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Abstract

How rigid are producer prices? A longstanding conventional wisdom among economists holds that producer prices are more rigid than, and so play less of an allocative role than do, consumer prices. In the 1987-2008 microdata collected by the U.S. Bureau of Labor Statistics for the producer price index (PPI), we find that producer prices for finished goods and services in fact exhibit roughly the same degree of flexibility as consumer prices, with a median frequency of price change that falls between that of consumer prices including, and excluding, sales. This pattern becomes clear once one weights large firms by their revenue in aggregating the data, as large firms change prices two to three times more frequently than do small firms, and by smaller amounts. We also find that longer price durations are associated with larger price changes for goods firms, but not for services firms, and that while long-term contracts are associated with somewhat greater price rigidity for both goods and services firms, the differences are not dramatic. Finally, the size of price decreases plays a key role in PPI inflation dynamics, a fact that is not accounted for by standard workhorse macroeconomic pricing models.

Key words: price rigidity, inflation

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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 (and surprising degree of) 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 (1983; 1986; 1991), emphasizes how other mechanisms, enabled by long-term relationships between buyers and sellers, and formalized perhaps by an explicit contract, may substantially reduce (or, indeed, substitute for) 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 or other characteristics (via delivery delays and the like) alter its price (Carlton, 1983, 1991). Over time, 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, despite the fact that due to data availability constraints, there have traditionally been no direct measures enabling researchers to compare, say, the frequency of price change or similar summary statistics between the two.[1]

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.[2] These types of studies are important as they deepen our understanding of monetary policy's impact on the real economy. 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 households, economists, and from markets of inflation-indexed securities, there is only very limited information about the determinants of firms'

[1] Mackowiak and Smets (2008) simultaneously articulate and challenge this view: "Economists... sometimes express the view that firms operating in retail markets view recurrent interactions as unimportant compared with firms operating in wholesale markets. We think that recurrent interactions matter in some wholesale sectors and some retail sectors. Holding the prior that recurrent interactions matter only for producer prices appears unjustified."

[2] Notable exceptions include Stigler and Kindahl (1970), Carlton (1986), Blinder, Canetti, Lebow, and Rudd (1998), and more recently, Nakamura and Steinsson (2008).

pricing behavior.[3]

This paper uses confidential microeconomic data collected by the Producer Price Program of the Bureau of Labor Statistics to establish several stylized facts about the patterns and determinants of firms' pricing behavior in the U.S. Our data cover a comprehensive set of industries, both goods and services, from 1987 to 2008. We examine how firms' characteristics affect their pricing behavior along two dimensions: their size and their use of contracts. These two simple ways to cut the data produce surprisingly rich results. We also examine the relative importance for aggregate inflation dynamics of the four classic margins of price adjustment, the frequency and size of price increases and decreases, respectively, and their relationship to these firm characteristics.

We find, first, strikingly different patterns of price adjustment across large and small firms. Across industries, large firms change prices much more frequently than do small firms, and by smaller amounts. Once large firms are weighted correctly in the data, the rigidity of producer prices falls between the rigidity of consumer prices including, and excluding, sales. Our findings are consistent with returns to scale in the technology of price setting, and counter the conventional wisdom, whose roots lie in the administered price thesis of Means (1935), that producer prices are not allocative. Indeed, Means (1935) argued that large firms exhibited more rigid pricing behavior than did small firms, that they were more likely to exercise administrative control over prices, and so keep them constant over multiple transactions, rather than allowing them to vary along with market trends. In his view, the rise of large corporations in the late 19th century contributed to the severity and duration of the Great Depression by their failure to equilibrate demand and supply in markets across the United States, most egregiously in periods when real economic activity declined.

We turn next to an analysis of firms' pricing behavior in the presence and absence of contracts. We document the share of transactions conducted under contract across industries (the first tabulation of its kind, to our knowledge) finding that it averages one out of every three transactions, for both goods and services. The conventional wisdom in the literature, as articulated by Fischer (1977) and Barro (1977), is that contract prices exhibit considerably more rigidity than do spot prices. Somewhat contrary to this line of thought, we find that transactions conducted under medium- to long-term contracts are associated with slightly greater price rigidity for both goods and services but that the differences are fairly subtle, and certainly much less dramatic than those across the firm-size distribution.

Relatively little is known about how firms' pricing behavior evolves over time and the business cycle, which we turn to next. We examine the relative importance of the size and frequency of

[3] http://www.federalreserve.gov/newsevents/speech/bernanke20080609a.htm

price changes in the PPI's overall variability, finding the size of price decreases to be a key margin of adjustment, a result that is particularly striking for periods in which price pressures trend lower. As central bankers still do not understand why deflations are so costly (are generally associated with stagnant or falling aggregate output), our findings offer some insight into how and why firms adjust their prices in periods when aggregate prices are falling.

We also show that, despite the greater flexibility exhibited by aggregate producer prices once one weights large firms appropriately in the data, they still exhibit some time-series properties consistent with the presence of nominal rigidities, and most strikingly in periods in which aggregate output contracts. This finding – that the frequency of price decreases remains stable in contractionary periods while the average size of price decreases jumps – is suggestive of the presence of downward nominal and real rigidities and so with one feature of Means's administered price thesis. Finally, we evaluate the implications of our findings for standard workhorse macroeconomic pricing models and for the potential sources and magnitudes of the contract multiplier, noting which have yet to be addressed by this literature and are likely to be promising avenues for future work.

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 (2010). We find a somewhat higher frequency of price change for the U.S. PPI than found for most euro-Area PPI's, as discussed in Vermeuelen et al. (2007) and Fitzgerald and Haller (2010), which is consistent with the differences found for CPI's across 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.

The evidence remains mixed and incomplete as to the relative rigidity of wages and prices, though there is important work in progress on this topic.[4] Barattieri, Basu, and Gottshalk (2010) use the microeconomic data from the Survey of Income and Program Participation and find the average duration of a wage change in the U.S. to be 5.6 quarters between 1995 and 1999, somewhat longer than the average duration found for consumer or producer prices in the period by Klenow and Kryvtsov (2008) (hereafter, KK), NS (2008), or in this paper. In contrast, Heckel et al. (2008) find the average duration of wage spells to be quite similar to that for price spells in French data, between 2 and 3 quarters.[5] Both sets of findings are consistent with the recent work of Nekarda and

[4] Druant et al. (2009) find in survey evidence from the euro area that roughly 40 percent of firms report a relationship between the frequency of their wage and price adjustment decisions, and they identify a statistically significant relationship between the frequency of wage changes and prices.

[5] An exciting new line of research has been embarked upon by the ECB's International Wage Flexibility Project, which is collecting data on wages to analyze their dynamics across the euro area. Preliminary reports from the

Ramey (2010) showing that markups in the aggregate economy, and in the manufacturing sector in particular, appear to be either procyclical or acyclical.

We emphasize several important points about our analysis. First, we acknowledge the *crucial* importance of the use of non-price mechanisms by firms to clear markets, as examined in detail in the industrial organization literature. An overarching theory of firms' use of these alternative mechanisms to achieve efficient allocations is found in Carlton (1991). In some sense, the main question of our paper may be restated as whether the importance of these non-price mechanisms differs sufficiently across producer and consumer markets to cause the latter to be much more flexible than the former. That is, our analysis does not question the presence and importance of these mechanisms in market clearing, but rather whether they are more likely to operate in producer than consumer markets. As noted by Carlton (1991), economists are rarely able to observe these alternative mechanisms directly (e.g. rationing, delivery delays, and the like), and certainly not in aggregate datasets. To assess whether prices retain an allocative function, then, we propose to examine the market outcome, that is, the flexibility of the observed price. To the extent that the frequency of price change may be regarded as a sufficient statistic to characterize the degree to which prices are allocative, our point is that it appears that producer prices are at least *as* allocative as consumer prices.

Second, we acknowledge that the use of non-linear pricing (when per-unit prices vary with the quantity purchased) such as end-of-year discounts, may make it difficult to identify the marginal prices for some industrial commodities, as we discuss in more detail in the data section. We note, however, that tremendous effort goes into gathering detailed information on such discounts by BLS field economists. We firmly believe that the information on such discounts in the PPI is the best economists can hope for in an aggregate data set. We also note recent evidence that consumers who face nonlinear price schedules may respond to their average price rather than the marginal price they actually pay (Ito, 2010). These findings imply that to characterize price rigidity as perceived by buyers, one should perhaps focus on the frequency of change of the average, and not the marginal, producer price.[6]

The rest of the paper proceeds as follows. The next section describes the data and various estimation issues. Section 3 describes our results regarding the firm size distribution, Section 4 for the use of long-term contracts, and Section 5 for firms' pricing behavior over time, with a focus

project indicate that the degree of wage rigidity varies considerably across countries, however, which suggests caution in generalizing from the results from any one country.

[6]Ito (2010) reviews the literature on consumer responses to nonlinear price schedules, noting that, "Laboratory experiments find... that people have limited understanding of nonlinear price structures, and tend to respond to the average price at the point where they consume."

on business cycle downturns, highlighting the key role of the size of price decreases in accounting for the variation in PPI inflation. Section 6 examines the relevance of our findings for various macroeconomic pricing models, and Section 7 concludes.

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."[7] 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.[8]

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

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

[8] 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.

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, 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.[9] 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 finished goods and services index provides 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

[9] The commodity classification of each industry's output may be found in Table 6A of the Census Bureau's industry series report.

do in the CPI, as documented by NS (2008) and KK (2008).[10] 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 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. 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

[10] 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.

aggregate price spells. We adopt the standard frequency approach here, cognizant, however of its drawbacks.

3 Firm Size Distribution and Price Rigidity

3.1 Aggregation Method

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:

$$\overline{fr_i} \equiv \frac{\sum_t I_{it}}{\sum_t N_{it}} \tag{1}$$

gives the average frequency of price changes for item i over its lifetime.[11] We then aggregate across cell codes, which denote industries, within the sample. The weighted cell-code mean over the sample period is given by:

$$\overline{fr_j} \equiv \frac{\sum_{i \in j} \omega_i \left| fr_i \right|}{\sum_{i \in j} \omega_i} \tag{2}$$

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:

$$\overline{fr} \equiv \frac{\sum_j \omega_j \left| \overline{fr_j} \right|}{\sum_j \omega_j} \tag{3}$$

[11] 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.

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. A final set of weights reflects the share of each industry's output going to final demand. These weights are applied at the cell-code level for services, derived by us from input-output tables, and at the commodity-code level for goods, using the BLS's published weights for finished goods. We discuss the impact of applying each of these weights on aggregate measures of price flexibility after presenting our results across the firm size distribution.

3.2 Firm Size Distribution

A recent macroeconomic literature emphasizes the importance of accounting for the extreme skewness in the firm size distribution, the fact that a small number of firms accounts for a large share of output, to understand aggregate fluctuations. Many studies assume that shocks to individual firms average out in the aggregate, but this does not occur if the firm size distribution is fat tailed. Along these lines, Gabaix (2010) shows that the idiosyncratic output movements of the largest 100 firms in the U.S. explain one-third of the variation in the U.S. economy's growth. He suggests that our understanding of the behavior of other macroeconomic aggregates may be similarly clarified by focusing on the behavior of large firms. We examine here how pricing behavior varies across the firm size distribution, to see if firm size qualifies as one of Bernanke's factors determining price-setters' behavior. Given the shape of the firm size distribution in the U.S., any systematic differences between large and small firms are likely to be key to understanding the behavior of aggregate prices.

To characterize how a firm's size may affect its pricing behavior, Table 1 breaks up the firm size distribution of the BLS sample into three tranches. This is done at the most disaggregated industry level in the BLS data, the cell code level, in which there are several thousand industries. Before describing our results, it may be useful to describe in more detail how we identify these firm tranches for each industry, and why any differences that result in the aggregate statistics come from intra-industry variation in firm characteristics, and *not* from cross-industry variation. To compute, for example, the weighted median frequency of price change for the top tercile of firms, economy wide, we first cull the item codes associated with the smallest tercile of firms in each cell-code industry, after sorting firms by their establishment's average value of sales over the sample period multiplied by the item's relative importance in their total sales (Our results are all robust to leaving off this second factor). We then compute the industry's weighted median frequency of price change using a variant of Equation (2) that includes only the mean frequency of price change and the item-code weights of the selected firms. It is crucial that the weight then used to aggregate this statistic across industries, the ω_j of Equation (3), does not vary with firm characteristics. Our results by firm tercile thus reflect differences in *firm* characteristics, with the industry weights unchanged relative to the more general case in which all item codes are used to compute the cell code's weighted median.

The first column of Table 1 reports statistics for the top tercile of firms, the next the middle tercile, and the last the bottom tercile. In the remainder of the paper, we will refer to this top tercile as large firms and to this bottom tercile as small firms. We report results for goods and services firms separately, as some pricing patterns differ across these two sectors in important ways. To ensure that our results are not dominated by outliers (whether firms or industries), we report weighted medians. This also stacks the deck against finding that firm size matters, as the pricing behavior of large firms would likely affect industry means much more than it would medians.

Large firms change their prices more often than do small firms. We find, first, that among goods industries, large firms change their prices almost twice as often as do small firms. The weighted median frequency of price change is 18.2 percent for large firms and 10.5 percent for small firms, which translates into an implied price duration of 4.3 months for large firms and 8.5 months for small firms. Among services industries, one sees a similar pattern across the firm size distribution, though the differences are not as pronounced between the top and bottom terciles, which have a weighted median price-change frequency of 14.0 and 9.9 percent, respectively, which implies that large firms change their prices every six months, and small firms every nine months. We illustrate these patterns in Figure 1, in which the horizontal axes identify each of these three size groups, or terciles, and the vertical axes the weighted median frequency of price changes (in the top panel) and the weighted median duration of a price change (in the bottom panel).

Going a bit deeper into the data by examining price increases and decreases separately reveals some additional and quite interesting patterns. We find that among goods industries, the weighted median frequency of price increases and decreases both rise with firm size, perhaps not surprising, and that the frequency of price increases is greater than that of price decreases across all three terciles, by about seven percentage points in each case. The weighted median frequency of price increases is 18.2, 12.2 and 10.5 percent, respectively, for the top, middle, and bottom tercile of firms. It is quite striking, however, how low the frequency of price decreases is for the bottom two terciles of firms, with a weighted median of about 1.5 percent for each, compared with 5.5 percent for the top tercile. Small- to medium-sized goods firms appear to decrease their prices fairly rarely, an unexpected finding, and one whose implications we explore further in Section 6. For services industries, in contrast, the frequency of price increases appears fairly stable over the firm size distribution, with the weighted median falling slightly from 7.4 percent in the top tercile to 7.1 percent in the bottom tercile. In contrast, and as in goods industries, the frequency of price decreases rises with firm size: Its weighted median is 0.0, 2.4, and 3.6 percent, for the bottom, middle, and top tercile of firms, respectively.

These results establish a new stylized fact for the United States and raise the question of whether similar patterns exist in other countries. While some recent studies report similar results in a couple of other countries (Canada and New Zealand, among myriad other findings), there has been no systematic empirical analysis of the relationship between firms' size and their pricing behavior. Amirault et al. (2005) find that large Canadian firms change prices more frequently than do small firms and Buckle and Carlson (2000) find similar patterns for New Zealand firms. In related work, Fabiani et al. (2005a) use a chi-square analysis to establish 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), though it is not apparent that this affects the frequency of price change. One euro-area study that examines this question explicitly, for the Netherlands (Hoeberichts and Stockman, 2006), finds that small firms have more rigid prices than do large firms. It is also intriguing that several studies that examine CPI data from euro-area countries report that large retail outlets change prices more frequently than do small outlets (Jonker et al., 2004; Fabiani et al., 2005b, for Italy; and Dias et al., 2004, for Portugal), a question which has not been examined for the U.S.

And by smaller amounts. We also find that the absolute size of price changes varies systematically over the firm size distribution. Large firms change their prices by smaller absolute amounts than do small firms, though this pattern is more pronounced in services than in goods industries. Among goods industries, the weighted median size of a price change is 5.6 percent in the top tercile of firms, and 6.0 percent in the bottom tercile, as reported in the top panel of Table 1. Further disaggregating the data between price increases and decreases reveals that most of the variation across the firm size distribution is in the absolute sizes of price decreases, which range from a weighted median of 5.6 percent in the top tercile to 6.7 percent in the bottom tercile while, in contrast, summary statistics for the absolute size of price increases vary only marginally with firm size.

For the size of price changes, the patterns exhibited by firms in services industries appear quite similar to those in goods industries. Among services firms, the weighted median of the absolute size of price changes ranges from 6.3 percent for large firms to 7.5 percent for small firms. There is very little difference between the absolute sizes of price increases and decreases in the top tercile of firms. This gap widens in the bottom two firm terciles, where the absolute size of price decreases is much larger, at 7.6 and 7.8 percent for the middle and lower tercile, respectively, than is the size of price increases, at 5.0 and 6.4 percent, respectively.

Price changes are large in average absolute value. Despite this variation over the firm size distribution, the average absolute size of a price changes remains large in the sample as a whole, with a weighted median of 7.0 percent, and a weighted mean of almost 11 percent across goods and services firms; This result is consistent with large idiosyncratic disturbances driving much of firms' price adjustment, as Klenow and Willis (2006) and Golosov and Lucas (2007) suggest must be the case given a set of analogous moments for the CPI, in particular, the presence of large relative price changes across industries.

To summarize, then, in the microeconomic data used to construct the PPI, small firms rarely cut prices, but when they do, they do so by a lot.[12] The marked asymmetry in the frequency of price decreases across large and small firms is matched by an asymmetry in the absolute size of price decreases in the opposite direction, for both goods and services firms. This finding suggests the presence of returns to scale in the technology of price setting, possibly due to fixed costs of price adjustment. As Carlton (1986) notes, while no one doubts that such costs of price adjustment exist, (even electronic exchanges, for example, must pay some small cost to update posted prices) the question is how these affect price-setters' behavior, if at all. A common approach to address this question is to compute how often firms make small price changes. Carlton does this for the Stigler and Kindahl (1970) data, finding that across industries, firms routinely change their prices by very small amounts. In the categories of glass and trucks, for example, he finds that up to 67 percent of price changes are less than two percent. Similarly, KK (2008) document a high fraction of price changes that are very small in the micro-data underlying the CPI and Vermeulen et al. (2007) for euro area PPI's. We confirm that this stylized fact holds in the BLS's PPI data and show, in addition, that it varies systematically over the firm size distribution.

[12] Like NS (2008), we find little evidence of sales in the PPI.

Large firms make many very small price changes, while small firms make very few... Table 2 reports the weighted mean or median share of price changes that are below 1, 2.5, and 5 percent in absolute value, first across all firms, and then for each firm tercile sorted by size. To compare our results to those for the CPI, the first column reports the mean share under these same cutoffs for the CPI, as reported by KK (2008) using posted prices (all prices including sales prices) from the top three urban areas, from January 1988 to January 2005. The second column reports the weighted mean of our finished goods and services PPI data, indicating that roughly one of every five price changes is less than 1 percent, 30 percent are less than 2.5 percent, and 40 percent are less than 5 percent. These numbers appear roughly comparable to those for the CPI, though with a somewhat higher share of price changes under 1 percent in the PPI than in the CPI, and to those for the euro area, for which Vermeulen et al. (2007) report that about one quarter of producer price changes are less than 1 percent.

The remaining entries in column 2 show that these shares vary with firm size. While 23.5 percent of the largest firms' price changes are less than 1 percent, only 15-16 percent of price changes by firms in the bottom two terciles are. One sees a similar pattern for price changes below 2.5 percent, with about 31 percent below this mark in the top tercile, and 21-23 percent in the other two terciles. Column 3 reports the weighted medians, with results that are even more pronounced over the firm size distribution, suggesting that these firm size patterns may be present within each tercile as well (as means should be more susceptible to the behavior of large firms within each tercile than are medians). For the top tercile, the share of price changes below 1 percent is 19 percent, while it is only 7.8 percent for the middle tercile, and 0.0 percent for the bottom tercile. The final two columns report results for goods and services industries separately. The most striking difference that emerges is in the middle tercile, where the weighted median share of price changes below 1 percent is 0.0 percent for both the middle and bottom terciles among goods industries, while remaining in positive territory, at 10.3 percent, for the middle tercile for services, though also falling to zero in the bottom tercile. This implies that any costs of price adjustment are much more binding for small firms than for large firms, and even for mid-sized firms among goods industries.

We conduct a number of robustness checks to ensure that our results across the firm size distribution do not reflect some underlying confounding factor. To assess whether the firm size results can be explained by industry characteristics, for example, 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. Additionally, as we discuss in the next section, there has been a secular upward trend in the frequency of price change among services industries. As our firm weights are in nominal terms, the (contemporaneous) upward trend in the price level over the sample period could cause us to weight firms sampled later more heavily. If these firms also exhibit a higher frequency of price change, this could produce a spurious effect of a differential frequency of price change over the firm size distribution, but in fact driven by the upward trend in the frequency of price change over the sample period. To ensure this is not the case, we have re-computed each of the statistics in Table 1 and 2 separately for each year in the sample, where any upward trend should not be an issue, and found that our results are unchanged (indeed, look nearly identical to those over the full sample).

3.3 Aggregate Measures of Price Rigidity

What are the implications of our findings for aggregate measures of price flexibility in the U.S. economy? As reported in Table 3, across all goods and services industries, we find that the median frequency of price change is 13.1 percent, with a median implied duration of 6 months. The median frequency is 16.5 percent for goods and 11.9 percent for services, with a median implied duration of 5.1 and 6.4 months, respectively. Klenow and Malin (2010) report that the median duration of a price change in the U.S. lies between 3 and 5 months in the CPI, including sales, and between 7 and 9 months excluding sales. Our findings suggest that the rigidity of finished goods and services producer prices lies between the rigidity of consumer prices including, and excluding, sales. So once large firms are weighted appropriately in the data, *producer prices appear to be about as flexible as consumer prices.*

How do our results compare to previous work on producer prices? For the Finished Goods PPI, our numbers are roughly half the 9-month duration reported by NS. Table 4 sheds some 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.

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 4'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 BLS sample in their pricing behavior.* We note that our use of item- and cell-code weights makes our summary statistics for the PPI consistent with the indexes produced by the BLS itself, and with NS and KK's weighting of CPI data.

Regarding other work on producer prices, our mean implied duration of a price change across goods and services, at 10.9 months, is fairly close to that reported by Blinder et al. (1998) from survey of U.S. firms. As for cross-country comparisons, we find a somewhat higher mean frequency of price change for goods in the U.S. PPI, at 31.9 percent, than found for goods in most euro-area PPI's, 21 percent, as surveyed in Vermeuelen et al. (2007).[13] This result is consistent, however, with the differences found for CPI's between the two economies, as discussed in Dhyne et al. (2006).

Our results indicate that large firms not only make many more price changes in any given period, but in particular, many more *small* price changes than do smaller firms in the same narrowly defined industry. Once items produced by large firms are weighted by their output, the rigidity of producer prices appears to lie in the middle of the range of consumer price rigidity including, and excluding, sales. Weighting large firms appropriately in the data also affects other moments commonly used to calibrate monetary macroeconomic models. Of these, we report more disaggregated results for one used to differentiate between two broad classes of monetary models, those with time- or state-dependent pricing by firms – the cross-correlation between the duration of a price spell and the

[13] Note that these euro-area studies generally do not use product- or firm-level weights in aggregating their frequency measures, so their true aggregate mean frequency of price change may be higher than currently reported if the same differences in firms' pricing behavior operate over the firm size distribution.

absolute size of the subsequent price change – finding that it varies systematically across goods and services firms.

Longer price spells are associated with larger absolute price changes for goods but not for services. The conventional wisdom received from an earlier generation of studies was of 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 relationship between the duration of a price spell and the absolute size of the subsequent price change. KK (2008, p. 20) argue that the CPI data show that "the size of price changes is unrelated to the time since the previous change (for a given item)."

To examine whether this relationship holds in the PPI data, we computed this correlation for each item in the sample, aggregating the results according to the procedure described in Section 3.1. Our results are presented in Table 5 and indicate a modest positive correlation between the length of price spells and the absolute size of price changes in most goods industries, which is substantially weakened (or in some cases, non-existent) across services industries. The weighted median correlation across industries is 15 percent and ranges from -.04 percent for *Retail Trade* and -.01 percent for *Food and Accommodation Services* to 29 percent for *Rubber and Plastic Products* and 34 percent for *Transportation Equipment.* This relationship is strengthened for goods industries once large firms are weighted appropriately in the data. This suggests that time-dependant models may characterize pricing behavior by some goods firms fairly well, while state-dependent models capture somewhat better the pricing behavior of services firms. We discuss further the implications of these findings in Section 6, and turn next to our evidence on price rigidity associated with contracts.

4 Contracts and Price Rigidity

Little is known about the incidence of contract use across industries. Empirical studies of the decision to contract or of the choice of contract duration across industries are few and far between.[14]

[14] In their review of this literature, Masten and Saussier (2000) note "only one large-scale empirical study of the choice between formal contracting and informal agreement has been undertaken to date," that of Lyons (1994) who examines the probability that firms adopt a formal contract in a study of U.K. engineering subcontractors. There has been some work tieing the use of specific contractual forms (e.g. franchises) or the choice of contract duration to aspects suggested by theory, primarily risk sharing and transaction costs, though these tend to be limited to a few sectors. For example, a number of papers examine agricultural contracts for which there is good data on the incidence

Nonetheless, despite this limited evidence, both the theoretical and empirical literatures associate the use of medium- to long-term contracts with greater price rigidity. Theoretical contributions include Barro (1977) who emphasizes how recurrent interactions, formalized by an explicit contract, may substantially reduce (or, indeed, substitute for) the allocative role of prices in producer-to-producer transactions, as quantities are also specified in the contract, and Carlton (1979) who presents a model in which the effects of cash-flow variability on a firm's costs cause it to enter long-term contracts, and where the resulting index of long-term-contract prices behaves differently than does an index of spot prices, due to the different responsiveness of each to demand and supply shocks.

The empirical finding that contract prices behave differently than do spot prices can be traced back to the work of Stigler and Kindahl (1970), who noted that a price index constructed from their dataset of industrial commodities prices, which was comprised primarily of commodities sold under contract, exhibited a different trend over the business cycle than did the BLS's wholesale price index, thought to be comprised mainly of commodities sold on spot markets.[15] Similarly, using the Stigler and Kindahl (1970) data, Carlton (1986) found greater price rigidity in long-term than short-term contracts.[16] A key issue in this literature, however, is that the industries most scrutinized for the impact of long-term contracts on pricing are not exogenously chosen, but instead are those most likely to exhibit collusive pricing behavior, with academic studies (quite naturally) spurred in part by political or regulatory interest. Indeed, as Stigler and Kindahl (1970) note about their work, "It is difficult to generalize these results because our collection of commodities is in no sense random; indeed it is purposely concentrated in the areas where 'administered' prices are most often said to exist... We naturally pay special attention to the areas in which the charge of inflexible prices has been heard most frequently."

Similar reservations may be voiced about the literature on two-price systems in industrial commodities markets, the focus of most empirical studies that compare the behavior of contract and spot prices. Several papers in this literature find that contract and spot prices exhibit very dif-

of sharecropping and the like. The classic reference in the contract duration literature is Joskow (1987) who tests the prediction from the transaction costs literature that longer-duration contracts will be used when relationship-specific investments matter more, using the example of the relationship between coal suppliers and electric plants that burn coal. As Chiappori and Salanie (2002) note in their survey of the empirical literature on contract theory, "we would certainly want to see wider-ranging empirical work in the future."

[15] As Carlton (1979) notes, "One fascinating yet puzzling finding of Stigler and Kindahl was that their index of price (based mainly on long-term-contract prices) behaved differently over time than the BLS index (which is probably closer to an index of spot price than of long-term-contract price). It was expected that the Stigler-Kindahl index would move more smoothly than the BLS index, yet there was no expectation that the trend in the two indices should differ" Carlton (1979), p. 1037.

[16] He notes that "As one would expect, the annual category (of contracts) involves less price flexibility than the quarterly category which itself exhibits less flexibility than the monthly category" (Carlton, 1986, p. 643).

ferent stochastic properties over time.[17] For example, Hubbard and Weiner (1989) find that the "persistence effects of (transitory) shocks on prices depends on, *inter alia*, the fraction of trades carried out through contracts," where contracts are, however, defined in the context of the collusive arrangements associated with the two-price system in the copper and oil markets in the 1970s.[18]

A natural question, then, is whether these studies identify the causal relationship between long-term contracts and firms' pricing behavior, or instead, the use of these contracts as a coordination device for a set of collusive market arrangements. These studies may identify the different stochastic behavior of producer prices in collusive and non-collusive market environments, rather than the causal effects of contracts themselves. That said, recent survey evidence drawing from a somewhat broader range of industries does find explicit contracts to be one of the main sources of price rigidity according to firms' self-reporting (Fabiani et al., 2005a; Blinder et al., 1998).

In future work, we plan to document the time-series properties of spot and contract price indexes across industries: A careful analysis of these properties is beyond the scope of the current paper, however. We focus here on providing summary statistics of the degree of rigidity associated with spot and contract prices, along the lines of the evidence on price rigidity presented by Carlton (1986). We turn next to a description of the BLS data on firms' contractual arrangements.

4.1 BLS Data on Contracts

The BLS data include information on whether a product is sold under a contract, defined as an agreement with multiple deliveries over more than one month, when this agreement is identified as a price-determining variable by the reporting firm. This measure is meant to capture the recurrent interactions that the theoretical literature associates with contracts in producer-to-producer interactions. The measure includes verbal agreements, though it more often references written ones.

[17] See, for example, Hubbard (1986), Hubbard and Weiner (1989, 1992), and Slade (1991).

[18] As Hubbard and Weinar (1989) note, "The visibility and longevity of the two-price system elicited considerable interest from policy-makers and applied macroeconomists. The Houthakker Committee's investigation found that the two-price system was inequitable and economically inefficient." They explain how in the copper system, from World War II until the late 1970s, "most U.S. copper producers sold their products via long-term contracts at the 'producer's price,'" the price set by the largest firms in the industry. Similarly, in the oil industry, from the early 1970s on, the major refiners purchased oil through long-term contracts that specified "fixed prices and volumes", with a small fraction conducted through the spot market. By the end of the decade, most of the market had transitioned to spot market pricing. Slade (1991) also examines the two-pricing system in the 1970s, and its subsequent demise: "Nonferrous-metal sales in North America have traditionally been conducted under a system known as producer pricing, whereas sales in the rest of the western world have generally relied on commodity exchanges. Producer prices are set by the major firms in the industry. Exchange prices, in contrast, are related to price quotations on metal exchanges, principally the London Metal Exchange (LME). In the late 1970s and early 1980s, radical changes occurred in the pricing of many metals. This period saw the virtual demise of the producer price of copper and the introduction of aluminum and nickel contracts on the LME. Even those industries where producer prices remained relatively strong were affected. The producer price of lead showed a tendency to follow exchange prices more closely, and more recently, producers began discounting the price of zinc."

Though it certainly understates the incidence of implicit contracts within industries, it nevertheless provides useful information about the relative importance across industries of recurrent interactions codified in some form of explicit agreement, even a verbal one.

Following the aggregation method described in Section 3, we tabulate the share of transactions conducted under contract by industry, with the results reported in Table 6. We find that one out of every three transactions in the PPI occurs under contract, a fairly high share of aggregate transactions. This figure is almost identical for goods and services, though there is considerable heterogeneity across more disaggregated industries, particularly among services. Industries that produce more differentiated goods are more likely to use contracts, such as *Transportation Equipment*, with almost 60 percent of its transactions conducted under contract. Industries known to be dominated by spot pricing, such as *Fuels* or *Chemicals*, exhibit much lower shares of transactions conducted under contract, on the order of 20 percent. Among services industries, the overwhelming share of *Finance and Insurance*, *Real Estate*, and *Professional Consulting Services* are conducted under contract, 82, 76, and 65 percent, respectively. *Wholesale* and *Retail Trade*, dominated by construction and building materials wholesalers, appears to have quite limited use of medium- or long-term contracts. *Transportation and Warehousing*, comprised primarily of air and truck freight, exhibits a substantial share of transactions under contract, 43 to 44 percent. This share likely depends on the stochastic nature of demand facing the buyers of freight services, and so of their shipments. In future work, we hope to use these data to examine the product and industry determinants of contract use (assessing the relative importance of industry measures of capital intensity or risk sharing, for example).

4.2 Price Rigidity

Turning to the evidence on price rigidity, we find that transactions conducted under contract are associated with somewhat greater price rigidity across industries, but that the results are not dramatic, and are much less pronounced than those for the firm size distribution. Table 7 reports that the weighted median frequency of price change is 11.5 and 11.7 percent for goods and services sold under contract, respectively, and 13.7 and 13.0 percent for goods and services sold without a contract, respectively. The weighted median price duration is 1.7 months longer for goods sold under contract, and about 1 month longer for services, compared with those sold under more spot-like arrangements. Looking separately at price increases and decreases reveals that the greatest disparity is in the frequency of price increases for goods: Its monthly weighted median frequency of price change goes from 6.3 percent for contract pricing to 9.2 percent for spot pricing. The frequency of price decreases and the size of price changes vary hardly at all by contract use.[19]

We do not, therefore, find a pronounced effect of contracts on price rigidity in the PPI data. This result, together with our findings from Section 3, imply that contracts may not play as salient a role in aggregate price rigidity as do returns to scale in the technology of price setting.

Why would this be the case, and why do our findings depart from those of the earlier literature, reviewed above? Beyond the reasons we have already laid out (that we examine data for a broader range of industries than that available to the previous generation of studies), we emphasize that markets for industrial commodities have changed significantly since the 1970s. We believe our findings differ from the earlier literature in large part due to the evolution of the market structure of industrial commodities markets away from the two-tired producer-price system that dominated, for example, the oil, copper, and other metals markets through the mid 1970s (as described in more detail in Footnote 18). Our dataset begins in the late 1980s, after these markets had transitioned to more spot-based pricing for most transactions.

Second, studies of the actual contracts used by businesses reveal them often to be informal agreements that may not specify fixed prices or quantities over the period they are in effect, particularly if they are of a long duration. Their use, therefore, may not in itself imply greater price rigidity. Carlton (1986) makes a related point in his analysis of the Stigler and Kindahl data, "One important point to note about these transactions is that an annual 'contract' rarely means a price change every twelve months, nor does a monthly contract mean a price change every month. Although annual contracts do involve more rigidity than monthly ones, it is incorrect to think of contracts as inflexible price rules set at specified intervals. A more appropriate view is that they are flexible agreements that can be renegotiated when and if the need arises."[20] Indeed, and consistent with Carlton's observation, we find that among the major groups of manufactured goods in the PPI, the one with the highest share of transactions conducted under contract, *Transportation Equipment*, also exhibits the highest monthly frequency of price change, at 82.3 percent. This result is also consistent with the findings of Ben-Shahar and White (2007), who, in a detailed study of the contracts used by Original Equipment Manufacturers (OEMs) in the auto industry (e.g. Ford, Honda, and the like), show that while an OEM may have a long-term sourcing contract with one supplier for a part for a particular model, actual purchase orders are issued on a short-term basis

[19]It is worth noting that the correlation across the PPI's major groups between the share of contracts and the absolute size of price changes is negative and significant, while the frequency of price change is not. A simple OLS regression indicates that a 10-percent increase in the share of transactions conducted under contract corresponds to a 0.7 percentage point decline in the weighted median size of price changes which, given that the median size of price change of 6.6 percent across the sample as a whole, is a decline of almost 10 percent.

[20]Carlton (1986), p. 643.

and are typically associated with renegotiation on price. When setting up a new model's production line, an OEM generally commits to an overarching contract for four to eight years but then orders parts in individual purchase orders whose duration can go from several days to twelve months. This practice may reconcile the high frequency of price adjustment observed in this industry with the high share of its transactions conducted under contract. Though detailed studies of the actual contracts used in individual industries along the lines of Ben-Shahar and White (2007) are fairly rare, anecdotal evidence suggests this fairly flexible approach to contracting to be common practice across many industries.

To summarize, then, the evidence from the PPI does not suggest that contracts do not play a role in producer price rigidity, but rather that they may be less important than other factors, particularly those with scale effects. To further address this point, we turn next to evidence on the time-series properties of the PPI and the possible role of fixed costs of price adjustment in producer price rigidity.

5 Price Adjustment Over Time

Relatively little is known about how firms' pricing behavior evolves over time and the business cycle. Along with the unconditional statistics reported thus far, it may also be useful to study how prices change over time. In many macroeconomic pricing models, firms incur fixed costs of price adjustment and so face dynamic decision problems: The time-series features of the data may therefore help us to differentiate between these models by their implied dynamics. 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:

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

We follow a similar procedure to compute weighted medians.

Table 8 reports the mean, standard deviation, and cross-correlation of each of these margins with inflation for our finished goods and services PPI and for the CPI as reported by KK (using microeconomic price data from the three largest urban areas in the U.S.). Most of the first moments for the PPI appear similar to those for the CPI. For example, the fraction of items with price increases or decreases, 17.9 and 13.8 percent, respectively, for the PPI is pretty similar to the analogous fractions for the CPI, which are 15.0 and 11.5 percent, respectively. We also find higher standard deviations of most of these margins in the PPI than the CPI data, with values that nonetheless appear plausible. The most interesting points of comparison between the PPI and CPI summary statistics are the cross-correlations between each of these margins and the relevant inflation rate. Like KK for the CPI, we find the cross-correlation between the PPI inflation rate and the size of price changes to be higher than that for frequency, at 0.78 and 0.15, respectively: These cross-correlations are 0.99 and 0.25, respectively, in the CPI data. The cross-correlation of our PPI inflation measure with the frequency of price increases appears greater than with the frequency of decreases, at 0.46 relative to -0.26, respectively, compared to KK's 0.69 and –0.41 for the CPI. Finally, while the size of price increases has a modest positive correlation with PPI inflation, at 0.22, its negative correlation with the size of price decreases is somewhat larger in absolute value, at -0.40. This difference also departs somewhat from KK's strikingly symmetric findings for the CPI, at 0.19 and -0.19, respectively: The correlation of the size of price decreases with the PPI inflation rate is almost twice the analogous correlation for the CPI, and similarly twice the analogous correlations between the size of price increases and the inflation rates for both the PPI and the CPI. This is an intriguing result, both in itself, and in its departure from the patterns in the CPI, one worth examining in a bit more depth. We begin by computing the relative importance of each of these margins in several inflation decompositions.

The size of price changes (the intensive margin) dominates the variance of PPI inflation. Our first decomposition relates the intensive margin and extensive margin – the size-effect and frequency-effect of changing prices, respectively – to the variation in PPI inflation.

Because inflation may 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), its variance can be computed 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, as in KK (2008) 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 this variation that is associated with 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's variation that can be attributed to variation in the frequency of price changes.

Table 9 reports that variation in the size of price changes accounts for 75 percent of the variation in our PPI inflation measure. It is interesting that KK find that this intensive margin measure accounts for an even higher share of their CPI's inflation variance, over 90 percent. To provide some visual intuition for this result, Figure 2 displays twelve-month moving averages of π_t, dp_t, and fr_t. It shows that the extensive margin, fr_t, trends upward from 2001 on, but does not appear highly correlated with inflation, while the intensive margin, dp_t, exhibits more volatility but also comoves much more closely with inflation (with a correlation of 0.78, as we note above): These patterns are almost identical to those described by KK for the CPI. They are also consistent with the more general finding in the literature (as summarized by Klenow and Malin, 2010), that in countries and periods with low and stable inflation, the intensive margin tends to dominate variation in CPI inflation, while in periods of high inflation, the extensive margin plays a more prominent role.

Price decreases contribute substantially to the variation in PPI inflation. It may be instructive, following Gagnon (2009), to decompose our PPI inflation measure further into two signed components: the first, capturing the contribution of positive price movements to inflation's variation, and the second, negative price movements. If 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 less the average (across goods) price decrease at a point in time multiplied by the fraction of items with price decreases, then it follows that its variation is the sum of the variation in positive price movements and in negative price movements, less two times their covariance:

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

in turn, dividing the positive price terms (the first two terms) and, separately, the negative price terms (the second two terms) by the total variation to gauge each's contribution to it.

Table 9 reports that the size of negative price changes weighted by their frequency accounts for 60 percent of the variation in PPI inflation and the remainder the size of positive price changes weighted by their frequency. For the CPI, in contrast, KK report an even split between the analogous positive and negative price terms, with each accounting for 50 percent of CPI inflation's overall variability. We plot the time-series of these two terms together with the PPI inflation rate in Figure 3: It shows that our neg_t times series jumps in periods of disinflation, though, and as confirmed by the decomposition, the pos_t series also exhibits some nonlinearities in periods of unusual movement in the PPI inflation measure.

The size of price decreases is a key contributor to the variability of inflation... Bringing together the results from the previous two tables, Table 10 reports the coefficients from regressing the twelve-month moving average of our PPI inflation measure on each of the four margins of price adjustment considered above: the size and frequency of price increases and decreases. The coefficients on all four margins are statistically significant at the 5-percent level, and while the coefficients on the frequency of price increases and decreases more or less cancel one another out, at 0.045 and -0.051, respectively, the coefficient on the size of price decreases, at -0.110, is almost three times as large as that on the size of price increases, at 0.042. This asymmetry implies that of the four margins considered here, the size of price decreases is a unique driver of movements in the PPI – a result that is consistent with the dominant role for both the intensive margin and negative price movements in the variance decompositions reported in Table 9. To further illustrate this special relationship, Figures 4 and 5 plot twelve-month moving averages of the PPI inflation rate and of the size and frequency of price increases and decreases, respectively, illustrating how the frequencies of price increases and decreases in the PPI tend to move together over time, thereby cancelling one another out, and the size of price increases is quite flat over time, while, and in contrast, the size of price decreases moves inversely with inflation, most strikingly in periods of disinflation. In a sense, given the behavior of the three other margins of price adjustment, the size of price decreases is left almost by default left to play an important role in PPI inflation.

...particularly when real activity declines. From Figures 4 and 5 it is apparent that the size of price decreases plays a key role in periods when real activity contracts. But due to data limitations (the BLS only began collecting services prices in the late 1990s), our goods and services index only goes back to 1999, and so includes only one full recession, from March to November

2001, according to the NBER's Business Cycle Dating Committee. (Although the most recent recession begins at the end of our data set, in December of 2007, we only observe six months of data after this point, so our understanding of it is necessarily truncated.) We therefore reproduce Figures 4 and 5 for the component of the PPI with the longest time series of data, *Machinery and Equipment Manufacturing* (which comprises 15 percent of the finished goods PPI, after *Fuels*, 21 percent, *Processed Food*, 22 percent, and *Transportation Equipment*, 17 percent), with data from 1985 to 2008, with significant industry disinflations in 1985 and early 1986, from 1990 to 1991 during the recession, and in 2000. The frequency of price increases or decreases is generally stable (or increasing) during these downturns, as illustrated in Figures 6 and 7. Neither series declines significantly in periods of declining inflation or real activity. Such consistency in pricing behavior over the business cycle might be interpreted as evidence of downward nominal or real rigidities, as one might reasonably expect firms to vary the size or frequency of their price decreases in such periods. Put differently, while there is no evidence of increased reluctance by price setters to curb nominal price decreases in periods of declining real activity or inflation, there is no evidence of decreased reluctance either. The fact that the frequency of price decreases does not accelerate during disinflations may in itself reflect the presence of nominal or real rigidities at the producer level. Other industries in our sample exhibit similar trends in the size and frequency of price changes over the business cycle, whereby the frequency of price decreases does not accelerate during disinflations, but their average size jumps.

To summarize our findings for the time series of the PPI, the size of price changes, and in particular, of price decreases, plays a key role in PPI inflation dynamics. In contractionary periods, the stability of the frequency of price decreases taken together with the contemporaneous jumps in the average size of price decreases may be consistent with the presence of nominal or real rigidities at the producer level, as we explore in more depth in the following section.

6 Producer Price Rigidity: Facts and Models

In this section, we evaluate the implications of our empirical findings through the lens of standard workhorse macroeconomic pricing models. We touch on three broad themes, first, the implications of our findings on the frequency and nature of micro producer price changes for the pricing assumptions of such models, second, their implications for the potential sources and magnitudes of the contract multiplier, and third, which of our findings have yet to be addressed by the models available in the literature and are likely to be promising avenues for future work.

We begin by reviewing the stylized facts set out above in light of the standard assumptions (i.e.

state- versus time-dependent pricing) of several classes of macroeconomic pricing models. We note, first, that such models are almost always calibrated to moments from the micro data underlying CPI's, in part due to the influence of the administered price thesis we discuss in the Introduction, that wholesale prices are not allocative, and so there is little benefit to looking at what is happening to prices early in the production pipeline. As we have found that this old "fact" is not true, this in turn implies that macroeconomic pricing models may want to look more closely at the possible role of nominal and real rigidities at the producer level to explain monetary non-neutrality.

We therefore discuss the implications of our findings for some models that do not include a producer sector, but whose assumptions regarding consumer price rigidity may be calibrated using sample moments from the producer price index if one were to assume fixed markups by downstream (retail) establishments, and completely flexible prices (no costs of price adjustment or real rigidities in play at the retail level of the market).[21] A constant markup for downstream firms implies full-pass-through of any cost shocks, and so any rigidities (nominal or real) must operate at the producer level. This assumption is certainly consistent with the observed rigidity of producer prices being roughly equivalent to that of consumer prices, and so with the key rigidities managed by producers.

We consider time-dependent pricing models, as in Taylor (1980) or Calvo (1983), that assume exogenous staggering of price changes across the economy, state-dependent models, such as Dotsey, King, and Wolman (1999), Midrigan (2010), and Gertler and Leahy (2008), as well as a new class of models with constrained information or rational inattention, which includes Mankiw and Reis (2002), Woodford (2009), and Mackowiak and Wiederholt (2011).

A number of the results we find for the PPI are quite similar to those found for the CPI by previous researchers. Like other papers in this literature, we find that there is considerable and persistent heterogeneity in the frequency of price change across products. Our finding that the size of price decreases, the "intensive margin" dominates the variation of PPI inflation is consistent with several classes of models. This includes staggered time-dependent pricing models, such as Taylor (1980) and Calvo (1983). Some state-dependent models such as Golosov and Lucas (2007) can match this feature of the data by assuming large idiosyncratic price changes coupled with aggregate shocks that have effects on the frequency of price increases and decreases that cancel out, while others, such as Dotsey, King, and Wolman (1999), assume instead that the frequency of price change is the key margin of adjustment in inflation dynamics.

The large average absolute price changes in the PPI data, much larger than the average changes in aggregate inflation (and similar to the findings of KK, 2008, and NS, 2008, for the CPI) suggest

[21] Consistent with this assumption, for example, Eichenbaum, Jaimovich, and Rebelo (2011) find full pass-through of cost shocks to reference prices by a large retailer.

an important role for idiosyncratic shocks in firms' price adjustment. A number of state-dependent pricing models allow firms to adjust their prices based on the idiosyncratic shocks they face, which in turns raises the pace of price adjustment (depressing the contract multiplier) a point emphasized by Golosov and Lucas (2007). Such large price changes may also be consistent with rationally inattentive sellers who respond to large idiosyncratic shocks but not to smaller aggregate shocks, as in Woodford (2009) and Mackowiak and Wiederholt (2011).

Our finding of many small price changes – similar to that of KK (2008) for the U.S. CPI and of Vermeulen et al. (2007) for euro-area PPI's – is consistent with time-dependent and some state-dependent pricing models, as well as information-constrained pricing models. Although it is not consistent with state-dependent pricing models with a single large menu cost, it is if these menu costs are variable as in Dotsey, King, and Wolman (1999) or Kehoe and Midrigan (2010) or small shocks arrive infrequently as in Gertler and Leahy (2008). This finding may also be consistent with a state-dependent pricing model in which there are economies of scope in the technology of price adjustment, so a multi-product firm pays one fixed cost to adjust the price of one or all of its products, as in Midrigan (2010) for consumer prices or Bhattarai and Schoenle (2011) for producer prices. In information-constrained pricing models, such as those emphasized by Mankiw and Reis (2002) and Woodford (2009), price changes may follow a sticky plan and hence ignore news about macroeconomic developments, leading to many small price changes.

Turning to our results for the relationship between a price's age and the size of its adjustment, time-dependent pricing models such as Taylor (1980) and Calvo (1983) predict a relationship between the age of a price and the size of a subsequent change as do state-dependent pricing models in which price changes depend on receipt of a low menu-cost draw (as in Dotsey, King, and Wolman, 1999). As we find the size of price changes rises with a price's age for most goods sectors, but almost no services sectors, this suggests that time-dependent pricing models may be more appropriate to describe goods pricing, while state-dependent pricing models may be a better fit for services pricing. This result differs somewhat from KK's (2008) finding of no relationship between a price's age and the size of its subsequent adjustment for the CPI.

Klenow and Malin (2010) note that there is little evidence that price changes are synchronized over the business cycle in the micro data underlying CPIs, at least in countries with moderate inflation over their recent history, such as the U.S. They note that this finding is consistent both with time-dependent pricing and with information-constrained state-dependent pricing, whereby managers are more preoccupied with idiosyncratic than with aggregate shocks. For the PPI, we do not find strong evidence of such synchronization in the frequency of price changes over the business cycle, but we do find evidence of some synchronization in the size of price decreases, as we discuss in detail in the previous section. This pattern of price adjustment appears most consistent with models of constrained information or rational inattention with some tail risk whereby managers remain preoccupied with idiosyncratic shocks except when an aggregate shock is particularly large and negative, in which case they respond by changing (lowering) their prices.

What are the implications of our findings for the potential sources and magnitude of the contract multiplier? Although a large literature (e.g. Christiano, Eichenbaum, and Evans, 1999) has estimated the real effects of permanent monetary shocks to last for several years, this result cannot be reconciled with the observed patterns of nominal price rigidity (that prices change, on average, several times a year) without including one of the so-called real rigidities to generate a large contract multiplier in the model: These may include strategic complementarities among firms, rational inattention by firm managers, and the like.

We consider first the possible relevance of demand-side rigidities for the contract multiplier. This literature focuses on strategic complementarities that make it costly for firms to deviate from their competitors' prices, and may include kinked demand as in Kimball (1999), specific factors, and the like. A number of studies have concluded that real rigidities associated with the demand side may not be sufficient to deliver monetary non-neutrality given the observed price rigidity in the micro-data underlying major developed economies' CPI's.[22] Given the aggregate degree of nominal rigidity in the PPI once one accounts for the behavior of large firms, it does not appear that the set of analogous moments in the PPI data will be much more amenable to such a model. For example, Klenow and Willis (2006) argue that given the moments computed from the CPI, a Kimball-esque real rigidity requires implausibly high levels of idiosyncratic productivity shocks to fit the CPI data. Many of the basic facts emphasized in Klenow and Willis (2006) for the CPI are found in the PPI as well – given an average annual inflation rate of 1.2 percent in the PPI, and a mean share of 32 percent of firms changing their prices each month, the fact that the average price change conditional on a price increase is 8.0 percent implies that sellers must be responding to idiosyncratic shocks, not just aggregate shocks, when they change prices. Although Gopinath and Itskhoki (2010) claim that this model is consistent with many of the features of producer price data, their model is calibrated to aggregate duration measures that do not take into account the behavior of large firms. As the median duration of a price change falls by almost half once one accounts for this stylized fact, it is not clear in turn that their original finding goes through.

On the cost side, a large literature has focused on a contract multiplier associated with the

[22] For example, Gopinath and Isthoki (2010) summarize this literature as showing that "strategic complementarities, for example operating through variable markups, play little role for retail prices and appear to be quite important for wholesale prices."

interaction of firms in an input-output production structure. This literature is reviewed in Huang and Willis (2010), who use a state-dependent model with even with more rigid assumptions on aggregate producer prices than implied by our findings and show that this source of real rigidities provides only limited additional persistence of aggregate monetary shocks on output in a model. Our findings of greater producer price flexibility than they assume (drawing on a survey of 45 manufacturing firms by the Federal Reserve Bank of Kansas City) should only strengthen their conclusion.

Our findings suggest two potentially fruitful areas for the development of macroeconomic pricing models that have, thus far, been largely unexplored. First, we are not aware of any models that focus on the size of downward price changes as a key margin of adjustment to understand the overall variation in inflation. One key area for future work, then, is to explain why the size of price decreases plays a key role in the variation in PPI inflation, and does so most strikingly when real activity slows. Of particular interest in light of our findings are the results of a randomized field experiment by Anderson and Simester (2010) in which firms lose some of their most valuable customers (those with recent purchases at high markups) when they cut prices. To the extent that this customer antagonism does not develop following price increases, only price decreases, it may shed some light on the apparent reluctance of firms to cut prices in the PPI data, particularly small firms. For a small firm there may be additional uncertainty about the price point at which this antagonism will be triggered – and it is also possible that the loss of a single large customer may be more devastating to its market share than would be the case with a large firm. Duncan and Simester's (2010) results are also consistent with the *primary* reason given by firms for not changing their prices in the surveys conducted in Blinder et al. (1998, p. 313) that "they hesitate to adjust prices for fear of antagonizing customers."

This behavioral quirk on the part of customers may explain some of the microeconomic mechanics underlying the declining (or stagnant) real output associated with deflations: If declining prices ratchet up this type of antagonism by customers to firms economy wide, spurring more search behavior, this in turn requires (repeated) rematching between producers and consumers and suggests an ongoing disruption of established economic relationships, and so in real activity.

Taken together with our results for the frequency of price decreases across the firm size distribution and over time, Duncan and Simester's (2010) findings suggest that a fruitful area for future research would consider price decreases as a form of exit. This could account for the asymmetry in the frequency of price increases and decreases, across all firms, but most notably for small firms, who may be particularly unwilling to risk losing customers and so to decrease prices. In Duncan and Simester's world, a firm will only decrease prices when the demand for its product has slowed sufficiently that although it will lose valuable customers, they must be sacrificed to survive. Cutting prices may, thus, be akin to exiting a local neighborhood along the demand curve and finding a new neighborhood, and as part of that process, losing the cream of one's customer base.

Second, our findings suggest that models that incorporate returns to scale in the technology of price setting (different menu costs for different sized firms) may be important to characterize the distribution of price changes in the cross section as well as the time series and so to properly calibrate menu cost models. General equilibrium models in the trade literature, for example, incorporate assumptions about the shape of the firm size distribution as a standard feature: The macroeconomic pricing literature may want to adopt similar conventions to match the data.

7 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. Large firms may be more active price tweakers simply because their size provides them with greater technical abilities: They may enjoy returns to scale in the technology of price setting and so benefit from being able to devote more managerial time and effort to review market conditions and set new prices. Once one accounts for this fact, the rigidity of producer prices falls between the rigidity of consumer prices including, and excluding, sales. These results establish a new stylized fact for the United States and raise the question of whether similar patterns exist in other countries. A promising avenue for future work, in our view, would be a cross-country analysis of the relationship between firms' size and their pricing behavior as well as between the shape of the firm-size distribution and the degree of aggregate price flexibility. Our findings also suggest that policymakers seeking to gauge the momentum of inflation in the U.S. may want to pay particular attention to what is happening at large firms.

We also find that long-term contracts are associated with slightly greater price rigidity for goods and services, but that the differences are much less striking than those for the firm size distribution, and that the size of price decreases plays a key role in inflation dynamics. Our findings over the time series are particularly striking for periods in which price pressures trend lower. The stability of the frequency of price decreases, in contrast with the jump in the average size of price decreases in contractionary periods may be consistent with the presence of downward nominal and real rigidities. As central bankers still do not understand why deflations are so costly (are generally associated with stagnant or falling aggregate output), our findings may offer some insight into how and why firms adjust their prices in periods when aggregate prices are falling. They also suggest that a better understanding of the microeconomic mechanics of a disinflation (or deflation) may, in turn, explain why the size of price decreases plays such an important role in the PPI's overall variation and perhaps in monetary non-neutrality more generally.

How firms price their goods and services isn't the whole story for inflation, as other factors also influence overall rates of inflation, including consumers' inflation expectations. That said, our paper provides some new insights into what have been very limited aggregate data on firm pricing dynamics.

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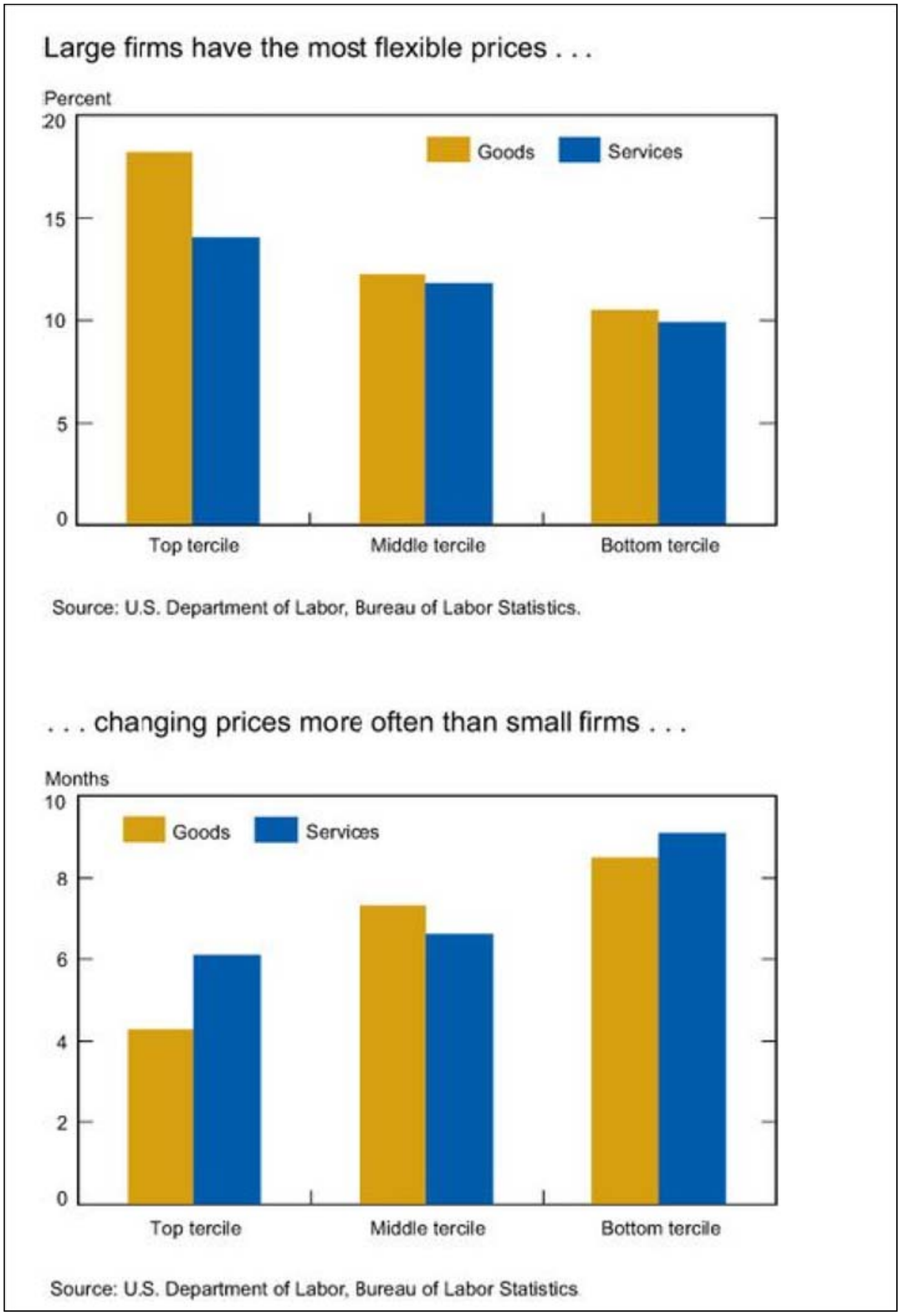

Figure 1: *Weighted Medians of the Frequency and Duration of a Price Change across the Firm Size Distribution: Finished Goods or Services PPI.* The horizontal axes identify each of the three groups of firms ordered by size (separated into goods and services firms) and the vertical axes the weighted median frequency of price changes (in the top panel) and the weighted median duration of a price change (in the bottom panel).

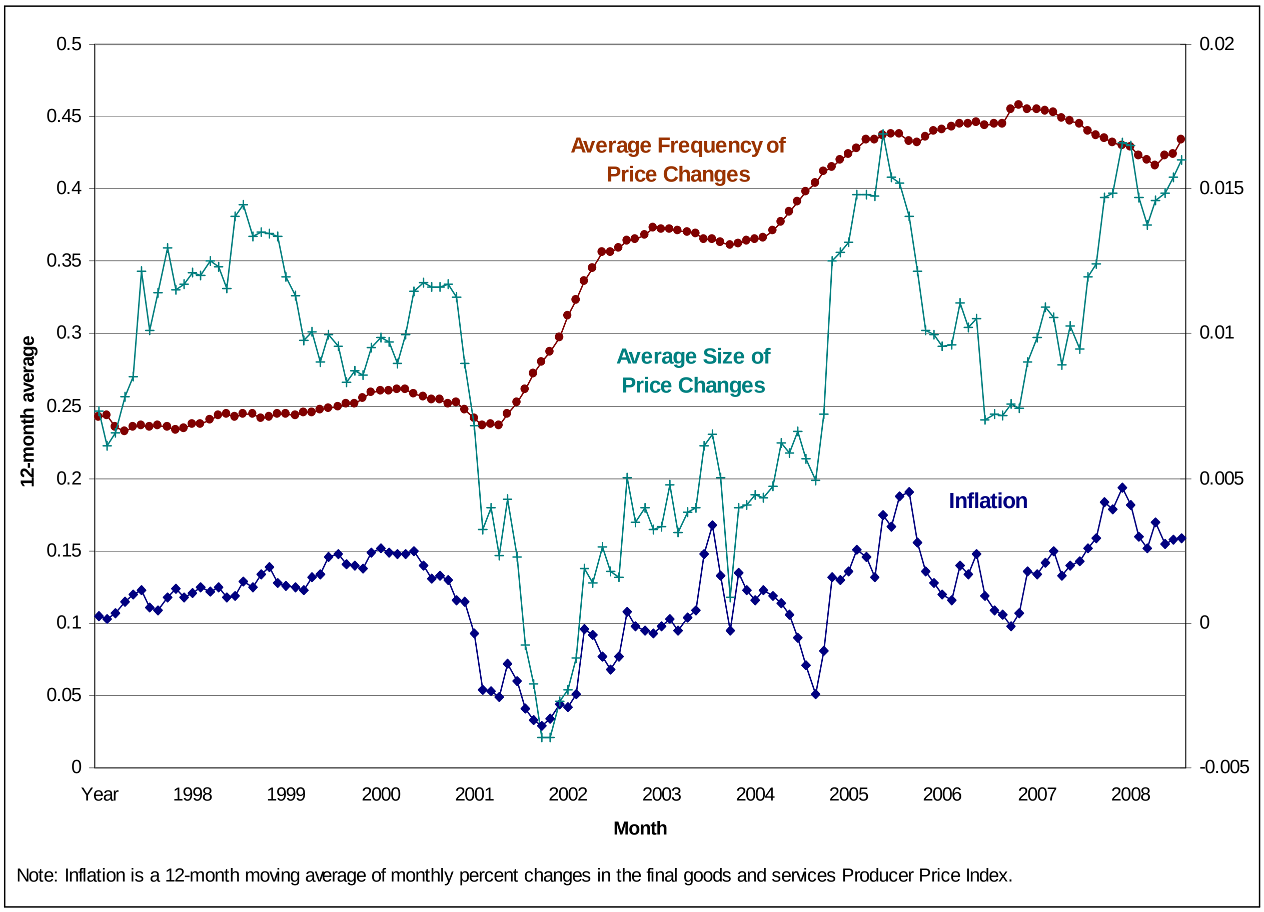

Figure 2: *Inflation and the Size and Frequency of Price Changes: Finished Goods and Services PPI.* Source: BLS.

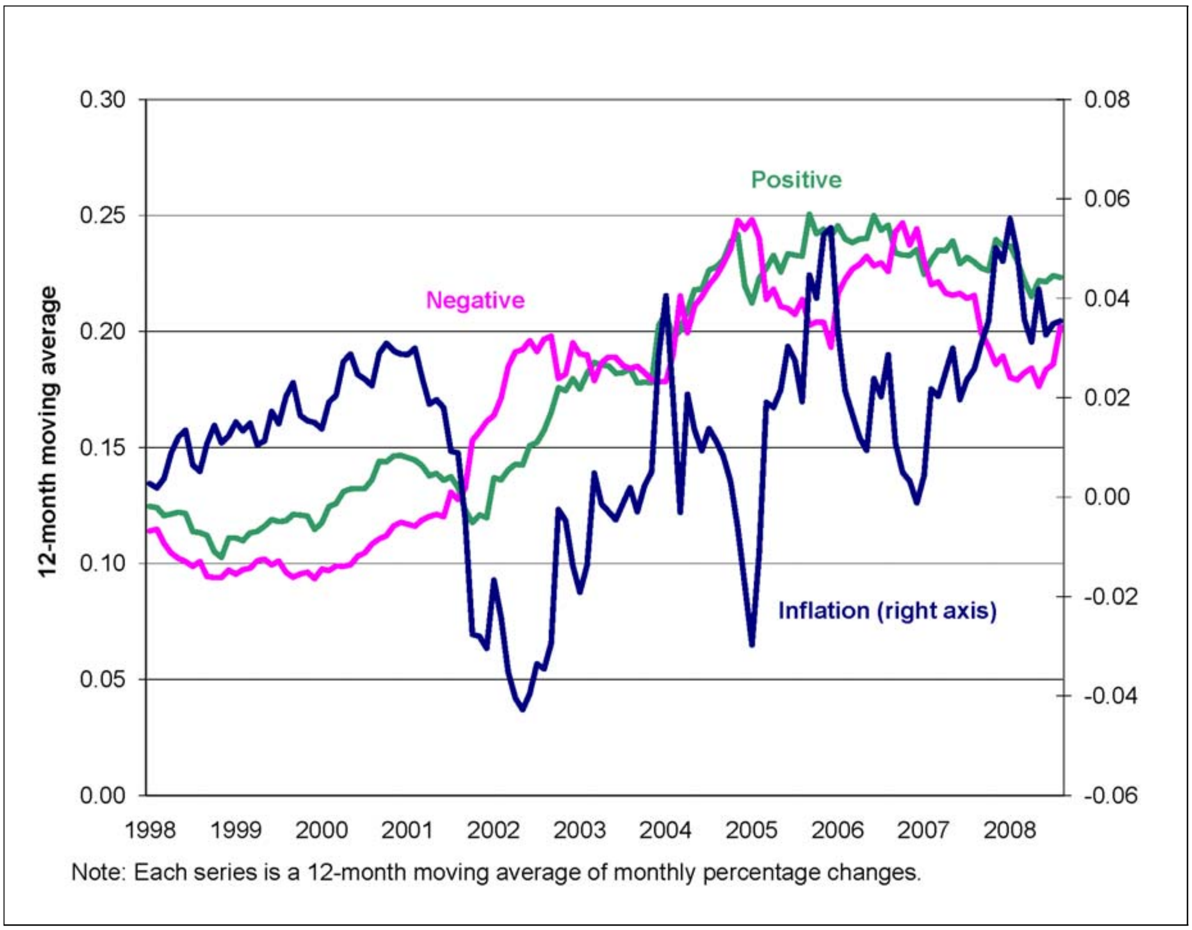

Figure 3: *Finished Goods and Services PPI Inflation Due to Positive or Negative Price Changes.* Source: BLS.

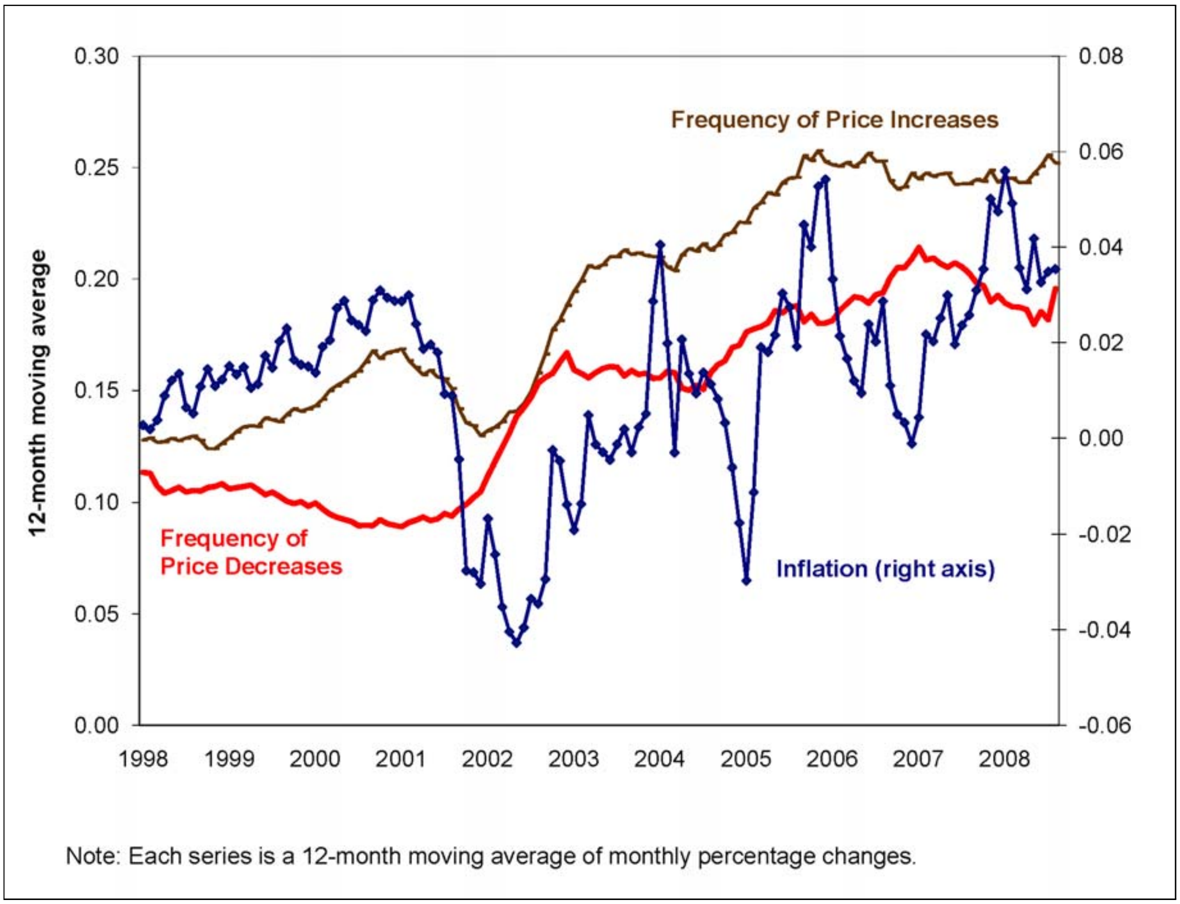

Figure 4: *The Frequency of Price Increases and Decreases: Finished Goods and Services PPI Inflation.* Source: BLS.

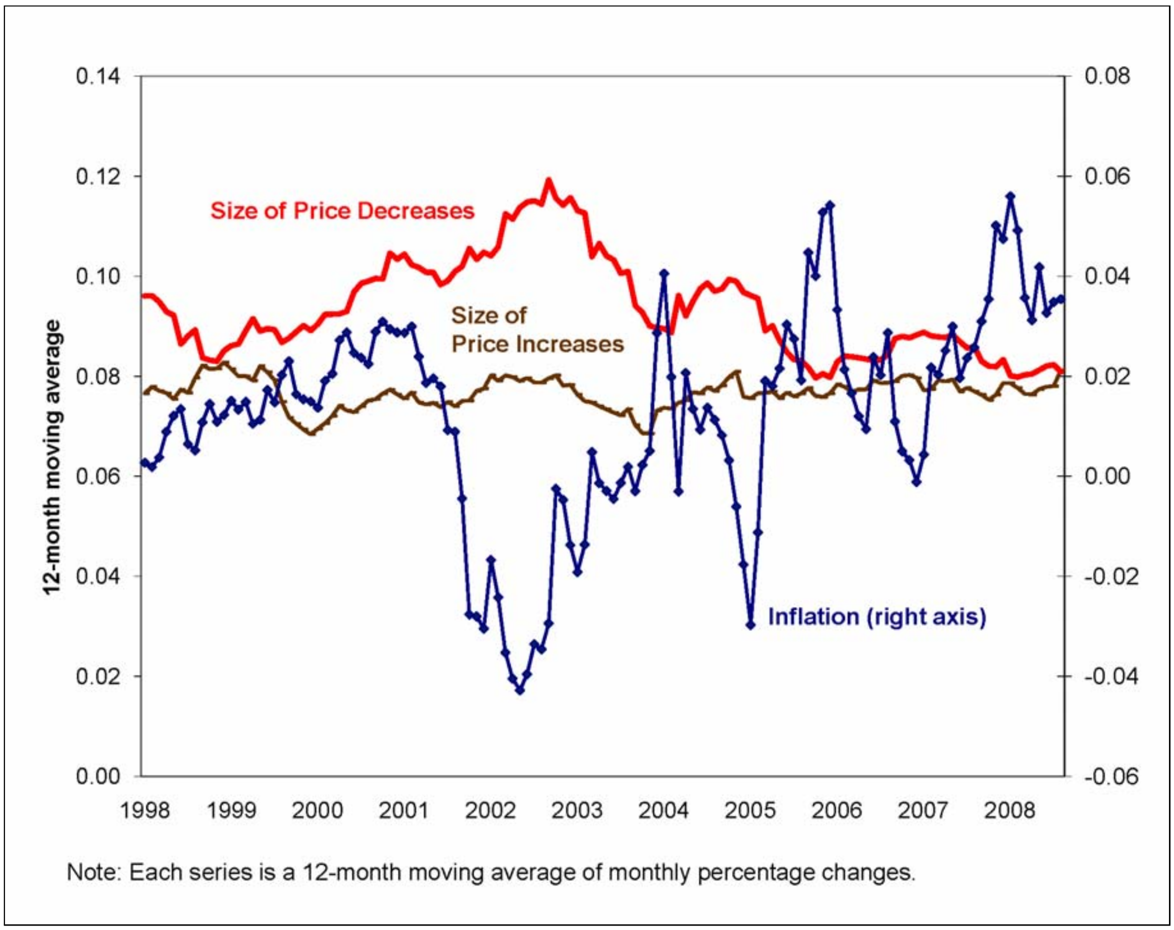

Figure 5: *The Size of Price Increases and Decreases: Finished Goods and Services PPI Inflation.* Source: BLS.

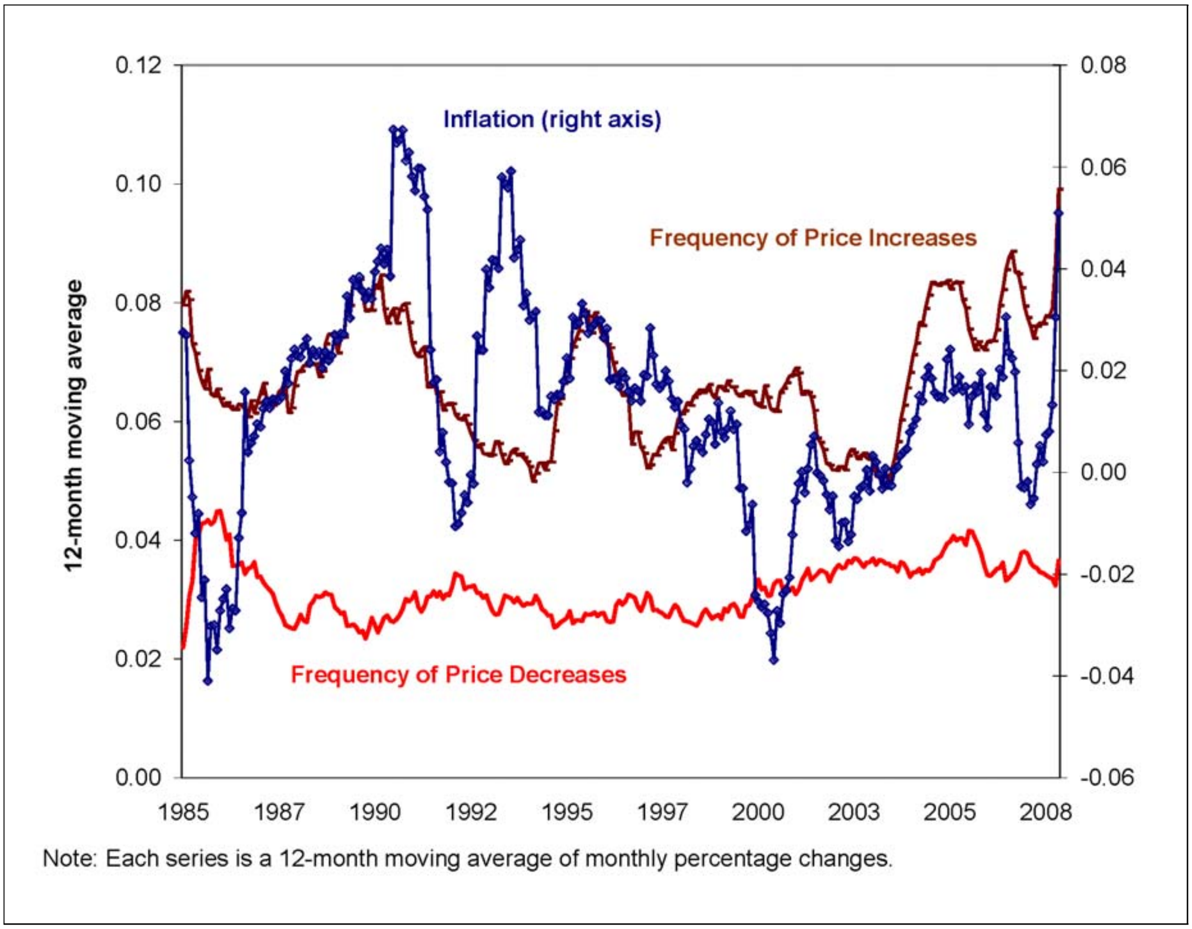

Figure 6: *The Frequency of Price Increases and Decreases: Machinery and Equipment PPI Inflation.* Source: BLS.

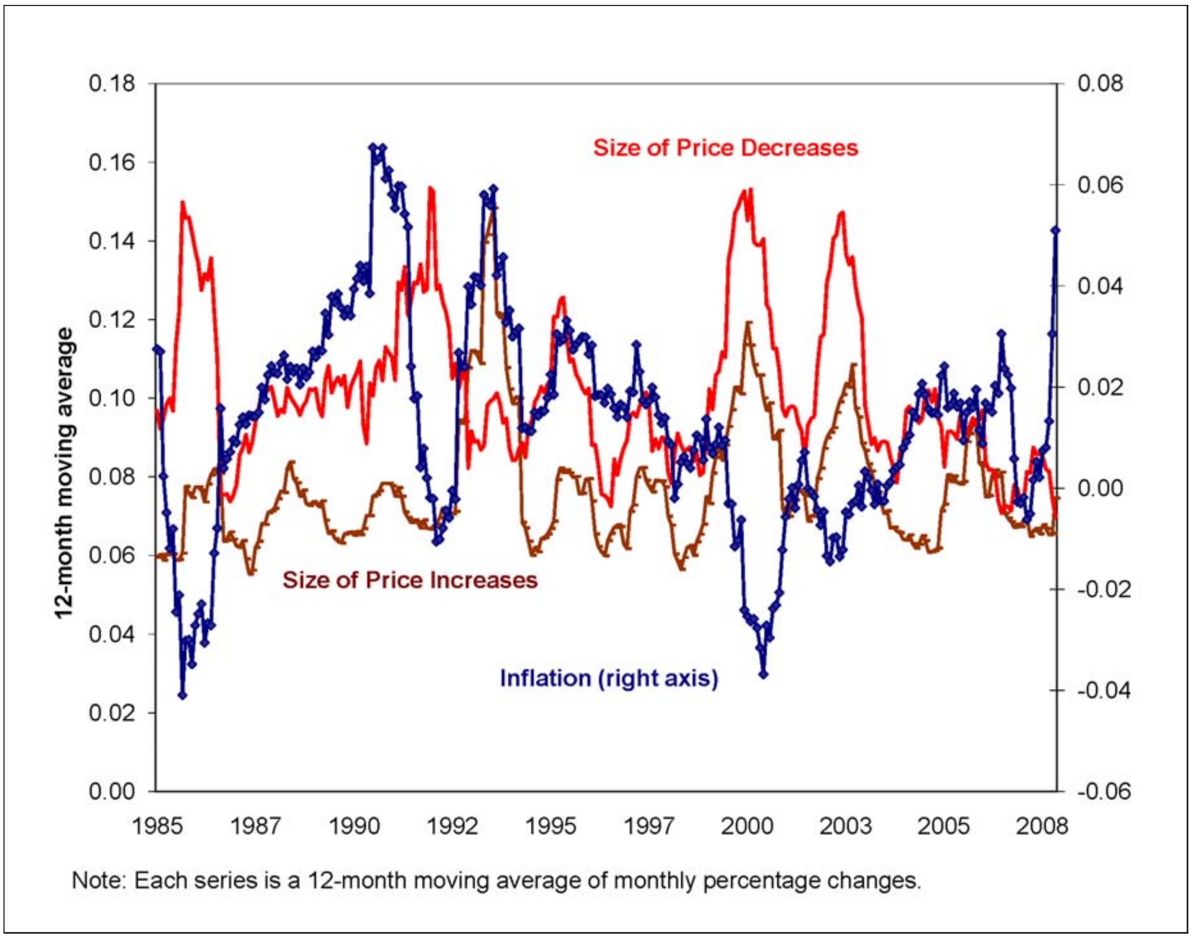

Figure 7: *The Size of Price Increases and Decreases: Machinery and Equipment PPI Inflation.* Source: BLS.

Table 1. Summary Statistics by Firm Size

	GOODS		
weighted medians	top tercile	middle tercile	bottom tercile
FREQUENCY			
frequency price change	18.2%	12.2%	10.5%
frequency of increases	13.6%	10.3%	8.2%
frequency of decreases	5.5%	1.6%	1.5%
DURATION			
implied duration	4.3	7.3	8.5
SIZE of CHANGE			
absolute size change	5.6%	6.0%	6.0%
size upward change	5.7%	5.4%	5.6%
size downward change	5.6%	5.9%	6.7%

	SERVICES		
weighted medians	top tercile	middle tercile	bottom tercile
FREQUENCY			
frequency price change	14.0%	11.8%	9.9%
frequency of increases	7.4%	7.1%	7.1%
frequency of decreases	3.6%	2.4%	0.0%
DURATION			
implied duration	6.1	6.6	9.1
SIZE of CHANGE			
absolute size change	6.3%	6.8%	7.5%
size upward change	6.3%	5.0%	6.4%
size downward change	6.5%	7.6%	7.8%

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 2. Fraction of Price Changes Below Size Thresholds

	CPI	ALL		GOODS	SERVICES
variable	mean	mean	median	median	median
share of price changes below 1%	11.3%	22.3%	16.4%	13.3%	17.4%
share of price changes below 2.5%	23.4%	29.8%	29.1%	32.1%	28.1%
share of price changes below 5%	39.8%	40.4%	56.1%	51.2%	57.7%
For top firm tercile					
share of price changes below 1%		23.5%	19.1%	21.3%	18.3%
share of price changes below 2.5%		31.0%	36.1%	34.6%	36.5%
share of price changes below 5%		41.4%	61.7%	50.9%	65.3%
For middle firm tercile					
share of price changes below 1%		15.2%	7.8%	0.0%	10.3%
share of price changes below 2.5%		23.4%	24.1%	22.0%	24.7%
share of price changes below 5%		36.5%	49.7%	42.8%	51.9%
For bottom firm tercile					
share of price changes below 1%		16.2%	0.0%	0.0%	0.0%
share of price changes below 2.5%		21.6%	15.6%	11.0%	17.1%
share of price changes below 5%		32.8%	42.8%	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 posted prices from the top three urban areas. Entries are weighted mean or weighted median fractions of price changes 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 3. 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	13.1%	31.9%	16.5%	37.3%	11.9%	30.1%
frequency of increase	9.8%	17.7%	13.6%	22.6%	8.5%	16.1%
frequency of decrease	3.7%	13.8%	4.2%	16.0%	3.6%	13.0%
DURATION						
implied duration	6.0	10.9	5.1	11.3	6.4	10.8
SIZE						
absolute size change	7.0%	10.5%	5.6%	8.2%	7.4%	11.2%
size upward change	5.8%	9.7%	5.7%	7.7%	5.8%	10.4%
size downward change	6.8%	13.8%	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 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. 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				
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				
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 5. Correlation between Durations and the Sizes of Price Changes

Major Group/NAICs Description	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. 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 6. Share of Transactions Under Contract by Major Group

	Major Group/NAICs Description	Major Group	Share
GOODS	Farm Products	1	n.a.
	Processed Foods and Feeds	2	15.6%
	Textile Products and Apparel	3	31.5%
	Hides, Skins, Leather	4	27.1%
	Fuels and Related Products	5	21.3%
	Chemicals and Allied Products	6	23.2%
	Rubber and Plastic Products	7	34.6%
	Lumber and Wood Products	8	20.0%
	Pulp, Paper and Allied Products	9	26.4%
	Metals and Metal Products	10	42.5%
	Machinery and Equipment	11	40.1%
	Furniture and Household Durables	12	27.3%
	Nonmetallic Mineral Products	13	27.5%
	Transportation Equipment	14	59.1%
	Miscellaneous Products	15	23.5%
SERVICES	Wholesale Trade	42	6.7%
	Retail Trade	44	1.3%
		45	2.4%
	Transportation and Warehousing	48	44.1%
		49	43.3%
	Information	51	30.2%
	Finance and Insurance	52	82.2%
	Real Estate and Rental and Leasing	53	76.4%
	Professional, Scientific, and Technical Service	54	65.1%
	Management of Companies and Enterprises	56	46.8%
	Educational and Training Services	61	31.3%
	Health Care and Social Assistance	62	6.2%
	Arts, Entertainment, and Recreation	71	21.2%
	Traveller Accommodation	72	8.6%
	Total		33.1%

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 7. 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				
implied duration	5.5	7.2	5.9	6.8
SIZE				
absolute size change	5.6%	5.5%	5.8%	6.2%

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 8. Time-Series Moments for Prices

Variable	Mean	Standard Deviation	Correlation with π	Variable	Mean	Standard Deviation	Correlation with π
Producer Prices				**Consumer Prices**			
π	0.12	0.71		π	0.27	0.36	
fr	31.8	10.9	0.15	fr	26.6	3.2	0.25
dp	0.87	4.49	0.78	dp	0.98	1.19	0.99
fr+	17.9	7.5	0.46	fr+	15.0	2.6	0.69
fr-	13.8	5.8	-0.26	fr-	11.5	2.5	-0.41
dp+	7.99	1.16	0.22	dp+	8.87	1.10	0.19
dp-	9.08	2.93	-0.40	dp-	9.37	1.64	-0.19
pos	1.38	0.72	0.56	pos	1.33	0.27	0.74
neg	1.28	0.68	-0.55	neg	1.06	0.23	-0.60

The entries are means, standard deviations, and cross correlations across time of the monthly values of each variable. The PPI sample runs from January 1999 to August 2008. The consumer price moments come from Klenow and Kryvtsov (2008) with a sample that runs from January 1988 to January 2005 with price data from the top three urban areas. The monthly values of the variables are across-item weighted means of: π=inflation; fr=fraction of items that change prices; dp=size of price changes (not absolute value); fr^+=fraction of items with rising prices; fr^-=fraction of items with falling prices; dp^+=size of price increases; dp^-=absolute size of price decreases; pos=fr^+*dp^+; neg=fr^-*dp^-.

Table 9. Variance Decompositions

	IM vs. EM (%)		POS vs. NEG (%)	
	IM term	EM terms	POS terms	NEG terms
PPI	75	25	40	60
CPI	94	6	49	41

The PPI sample runs from January 1998 to August 2008. The CPI numbers come from Klenow and Kryvtsov (2008) and are for "Posted Prices" from the top three urban areas with a sample that runs from January 1988 to January 2005.

Table 10. Regression of PPI Inflation on Size and Frequency of Price Changes

		12-month moving average	
	Variable	Coefficient	Standard Error
Producer Prices	fr+	0.045	0.004
	fr-	-0.051	0.004
	dp+	0.042	0.021
	dp-	-0.110	0.010
	R^2	0.76	

The PPI sample runs from January 1998 to August 2008. 128 observations.