products by their similarity of end use or material composition, regardless of their industry classification.[4] The BLS's stage-of-processing indexes combine the commodity classification system with the U.S. Bureau of Economic Analysis's industry-level input-output tables. The stage of processing indexes measure the share of each commodity that goes to final demand, where final demand is defined as the sum of personal consumption expenditure and business fixed investment. We compute a finished goods and services index for the PPI by using the BEA's input-output tables to compute the share the output of each services sector that goes to personal consumption expenditure and business fixed investment. The industry classification system, based on NAICS, organizes products by their industry of origin. Our construction of a finished goods and services index is intended to provide a more representative number to characterize the frequency and size of price changes for the economy as a whole than that given by the finished goods PPI.

We use data from the PPI's Research Database (PPI-RDB) from January 1987 to August 2008. Following the BLS's parlance, we call the longitudinal string of prices for a particular product produced by a particular establishment an item. We have roughly 300,000 items in the sample and the mean (median) life of a good in the index is 72 (70) months.

2.1 Estimation Issues

Forced item substitutions occur when a firm ceases production of an item in the sample, and the industry economist identifies a similar replacement item from the producer to price going forward. We follow KK and NS in including multiple versions of an item due to forced item substitutions in price-change calculations. The BLS does not explicitly flag forced item substitutions in the PPI as it does in the CPI, but does assign a new base price to the item. One complication is that new base prices are also assigned to all the items in an industry when the industry is resampled, which occurs every five to seven years. We identify forced item substitutions as cases where new base prices are assigned when the industry is *not* resampled. We find that price changes from forced item substitutions do not substantially boost the overall rate of price changes in the PPI, as they do in the CPI, as documented by

[4]The commodity classification of each industry's output can be find in Table 6A of the Census Bureau's industry series report.

NS and KK (2008).[5] The weighted median frequency of price changes from item substitutions is 0.00 for both goods and services, and the weighted mean frequency is 1 percentage point for goods and 3.3 percentage points for services. All the remaining frequency and duration measures we report in the paper include price changes from forced item substitutions.

Regarding outliers, we drop any price changes as implausibly large if the absolute size of the monthly price change exceeds four log points. These observations make up less than 0.1 percent of all price changes in the sample. There are very few sales in the PPI, so we do not exclude these observations from our analysis.

We only include transaction prices in our data, so prices may be missing due to stockouts or if the reporting firm is nonresponsive. Like KK (2008), we assume a price change observed through a set of missing values is a price change. This raises the median frequency of price change by several percentage points (from 6 percent to 9 percent) and differs from NS (2008) who do not count these as price changes.

The analysis of price durations is complicated by three facts: first, 20 percent of the items in our sample do not change price over their entire lives; second, a nontrivial share of the items in our sample change prices only once over their entire lives; third, there is considerable heterogeneity in pricing patterns across items in the sample. That is, to identify the true distribution of price durations, we face three estimation issues that are inextricably intertwined: Left and right censoring in the data, considerable heterogeneity in price durations across items, and a large share of items in the sample with no or one price change over their lifetime. There is no way to address all three issues cleanly.

The standard frequency approach used in the microeconomic pricing literature (e.g. KK (2008), NS (2008), and Alvarez et al (2005)) computes the median implied duration as the inverse of the frequency: -1/ln(1-fr) where fr is the median frequency of price change. One issue with this approach is that observations with complete price flexibility are dropped from the summary statistics (fr=1), as are observations with complete price rigidity (fr=0). To illustrate these issues, we also report naive counted durations to compare with the implied durations.

[5] As the PPI resamples all the products in an industry every 5-7 years, the newly sampled items that enter the PPI are not necessarily new item introductions, as they appear to be treated in NS (2008). In the CPI, as noted by KK (2008), "items are rotated every five years or more frequently" (p. 868): KK (2008) do not count these rotations as price changes.

The duration literature has extensively documented how censoring introduces biases into simple counted duration measures. In the presence of considerable heterogeneity and rigidity, however, dealing with the censoring issue correctly may introduce other biases, as one may drop items with no or only one price change from the analysis entirely. Aucremanne and Dhyne (2004) discuss this issue in some detail. A standard approach in the duration literature is to drop left-censored spells, and estimate hazard models for right-censored spells. This will clearly introduce severe downward bias into our estimates of average aggregate price spells. We report naive counted durations to illustrate the differences with the implied duration measures currently used in the literature, and discuss these issues further in the next section.

3 Stylized Facts

We begin by computing summary statistics for the frequency of price changes. Let $\{p_{it}\}$ denote the set of log price observations in item code i. Let γ_{it} be the gap in months between the price change at t and the previous observation. Let I_{it} be a price-change indicator: $I_{it} = 1$ if $p_{it} \neq p_{it-\gamma_{it}}$ and 0 otherwise. We aggregate this simple statistic first, across time for individual items, and then across the items in the sample. We start by calculating means within item codes for 1987-2008. Let i denote item codes and j cell codes. Then:

$$\overline{fr_i} \equiv \frac{\sum\limits_t I_{it}}{\sum\limits_t N_{it}}$$

gives the average frequency of price changes for item i over its lifetime.[6] We then aggregate across cell codes, which denote industries, within the sample. The weighted cell-code mean over the sample period is given by:

[6] KK (2008) use a maximum likelihood estimator to estimate the frequency of price changes. The monthly Poisson rate of price change for an item in a cell code is assumed to be common across items within the cell code, and across time.

$$\overline{fr_j} \equiv \frac{\sum_{i \in j} \omega_i \left| fr_i \right|}{\sum_{i \in j} \omega_i}$$

The summation in the numerator is across item codes within a cell code. The denominator is the sum of the weights across item codes within a cell code. The same calculation is then done across cell codes. The weighted mean for the sample as a whole is given by:

$$\overline{fr} \equiv \frac{\sum_{j} \omega_j \left| \overline{fr_j} \right|}{\sum_{j} \omega_j}$$

The summation in the numerator is across mean price changes for cell codes and the denominator is the sum of the weights for all cell codes in the sample. We follow a similar procedure to compute weighted medians. We first compute the average price change for each item, then compute the weighted median across items within a cell code using the BLS's unpublished item-code weights, which are derived from establishments' value-of-shipments data reported directly to the BLS, and then compute the weighted median across cell codes using the BLS's unpublished cell-code weights, which are derived from the Census's value-of-shipments data for the industry.

Table 1 reports the results for our baseline specification. We find that price rigidity in finished goods and services producers prices is roughly comparable to the rigidity of consumer prices including sales, and substantially more flexible than the rigidity of consumer prices excluding sales. The median frequency of price change is 14 percent, with a median implied duration between 5 and 6 months. These results for finished goods and services appear similar to those reported by Klenow and Kryvtov (2008) (hereafter, KK) for the CPI including sales. KK find a median duration of price spells of 4 months when sales are included. The median frequency is 16.5 percent for goods and 11.9 percent for services, with a median implied duration of 5 and 6 months, respectively. For finished goods, our numbers are roughly half the 9-month duration reported by NS for the PPI.

Table 2 attempts to shed light on this discrepancy. The bottom line is that NS do not use the BLS firm and industry weights that we incorporate. The first column of the table reports summary statistics produced following NS's reported method for computing weighted medians. NS calculate the mean frequency of price change for each item code, then take the unweighted median across item codes in a 4-digit commodity code, then take a value-weighted median across 4-digit commodity codes. A commodity code is more aggregate industry classification than the cell codes we use. For finished goods, for example, there are roughly 375 commodity codes, and several thousand cell codes. For finished goods, we replicate NS's results fairly closely, finding a median frequency of price change of 9.2 percent, with an implied duration of 9.5 months. The use of slightly different sampling windows likely explains the small differences in our results relative to NS – They report a weighted median frequency of 10.6 percent from 1988 to 1997 and 10.8 percent from 1998 to 2005, while we report results for 1987 to 2008.[7]

The next column shows what happens if one weights industries at the most disaggregate level using the value of shipments date provided by the Census. Weighting industries according to their importance in overall output accounts for some of the difference with NS, as the implied duration falls by one month, and the frequency of price change rises by a percentage point. The differences are not substantial, however.

The next column shows that weighting price changes by item weights has dramatic implications for the aggregate statistics. This raises the frequency of price change by 6.5 percentage points, and causes the implied duration to fall by half. BLS item weights have two main components: items are weighted by their establishment's value of sales (multiplied by the item's relative importance to total sales) and small firms are oversampled, that is, given larger weights relative to their output to compensate for budget limits that cause the BLS to undersample small firms relative to their overall importance in industry and aggregate output.

Table 2's final column incorporates only the value-of-shipments portion of the item weights to show that most of the difference from the NS results comes from weighting large firms according to their importance in overall output. This drives home the point that large firms seem to behave very differently from the median firm in the sample in their pricing

[7]In addition, as we discuss in detail in section 2, there are two other key differences in our analysis compared with NS: First, we use a different measure of forced item substitutions, and find they are much less important in aggregate price movements; and second, we treat price changes associated with missing observations differently.

behavior. Our use of item- and cell-code weights makes our summary statistics for the PPI more consistent with the indexes produced by the BLS itself, and with NS and KK's weighting of CPI data than results based on the finished goods PPI alone.

Finally, we find a somewhat higher mean frequency of price change for goods in the U.S. PPI, at 37 percent, than found for goods in most euro-area PPI's, 21 percent, as surveyed in Vermeuelen et al (2007).[8] This result is consistent with the differences found for CPI's between the two economies, as discussed in Dhyne et al (2006). We also find a higher frequency of price change than found by Blinder et al (1998) in surveys of U.S. firms.

Large firms change prices more frequently than small firms... Relatively little is known about firm-level heterogeneity in pricing behavior. To look in more detail at how large firms may price differently than small firms, Table 3 breaks up the firm size distribution into three tranches. The first column reports statistics for the bottom 1/3 of firms, the next the middle 1/3, and the next the top 1/3. We break out goods and services, as some of the patterns differ across the two sectors in important ways. Small firms change their prices about half as frequently as large firms: the duration of a price change is 13 months for the bottom 1/3 of firms, and 6 months for the top 1/3 of firms. Similar patterns are observed for services, though the patterns are slightly less dramatic. The bottom 1/3 of large firms change their prices every 12 months, while the bottom third change them every 8.8 months.

These results are consistent with a number of findings in the literature. Amirault et al (2005) find that large Canadian firms change prices twice as frequently as medium firms, and five times more frequently than small firms. They argue that the managerial costs associated with changing prices is particularly onerous for small frms. Buckle and Carlson (2000) find similar patterns for New Zealand firms. Fabiani et al (2005a) use a chi-square analysis to establish that that large firms review their prices more frequently than do small firms in five out of six euro-area countries (Spain, France, Luxembourg, the Netherlands, and Austria, with France being the exception). Hoeberichts and Stockman (2006) find small firms have more rigid prices than do large firms in the Netherlands. Finally, several studies analyzing CPI data from euro-area countries find that large retail outlets change prices much more

[8] Note that the euro-area studies do not use product- or firm-level weights in aggregating their frequency measures.

frequently than do small outlets (Jonker et al, 2004; Fabiani et al, 2005b, for Italy; and Dias et al, 2004, for Portugal).

And by smaller amounts. The size of downward changes is greater for small firms than large firms – when they do cut prices, they do so by a lot. The size of price changes appears symmetric for large firms though the frequency is not. The absolute size of price changes for goods is smaller for large firms, at 5.6 percent, relative to small firms, at 6.0 percent. This difference is entirely due to differences in the size of downward price changes. The bottom 1/3 exhibit median downward price changes of 6.7 percent compared to the top third at 5.6 percent.

Large firms make many very small price changes, while small firms make very few... Cartlon (1986) and Klenow and Kryvstov (2008) document a high fraction of price changes that are very small. We confirm their results – many of the results for many of the detailed product categories reported in Carlton are markedly higher than the numbers reported in Klenow and Kryvstov. In the categories of glass and trucks, for example, Carlton finds up to 67 percent of price changes are less than 2 percent in certain categories. We confirm this basic stylized fact, but show it varies in important ways over the firm size distribution. Table 4 shows that for the smallest 1/3 of firms, the weighted median across goods of the share of price changes below one percent is 0 percent, while for the largest 1/3 it is 21 percent. Similarly, while 32 percent of the price changes of small firms are below 5 percent, 51 percent of the largest 1/3 are firms are.

To assess whether these results about firm size can be explained by industry characteristics, we consider whether the frequency of price change in each of our product categories is related to market structure measures like concentration ratios. Like Bils and Klenow (2004), we find that there is not a robust relationship between the two measures.

Longer price spells are associated with larger absolute price changes. Conventional wisdom received from an earlier generation of studies (e.g. Carlton (1986)) was a positive correlation between the average degree of price rigidity (duration from one price change to the next) and the average absolute size of price changes, as summarized by Carlton

(1986, p. 638) "The more rigid are prices, the greater is the price change when prices do change."

Recent empirical evidence, based on more complete data sets than used in the past, found no relation between duration and size of price change. KK (2008) argue that the CPI data show "the size of price changes is unrelated to the time since the previous change (for a given item)" p. 20). Similar results were found in Gopinath and Rigobon (2008). Our results are presented in Table 5 and show that there is a positive relationship between the two, though there is considerable heterogeneity in the relationship. The average correlation across industries is 16 percent and goes as high as 34 percent for Transportation Equipment and 29 percent for Rubber and Plastic Products. These patterns may be more consistent with time-dependent than state-dependent pricing by firms.

Long-term contracts are associated with somewhat greater price rigidity, though the results are not dramatic. Fabiani et al (2005a) and Blinder et al (1998) find explicit contracts to be one of the main sources of price rigidity according to firms self-reporting in surveys. Carlton (1986) finds greater price rigidity in long-term than short-term contracts. The BLS data include information on whether a product is sold under a contract, defined as long-term agreement with multiple deliveries, when this is identified as a price-determining variable by the reporting firm. Table 6 shows that we can confirm this stylized fact for goods and services, although the results are not dramatic. The median price duration is slightly higher for goods and services sold under contract, and the absolute sizes of price changes are slightly less. But in both cases, the results are fairly subtle, and certainly not as dramatic as the results for firm sizes.

The size of price decreases is a key driver of inflation dynamics. Relatively little is known about how firms pricing behavior evolves over time and the business cycle. To document firms' pricing patterns over time requires a different aggregation of the data, across goods at a given point in time, rather than across time for a given good, as in the statistics reported thus far. Within each month, we weight price changes (observations with $I_{it} = 1$) in proportion to the item code and cell code weights in the PPI-RDB. Let i denote item codes and j cell codes. The weighted cell-code mean over the sample period is given by:

$$\left|\overline{fr_t}\right|_j \equiv \frac{\sum_{i\in j} \omega_i \left|I_i\right|}{\sum_{i\in j} \omega_i}$$

The summation in the numerator is for the relevant statistic across item codes within a cell code for each month. The denominator is the sum of the weights for items in a cell code. The same calculation is then done across cell codes to arrive at a single number for the economy as a whole, at each point in time (month or year). In this case, the summation in the numerator is across mean price changes for cell codes and the denominator is the sum of the weights for all cell codes in the economy. The mean for the sample as a whole over the sample period is given by:

$$\left|\overline{fr_t}\right| \equiv \frac{\sum_{j} \omega_{jt} \left|\overline{fr_t}\right|_j}{\sum_{j} \omega_{jt}}$$

Table 6 shows the mean, standard deviation, and correlation of each of these margins with producer price inflation. Like KK, we find the correlation of the size of price changes to be higher than that for frequency, at 0.78 and 0.15, respectively. In these simple correlations, the correlation of inflation with the frequency of price increases appears greater with the frequency of decreases, at 0.46 relative to -0.26, respectively. The size of price increases has a moderate correlation, at 0.22, while the size of price decreases has a significant negative correlation, at -.40. In the time-series data for the finished goods and services index, the correlation between duration and the size of price changes is negative, as -.1154. When durations rise, the size of price changes falls, which means the size of price decreases rises more than the size of price increases. Accordingly, the correlation between duration and the size of price increases is -.0003, while that between duration and the size of price decreases is positive, at .0349. The correlation between duration and inflation is negative, as one would expect, at -.1214.

The regressions in Table 7 shows that the size of price decreases seems to play a significant role in variation in inflation, particularly over horizons of one year. In this case, while the coefficients on the frequency of price increases and decreases cancel one another out, the coefficient on the size of price decreases is much greater than that on the size of price increases. Of the four margins considered here, the size of price decreases appears to have a unique relationship to movements in aggregate inflation. Figures 1, 2, and 3 illustrate how the frequencies of price increases and decreases tend to move together over time, cancelling one another out. The sizes of price increases is quite flat over time, while the size of price decreases varies inversely with inflation. This comovement is particularly striking in Figure 2.

Next, we compute the relative importance of each of these margins in several inflation decompositions. The first decomposition relates the intensive margin and extensive margin– the size-effect and frequency-effect of changing prices, respectively – to the variation in overall inflation. This exercise replicates the CPI decomposition in KK (2008). Because inflation can be represented as the average price change across goods at a point in time (the intensive margin) multiplied by the proportion of items changing price at a point in time (the extensive margin), we can also represent the variance of inflation as a function of the variance of the intensive margin, the variance of the extensive margin, and their covariance. Taking a first-order Taylor series expansion of inflation around the frequency and size sample means gives:

$$var\left(\pi_t\right) = var\left(dp_t\right) \cdot \overline{fr}^2 + var\left(fr_t\right) \cdot \overline{dp}^2 + 2\overline{fr} \cdot \overline{dp} \cdot cov\left(fr_t, dp_t\right)$$

Dividing the intensive margin (the first term) by the total variation in inflation gives the share of variation in inflation caused by fluctuations in the size of price changes over time. Using the extensive-margin terms (the second two terms in the equation) in an analogous fashion gives the share of inflation variability attributable to variation in the frequency of price changes. Table 9 reports that variation of the size of price changes, rather than the variation of the frequency of price changes, is responsible for 75% of the variation in inflation.

A second decomposition, also reproduced from KK (2008) separates inflation into two components: positive price movements, and negative price movements. Aggregate inflation is the net price movement, or the sum of the average (across goods) price increase at a point in time multiplied by the fraction of items with price increases, and the average (across goods) price decrease at a point in time multiplied by the fraction of items with price decreases. We characterize the variation in inflation as the sum of the variation in positive price movements and the variation in negative price movements, less double their covariance:

$$var\left(\pi_t\right) = var\left(pos_t\right) + var(neg_t) - 2cov(pos_t, neg_t)$$

We divide the positive price terms (the first two terms) by the total calculated variation and the negative price terms (the second two terms) by the total calculated variation to gauge each's contribution to overall inflation variability. Table 9 reports that the size of negative price changes weighted by their frequency explains 60% of the variation in inflation, while the size of positive price changes weighted by their frequency explains 40% of the variation in inflation.

The third decomposition also uses the relationship between inflation, positive price movements, and negative price movements, but considers the behavior of the deviation of inflation from its trend at a single point in time, rather than its variance over time. This decomposition, which we will refer to as the demeaned inflation decomposition, is reproduced from the Belgian PPI decomposition in Cornille and Dossche (2008), and allows us to observe the contributions to changes in aggregate inflation across time. The demeaned inflation decomposition is calculated as the level of inflation at a point in time less the average positive and negative price movements:

$$\begin{aligned}
\pi_t - \overline{pos}_t - \overline{neg}_t &= \pi_t - \overline{fr_t^+ dp_t^+} - \overline{fr_t^- dp_t^-} \\
&= \overline{fr_t^+}\left(dp_t^+ - \overline{dp_t^+}\right) + \overline{fr_t^-}\left(dp_t^- - \overline{dp_t^-}\right) + \overline{dp_t^+}\left(fr_t^+ - \overline{fr_t^+}\right) + \\
&\quad \overline{dp_t^-}\left(fr_t^- - \overline{fr_t^-}\right) + \left(fr_t^+ - \overline{fr_t^+}\right)\left(dp_t^+ - \overline{dp_t^+}\right) + \left(fr_t^- - \overline{fr_t^-}\right)\left(dp_t^- - \overline{dp_t^-}\right)
\end{aligned}$$

The right-hand side of the equation is produced by simply rearranging terms after subtracting the average upward and downward price movements. Each term separated by an addition sign is a separate element of the decomposition, and can be parsed into positive size-effects, negative size-effects, positive frequency-effects, negative frequency-effects, positive mixed-effects, and negative mixed-effects, respectively. Breaking down the components of inflation to more detailed levels, as in the demeaned inflation decomposition, shows us that the most important contributors to inflation vary over time, as illustrated in Figure 4. Though the degree of contribution made by each component to inflation fluctuates, the frequency of positive price changes plays a generally more important role than the size of price increases, while the size of price decreases appears more salient than the frequency of price decreases, especially at business-cycle downturns (i.e. 2001 recession). The mixed components contribute far less to inflation than any of the other components.

4 Conclusion

In the 1987-2008 micro data collected by the U.S. Bureau of Labor Statistics for the PPI, large firms change prices two to three times more frequently than do small firms, and by smaller amounts, particularly for price decreases. Longer price durations are associated with larger price changes, though there is considerable heterogeneity in this relationship. Long-term contracts are associated with somewhat greater price rigidity for goods and services. The size of price decreases plays a key role in inflation dynamics, while the size of price increases does not. The frequencies of price increases and decreases tend to move together, and so cancel one another out. Overall, producer prices for finished goods and services exhibit the same rigidity as consumer prices that include sales, and substantially less rigidity than consumer prices that exclude sales.

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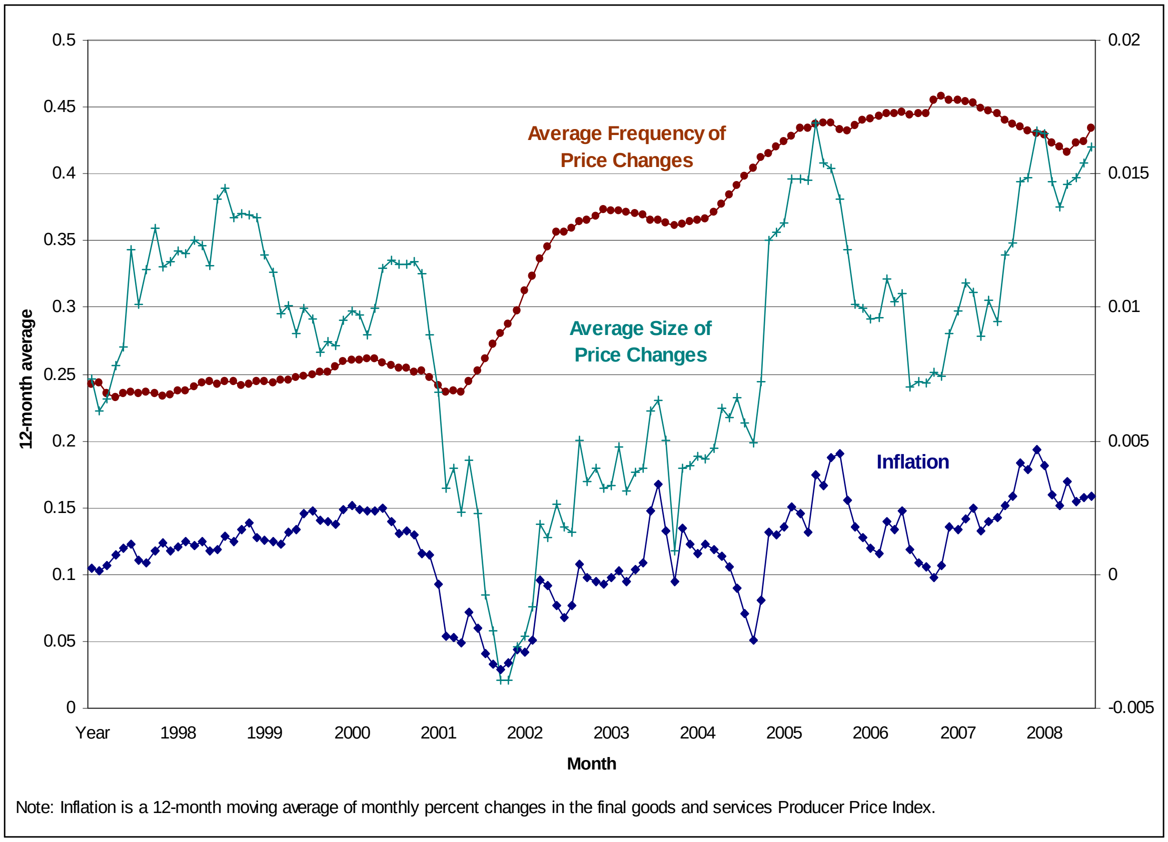

Figure 1: Inflation and the Size and Frequency of Price Changes.

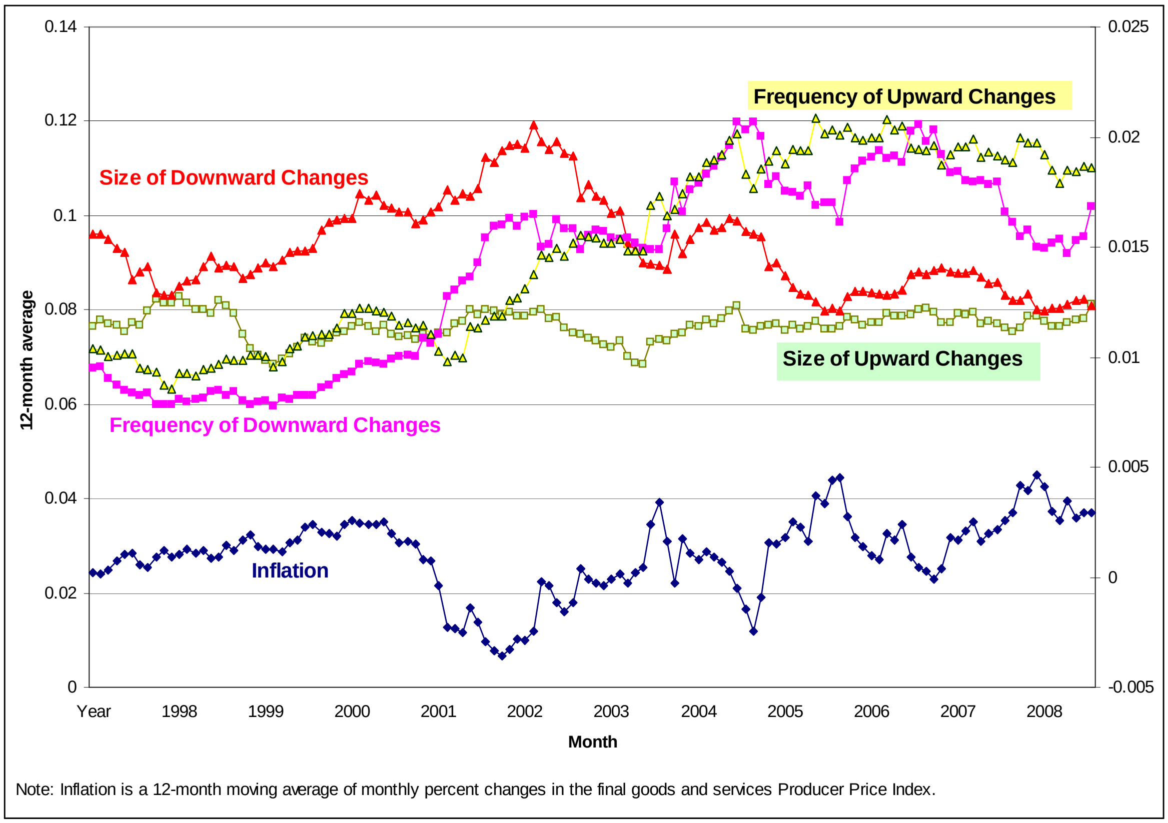

Figure 2: Inflation Due to Price Increases and Decreases.

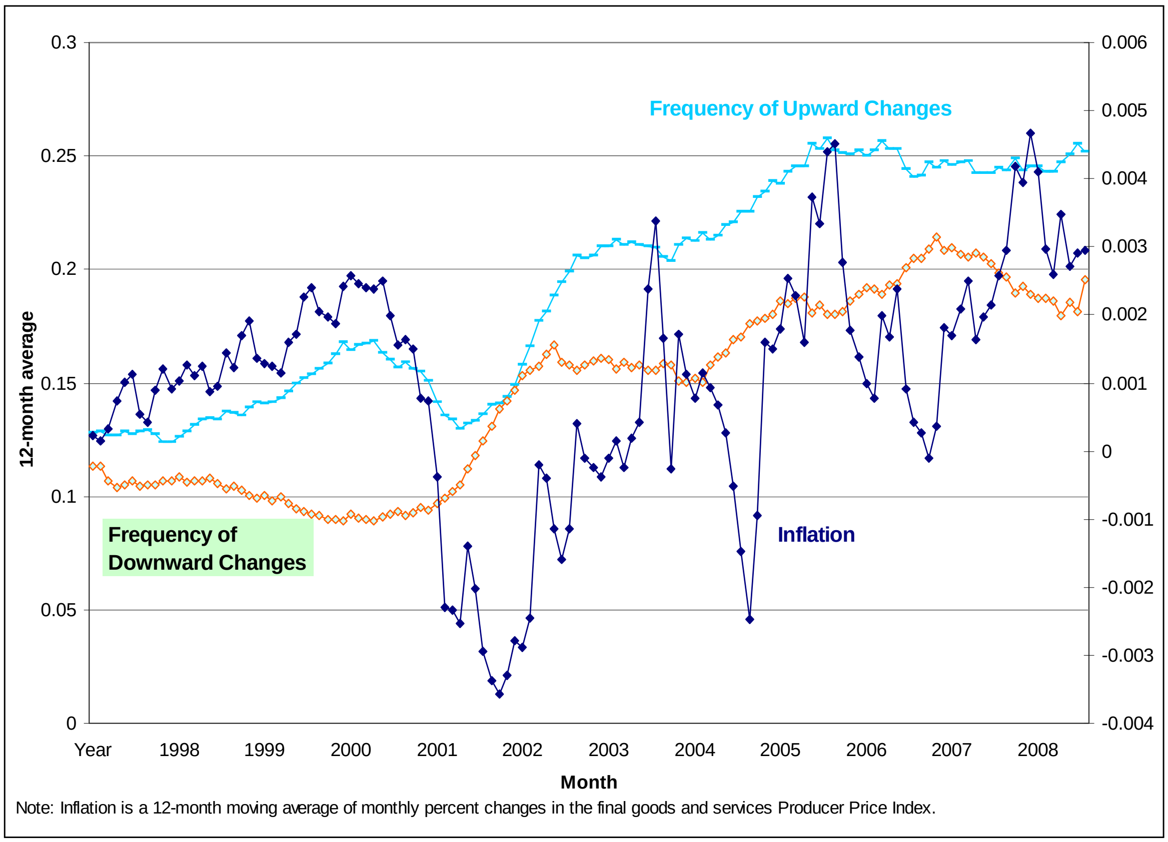

Figure 3: Inflation and the Frequency of Price Increases and Decreases.

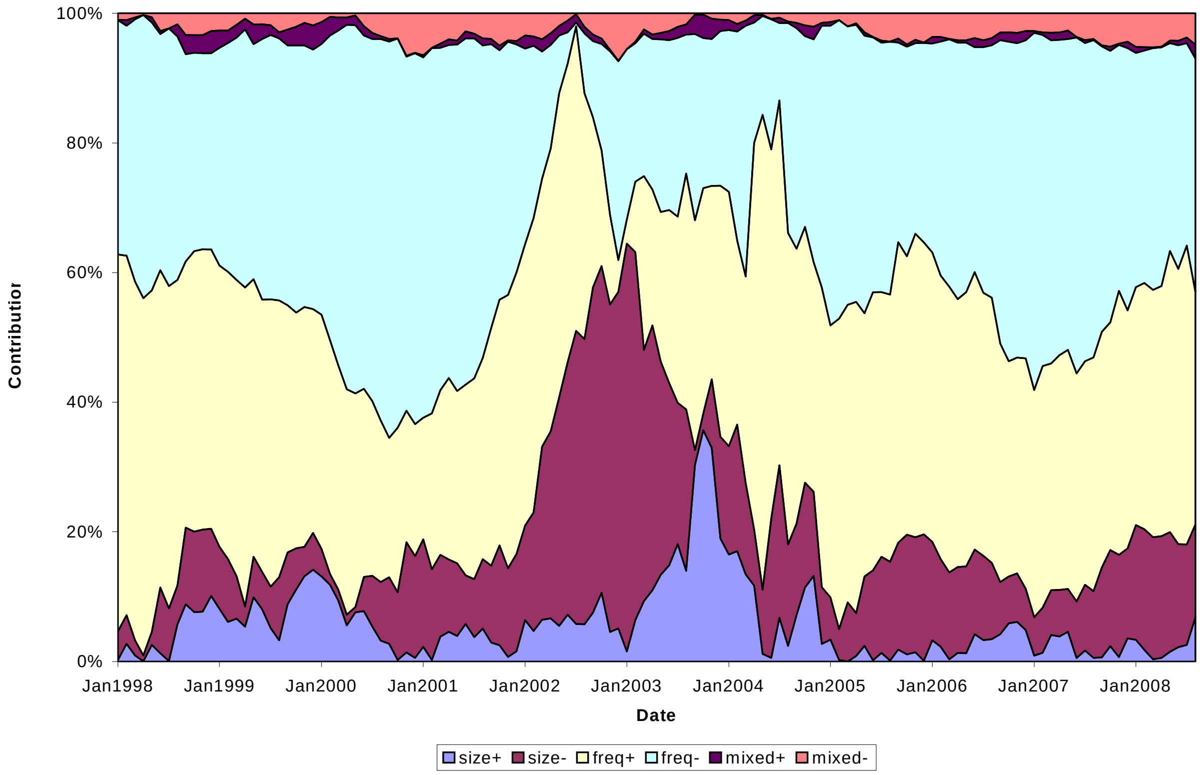

Figure 4: Decomposition of Producer Price Inflation

Table 1. Summary Statistics for the Frequency, Duration, and Size of Price Changes

	ALL		GOODS		SERVICES	
variable	median	mean	median	mean	median	mean
FREQUENCY						
frequency price change	14.0%	33.3%	16.5%	37.3%	11.9%	30.1%
frequency of increase	10.8%	19.0%	13.6%	22.6%	8.5%	16.1%
frequency of decrease	3.8%	14.4%	4.2%	16.0%	3.6%	13.0%
DURATION						
counted duration	8	17	6	16	9	19
implied duration	6	11	5	11	6	11
SIZE						
absolute size change	6.6%	9.8%	5.6%	8.2%	7.4%	11.2%
size upward change	5.8%	9.2%	5.7%	7.7%	5.8%	10.4%
size downward change	6.5%	12.9%	5.7%	10.3%	7.2%	15.0%

All the data are from the PPI-RDB and the sample runs from January 1987 to August 2008. Weighted medians and means use weights based on the BLS's unpublished item weights from establishment surveys and from Census and BEA data on industry value of sales to final purchasers.

Table 2. Summary Statistics Under Various Weightings

GOODS				
weighted medians	unweighted	cell weights	large firms	bls weights
FREQUENCY				
frequency price change	9.2%	10.0%	16.5%	16.5%
frequency of increases	7.7%	8.9%	13.6%	13.6%
frequency of decreases	0.5%	1.5%	4.1%	4.8%
DURATION				
counted duration	12	11	6	6
implied duration	9	8	5	5
SIZE				
absolute size change	6.1%	6.0%	5.3%	5.6%
size upward change	5.6%	5.6%	5.2%	5.6%
size downward change	6.2%	6.2%	5.2%	5.5%

SERVICES			
weighted medians	cell weights	large firms	bls weights
FREQUENCY			
frequency price change	10.9%	13.2%	11.9%
frequency of increases	8.1%	8.5%	8.5%
frequency of decreases	2.5%	3.7%	3.6%
DURATION			
counted duration	9	9	9
implied duration	7	6	6
SIZE			
absolute size change	6.6%	5.6%	6.1%
size upward change	5.6%	5.6%	5.6%
size downward change	6.3%	8.5%	6.5%

All the data are from the PPI-RDB and the sample runs from January 1987 to August 2008. Weighted medians use weights based on the BLS's unpublished item weights from establishment surveys and from Census and BEA data on industry value of sales to final purchasers.

Table 3. Summary Statistics by Firm Size

	GOODS		
weighted medians	bottom 33	middle 33	top 33
FREQUENCY			
frequency price change	10.5%	12.2%	18.2%
frequency of increases	8.2%	10.3%	13.6%
frequency of decreases	1.5%	1.6%	5.5%
DURATION			
counted duration	13	9	6
standard deviation	3	3	2
skewness	1.32	1.43	1.89
implied duration	9	7	4
SIZE of CHANGE			
absolute size change	6.0%	6.0%	5.6%
standard deviation	0.7%	0.6%	0.7%
skewness	1.06	1.16	1.12
size upward change	5.6%	5.4%	5.7%
size downward change	6.7%	5.9%	5.6%
	SERVICES		
weighted medians	bottom 33	middle 33	top 33
FREQUENCY			
frequency price change	9.9%	11.8%	14.0%
frequency of increases	7.1%	7.1%	7.4%
frequency of decreases	0.0%	2.4%	3.6%
DURATION			
counted duration	12.0	12.0	8.8
standard deviation	3.0	2.6	2.5
skewness	1.11	1.13	1.12
implied duration	9.1	6.6	6.1
SIZE of CHANGE			
absolute size change	7.5%	6.8%	6.3%
standard deviation	0.4%	0.2%	0.2%
skewness	0.99	1.04	1.05
size upward change	6.4%	5.0%	6.3%
size downward change	6.8%	7.6%	6.5%

All the data are from the PPI-RDB and the sample runs from January 1987 to August 2008. Weighted medians use weights based on the BLS's unpublished item weights from establishment surveys and from Census and BEA data on industry value of sales to final purchasers.

Table 4. Fraction of Price Changes Below Size Thresholds

	CPI	ALL		GOODS	SERVICES
variable	mean	mean	median	median	median
share of price changes below 1%	12.1%	22.3%	15.6%	13.3%	17.4%
share of price changes below 2.5%	25.4%	29.8%	29.9%	32.1%	28.1%
share of price changes below 5%	44.3%	40.4%	54.8%	51.2%	57.7%
For largest 1/3 of firms					
share of price changes below 1%		23.5%	19.7%	21.3%	18.3%
share of price changes below 2.5%		31.0%	35.7%	34.6%	36.5%
share of price changes below 5%		41.4%	58.9%	50.9%	65.3%
For middle 1/3 of firms					
share of price changes below 1%		15.2%	5.7%	0.0%	10.3%
share of price changes below 2.5%		23.4%	23.5%	22.0%	24.7%
share of price changes below 5%		36.5%	47.8%	42.8%	51.9%
For smallest 1/3 of firms					
share of price changes below 1%		16.2%	0.0%	0.0%	0.0%
share of price changes below 2.5%		21.6%	14.4%	11.0%	17.1%
share of price changes below 5%		32.8%	39.9%	31.8%	46.5%

The sample runs from January 1987 to August 2008 for the PPI. The CPI estimates come from Klenow and Kryvtov (2008) and run from January 1988 to January 2005, and include data for regular prices (posted prices excluding sales prices) from the top three urban areas. Entires are weighted mean or weighted median fractions of price changes that are smaller than 1%, 2.5%, or 5% in absolute value. Weights for the CPI are based on the BLS consumer expenditure surveys and unpublished BLS point-of-purchase surveys. Weights for the PPI are based on the BLS's unpublished item weights from establishment surveys and from Census and BEA data on industry value of sales to final purchasers.

Table 5: Correlation between Durations and Size of Price Changes

Category Name	Major Group	BLS Weights
Farm Products	1	0.21
Processed Foods and Feeds	2	0.23
Textile Products and Apparel	3	0.19
Hides, Skins, Leather, and Related	4	0.21
Fuels and Related Products	5	0.21
Chemicals and Allied Products	6	0.14
Rubber and Plastic Products	7	0.29
Lumber and Wood Products	8	0.15
Pulp, Paper and Allied Products	9	0.27
Metals and Metal Products	10	0.30
Machinery and Equipment	11	0.13
Furniture and Household Durables	12	0.18
Nonmetallic Mineral Products	13	0.26
Transportation Equipment	14	0.34
Miscellaneous Products	15	0.23
Wholesale Trade	42	0.14
Retail Trade	44	0.24
	45	-0.04
Transportation and Warehousing	48	0.13
	49	0.28
Information	51	0.18
Finance and Insurance	52	0.15
Real Estate/Rentals/Leasing	53	0.01
Professional/Scientific/Technical	54	0.17
Administrative and Support	56	0.08
Educational Services	61	0.09
Health Care and Social Assistance	62	0.18
Arts, Entertainment, and Recreation	71	0.02
Accomodation and Food Services	72	-0.01
Total		0.15

All the data are from the PPI-RDB and the sample runs from January 1987 to August 2008.

Table 6. Summary Statistics By Contract Type

	GOODS		SERVICES	
weighted medians	no contract	contract	no contract	contract
FREQUENCY				
frequency	13.7%	11.5%	13.0%	11.7%
frequency of increases	9.2%	6.3%	8.5%	8.3%
frequency of decreases	2.3%	4.0%	3.5%	3.4%
DURATION				
counted duration	8.6	9.0	8.0	9.6
implied duration	5.5	7.2	5.9	6.8
SIZE				
absolute size change	5.6%	5.5%	5.8%	6.2%
size upward change	5.8%	5.2%	5.6%	4.9%
size downward change	5.2%	5.1%	7.2%	6.2%

Table 7: Time Series Moments for Prices

Variable	Mean	Standard Deviation	Coefficient of Variation	Correlation with pi
Producer Prices				
pi	0.12	0.71	6.18	
fr	31.8	10.9	0.34	0.15
dp	0.87	4.49	5.16	0.78
fr+	17.9	7.5	0.42	0.46
fr-	13.8	5.8	0.42	-0.26
dp+	8.0	11.61	1.45	0.22
dp-	9.1	2.93	0.32	-0.40
pos	1.4	0.72	0.52	0.56
neg	1.3	0.68	0.53	-0.55

The PPI sample runs from January 1999 to August 2008. The entries are means, standard deviations, coefficients of variation, and cross-correlations across time of the monthly values of each variable.

Table 8: Regression of inflation and size and frequency of price changes

		1 month		12 months moving average	
	Variable	Coefficient	Standard Error	Coefficient	Standard Error
Producer Prices					
	fr+	0.066	0.009	0.045	0.004
	fr-	-0.075	0.011	-0.051	0.004
	dp+	0.140	0.051	0.042	0.021
	dp-	-0.136	0.029	-0.110	0.010
	Rsq	0.63		0.76	
	observations	128		128	

The PPI sample runs from January 1998 to August 2008.

Table 9: Variance Decompositions

IM vs. EM (%)		POS vs. NEG (%)	
IM term	EM terms	POS terms	NEG terms
75	25	40	60

The PPI sample runs from January 1998 to August 2008.