The Federal Reserve Bank of Kansas City
Economic Research Department

Convenient Prices, Currency, and Nominal Rigidity: Theory with Evidence from Newspaper Prices

Edward S. Knotek II

December 2005

RWP 05-11

Research Working Papers

Convenient Prices, Currency, and Nominal Rigidity: Theory with Evidence from Newspaper Prices

Edward S. Knotek II*
Federal Reserve Bank of Kansas City
December 15, 2005

RWP 05-11

Abstract: Newspapers, movie tickets, and concession stand items typically charge prices that facilitate rapid, simple transactions: their prices often coincide with available monetary units, require few pieces of money, or require little change. In this sense, these prices are more convenient than other proximate prices. I model a firm that explicitly incorporates convenience into its pricing decisions, where convenience is quantified by the number of currency units in a transaction. The model illustrates how alternating periods of price rigidity and flexibility can arise in such a setting, along with rapid switching between convenient prices. I compile time series data on newspaper cover prices and use simulations to show that convenience is an essential component of these prices. In the empirical data, firms set prices that were more convenient than adjacent prices 61% of the time. Standard menu costs cannot replicate this behavior. Because convenience appears to affect many of the consumer goods and services with the stickiest prices in the U.S. economy, studies focusing on very sticky prices must be cognizant of convenience's role in effecting above-average price rigidity.

Keywords: Convenient prices, relative inconvenience, price rigidity, menu costs, indirect inference, newspaper pricing history

JEL classifications: E31, D40, C15, N81, N82

*Edward S. Knotek is an economist at the Federal Reserve Bank of Kansas City. I thank my dissertation committee—Bob Barsky, Chris House, Miles Kimball, and Valerie Suslow—for numerous comments and discussions about this paper, as well as Susanto Basu, Stephen Cecchetti, Andrew Coleman, Yuriy Gorodnichenko, Daniel Levy, Matthew Shapiro, Jonathan Willis, Andrew Young, and participants in seminars at the University of Michigan and the economics academic job market. This is the revised first chapter of my dissertation. The views expressed herein are solely those of the author and do not necessarily reflect the views of the Federal Reserve Bank of Kansas City or the Federal Reserve System.

Knotek email: Edward.Knotek@kc.frb.org

I Introduction

Newspaper cover prices are typically a multiple of a quarter and most have not required pennies in the last 40 years. Movie tickets are often priced in whole or half dollars. The prices of concession items at a baseball game normally require little or no change. Casual observation of these and many other goods suggests that firms sometimes choose certain prices because they facilitate rapid, easy-to-make transactions. In this sense, these prices are relatively more *convenient* than other nearby prices.

To explain the above phenomena, this paper posits that some firms explicitly take convenience into account when making pricing decisions. If the amount of time or extra change involved in making a transaction is important—as it appears to be in the examples provided—setting relatively convenient prices may be advantageous to both firms and consumers. On the other hand, charging relatively inconvenient prices may adversely affect a firm's profits.

I construct a model of a dynamically optimizing firm whose profits are affected by the *relative inconvenience* of the prices it charges. I propose a measure of relative inconvenience that is the minimum number of coins and bills needed to make a transaction at a given price. For instance, a price of 26¢ (a quarter plus a penny) is relatively more inconvenient than 25¢ (a quarter) since it requires an extra unit of money. Thus the available currency denominations determine which prices are more convenient than others.

The importance a firm places on charging relatively convenient prices can be crucial in determining price-setting behavior. If profits are only slightly affected by inconvenience, a firm sets and maintains relatively convenient prices when it is not onerous to do so. Since profits are not dramatically affected by inconvenient prices, it is also willing to charge—and move rapidly between—them at other times. This leads to the possibility of alternating intervals of price rigidity and price flexibility. If profits are more sensitive to inconvenience, the firm wishes to charge convenient prices almost exclusively. This results in prices that are relatively rigid. However, under certain circumstances the firm may engage in rapid switching between adjacent convenient prices as well. If inconvenience has a large impact on profits, the firm only sets the most convenient prices—prices that require a single unit of money. This leads to extensive periods of price rigidity.

Unlike other forms of price rigidity which are forward-looking, rigidity due to convenience is based upon a purely static decision. The stickiness described above is generated without menu costs and arises naturally when convenience affects profits and some prices are more convenient than others. In the model I construct, I nest the possibility that a firm faces costly price adjustment. This allows me to compare price-setting behavior when convenience matters with that when prices are costly to adjust, along with combinations of these phenomena.

Modeling the impact that convenience can have on pricing is important for a number of goods. One of these is weekday newspapers sold at the cover price. I compile a new quarterly data set extending from 1842 to 2004 and document three empirical facts for the newspaper industry over this period: (1) the frequency of price changes has significantly increased over time; (2) higher inflation has been associated with more frequent price changes; and (3) the average absolute percentage change in nominal price has significantly declined over time.

I simulate the model to compare its predicted price-setting behavior with the empirical evidence. As anticipated, I find that convenience is an essential component of these prices. Between 1904 and 2004, newspaper firms set weekday cover prices that were more convenient than adjacent prices in 61% of quarters. It is only when firms explicitly take a price's convenience into account that the model can match this empirical regularity. By themselves, standard menu costs for changing prices cannot replicate this behavior. Formal structural estimation of the model via indirect inference reveals that both convenience considerations and menu costs are necessary to match the newspaper data.

While it is often taken for granted, the model requires that the prices charged by firms be feasible under the available currency denominations. This effectively places an integer constraint on price-setting behavior (cf. Barro 1976). While this requirement is needed to compute a price's relative inconvenience, it has important ramifications when prices are very low. I present evidence that at very low prices newspaper firms were constrained by the denominations in circulation. Thus the rigidity I find is partly due to denomination constraints at low prices and convenience considerations at higher prices.

I also suggest broader implications of the paper. While convenience is not important for all goods, it is relevant beyond newspapers. Using data from Bils and Klenow (2004), I estimate that convenience may affect more than 5% of consumer spending. Moreover, convenience appears to affect many of the consumer goods and services with the stickiest prices in the U.S.

economy. This suggests that studies focusing on very sticky prices must be cognizant of convenience's role in effecting above-average price rigidity. I also note that during the Great Depression none of the papers in my data set decreased its cover price—for either its weekday or Sunday edition. This raises the question, were denomination constraints and/or convenience constraints a factor in these decisions?

The outline of the paper is as follows. Section II presents a general model of convenient prices and illustrates the price dynamics that arise when some prices are more profitable than others. Section III formalizes the model and proposes a specific way to measure the relative inconvenience of a price. The model nests the possibility that price adjustment is costly. Section IV describes the data set of newspaper prices compiled for this paper and presents empirical findings. Section V simulates the model of convenience and compares its performance with the data. Section VI concludes.

II An Intuitive Model of Convenient Prices

I begin with a general model that illustrates the role convenient prices can play in a firm's pricing decisions. The analysis assumes that there is a frictionless optimal price, P, which the firm would like to set before any frictions—such as the inability to costlessly change prices, or the fact that transactions are not instantaneous events—are taken into account. The profit function is symmetric (e.g., quadratic) around P. If P is known and there are neither frictions to adjusting prices nor frictions from making transactions, the firm's problem is trivial: it sets its price p equal to the static optimum (P) and earns a constant level of profits, $\Pi(p/P)=\Pi(1)=K$, in every period.

In reality, transactions are *not* instantaneous, frictionless events. Rather, it requires time—on the parts of both buyer and seller—to execute a transaction. A portion of this transaction time relates directly to the physical act of paying for the transaction, which is dependent upon the firm's price when purchases are paid for in cash. While this payment time is typically small, it nonetheless has important ramifications for cash purchases that are frequently repeated or require queuing.

To simplify the exposition, assume that any price the firm can charge falls into one of two categories: *convenient prices* and *inconvenient prices*. While the exact definition of a

convenient price may vary, in general these prices expedite and simplify transactions. For example, consider the case in which whole-dollar prices are "convenient" whereas those requiring coins are not. If a firm charges a convenient price—e.g., $p = p^{\#} \in \{\$1, \$2, \$3, ...\}$—it earns profits of K when $p^{\#}$=P (where a # denotes a convenient price). If a firm charges a convenient price when it does not coincide with the frictionless optimum P, its profits are reduced due to its quadratic profit function.

The firm is free to charge inconvenient prices, but doing so reduces profitability. Customers may tire of making frequent transactions at inconvenient prices and buy less of the good than when the price is convenient. Alternatively, a firm may have to hire additional employees to reduce waiting times in a queue. For simplicity, assume that profits are reduced by a constant amount N—an "inconvenience loss"—when a firm sets an inconvenient price, even if that inconvenient price is equal to P. Thus setting a previously optimal but inconvenient price—i.e., $p = \mathrm{P} \notin \{\$1, \$2, \$3, ...\}$—yields profits of $(\mathrm{K} - \mathrm{N})$.

If price changes are costless, the size of the inconvenience loss and the behavior of the frictionless optimum P determine the firm's price dynamics. Each period, the firm's profits are

$$\max\left\{\Pi\left(\frac{\tilde{p}^{\#}}{\mathrm{P}}\right), \mathrm{K} - \mathrm{N}\right\} \tag{2.1}$$

where $\tilde{p}^{\#}$ is the convenient price closest to P. If N is small or convenient prices are far apart, the firm sometimes charges inconvenient prices when the frictionless optimum lies between two convenience points. Figure 1 depicts this scenario. The stars in the top panel represent the profits the firm earns as a function of P in the range \$1 to \$4 (under the assumption that whole dollar prices are convenient). The firm prefers when its frictionless optimum nears certain points, as this allows it to set convenient, whole-dollar prices and earn maximal profits of K. Figure 1(b) is the firm's reaction function, graphing the price the firm sets as a function of P. This shows that for wide ranges of P, the optimal policy for the firm—including the impact of the transaction frictions—is to set and maintain convenient prices (\$1, \$2, etc.). At other times, the firm's price is flexible and tracks P in each period. With general trend inflation increasing the frictionless optimal price, periods of price rigidity—as measured by the length of time between price changes—interspersed with price flexibility are possible.

If N is large or convenient prices are not far apart, the firm never charges inconvenient prices and jumps exclusively from one convenient price to another, as depicted in Figure 2. Profits are maximized when the firm sets a convenient price, even if that price is far from P. Prices are quite sticky and change rarely (depending on the distribution of the convenient prices and the movements of the frictionless optimal price). If P follows a non-monotonic process, interesting pricing behavior is possible. When a firm is exactly between two convenience points, it may engage in rapid "switching" between adjacent convenient prices depending on the dynamics of the frictionless optimum. This switching is distinct from the flexibility described above when N is small and a firm is between convenient prices, since these are relatively large price changes.

Note that convenience affects the firm's pricing decisions in a purely static way: each period, the firm uses (2.1) to determine what price to set. The firm can be forward-looking, but it need not consider how current decisions affect its future price-setting problem in the absence of additional frictions that prevent price adjustments, such as menu costs. Yet even this static concept generates substantial price stickiness. Provided there is some minimal loss ($\mathrm{N} > 0$) to charging an inconvenient price, there will always be a range of P for which the firm makes larger profits by keeping a convenient price than by changing its price every period. In the next section, I nest the possibility that price adjustment is costly, a typical mechanism for generating price rigidity. Adding menu costs to the convenience model, while exacerbating stickiness, also helps channel prices to convenience points—since maintaining a convenient price will, ceteris paribus, be more profitable for a long period of time than maintaining an inconvenient price.

III Inconvenience, Money, and Menu Costs

I formalize the above with the following model, which focuses on a general profit function incorporating convenience considerations. By focusing on profits, I allow for the possibility that convenient prices affect both consumers and the firm.

I assume that real profits for a firm at time *t*, whose sales are predominantly made in cash rather than via some other means such as credit or debit cards, are given by

$$\Pi\left(p,\mathrm{P}\right)=\mathrm{K}-b\left(\frac{p}{\mathrm{P}}-1\right)^{2}-\zeta\left[n(p)\right],\quad \mathrm{K},b>0\,, \tag{3.1}$$

where P is the frictionless optimal price. Ignoring the last term, (3.1) embodies the general model laid out above, so that when the firm sets its price equal to P it earns constant real profits of K. The novel feature of the model is the final term, $\zeta\left[n(p)\right]$, in the profit function. This function measures the "inconvenience loss" from charging price *p*. A drawback of the model above is that dichotomizing prices into convenient and inconvenient is arbitrary; here, I allow for some prices to be relatively more convenient than others. This is accomplished through $n(p)$, which measures the *relative inconvenience* of charging price *p*.

Relative inconvenience $n(p)$ is the minimum number of monetary units needed to buy a good for price *p*; the notation denotes that it is a function of the good's price. The level of relative inconvenience is determined by the coin and bill denominations offered by the monetary system. This constrains the prices a firm can set to those possible under the available currency units—essentially an integer constraint as in Barro (1976). The more pieces of money needed to make a transaction at a particular price, the higher is the value of $n(p)$, and the higher is that price's inconvenience.[1] The positive relationship between pieces of money and inconvenience is natural: more units means that it takes more time to pay the seller, verify the amount received, and make change—a large amount of which may be undesirable in its own right.

Formally, relative inconvenience $n(p)$ is the minimum number of common coins and/or common bills that can be used, in any combination, to form *p*, allowing for the possibility that the buyer can receive change from the seller.[2] Common coins are pennies, nickels, dimes, and quarters. Common bills are the one, five, ten, and twenty dollar bills.

Each inconvenience level is the minimum for that price, even if this might not be the most obvious way to make such a transaction. For instance, if the price is 96¢, the buyer could give the seller a one dollar bill and a penny and receive a nickel in change [$n(\$0.96)=3$], rather than giving the seller a one dollar bill and receiving four pennies [$n(\$0.96)=5$]. This was done for two reasons. First, a customer who is averse to carrying around more change than absolutely

[1] Considering inconvenience in this manner is in the spirit of Watkins (1911), Galbraith (1936), or Levy and Young (2004). Also, it is the literal interpretation of the "customer antagonization" considerations presented by Blinder et al. (1998). Some studies—e.g., Sumner (1993), Telser (1995), Van Hove (2001), and Lee et al. (2005)—examine the ability to simplify transactions by endogenously determining the optimal set of currency denominations.

[2] This is only one measure of inconvenience. Others might include: the minimum number of common coins that can be used, in any combination, to form *p*, allowing for change—for items sold via automated locations where bills are not accepted; or the minimum number of common bills that can be given to the seller, plus the minimum number of common coins and bills returned to the buyer as change, to form *p*—for cases in which consumers only bring bills to a purchase. The analysis is not materially affected by the exact choice of measure.

necessary would quickly learn this trick as well. But second, heterogeneous consumers execute transactions with a variety of monetary combinations. Defining $n(p)$ in this way ensures that the measure captures the lower bound on inconvenience for a given price for every transaction. Table 1 contains some examples of the relative inconvenience measure.

To simplify the model, I assume that the inconvenience loss function takes the form

$$\zeta\left[n(p)\right] = z\left[n(p)-1\right], \quad z \geq 0\,, \tag{3.2}$$

so that the inconvenience loss is increasing in the number of units of money needed to make a transaction. The parameter z is one of the key parameters in the model: this measures *inconvenience sensitivity*. When z is zero, convenience is irrelevant and the firm earns the same real profits for a given p whether that price requires one or one hundred units of money. When z is positive, charging a price that requires more than one unit of money [$n(p)>1$] reduces real profits slightly. A priori, we should expect z to be positive but small relative to the other parameters in the profit function; if z were large, a firm would spend an inordinate amount of time on the most convenient prices—those requiring a single unit of money. The real profit function a firm maximizes is

$$\Pi\left(p,\mathrm{P}\right) = \mathrm{K} - b\left(\frac{p}{\mathrm{P}}-1\right)^2 - z\left[n(p)-1\right], \quad \mathrm{K}, b > 0, z \geq 0\,. \tag{3.3}$$

There are a number of reasons why convenience may affect a firm's profits when purchases are made in cash. First, consider the case of a good that is purchased very frequently as a stand-alone transaction. Here, customers may tire—because of both lost time and carrying excess change—of making relatively inconvenient transactions repeatedly and quantity demanded may fall as a result, lowering profitability. Separately, sellers may also wish to simplify transactions which they make extremely frequently. Second, consider the case of a good whose purchase requires queuing. Here, the time it takes to make each transaction is an externality imposed on everyone else in the line. Transactions that require many units of money thus raise waiting times multiplicatively and may lead to a reduction in quantity demanded of the good, and thereby profits. If the firm takes steps to reduce waiting times—by having employees divert time from other tasks to open up additional lines, for instance—this increases real costs for the firm and reduces profits as well.

In principle, the parameters in (3.3)—K, b, and z—could vary across time. For the sake of exposition, however, I assume that only the firm's frictionless optimal price P follows a

stochastic process exogenous to the firm; for instance, movements in P might be tied to economy-wide inflation. The firm sees all variables contemporaneously but cannot see P_{t+1} at time t. It discounts the future at rate $\beta = (1+r)^{-1}$, where r is the constant real interest rate.

Within the model, I nest the possibility that a firm may have to pay a constant real menu cost, Φ, to change its price. In any given period t, the firm decides whether it will keep its existing price p or change it. The value to the firm of keeping its price is

$$V^K(p,\mathrm{P}) = \Pi(p,\mathrm{P}) + \beta E_{\mathrm{P}'|\mathrm{P}} V(p,\mathrm{P}'), \tag{3.4}$$

and the value to the firm of changing its price is

$$V^C(p,\mathrm{P}) = \max_{\tilde{p}} \ \Pi(\tilde{p},\mathrm{P}) - \Phi + \beta E_{\mathrm{P}'|\mathrm{P}} V(\tilde{p},\mathrm{P}'). \tag{3.5}$$

Thus for a firm that enters period t with nominal price p and faces the current frictionless optimal price P, its choice of whether to change its price or not is based upon

$$V(p,\mathrm{P}) = \max\left\{V^K(p,\mathrm{P}), V^C(p,\mathrm{P})\right\}. \tag{3.6}$$

When there are no menu costs ($\Phi = 0$), only current profits determine the firm's decision and the problem is static, as in Section II. This is true even for a dynamically optimizing firm. When there are menu costs ($\Phi > 0$), the model is solved numerically using value function iteration. I present data and empirical statistics for a good for which convenient prices matter in Section IV and return to the model to compare its predictions with the data in Section V.

IV Empirical Data on Newspaper Prices

Modeling convenience is important to explain pricing for a number of goods, one of which is weekday newspapers sold at the cover price.[3] Because of this and their readily available history, newspaper prices form the empirical basis for this paper. While this section reports empirical statistics for several newspaper price series, its conclusions also hold for weekday cover prices.

[3] Newspaper cover prices are not unimportant in sales: they currently comprise approximately one-third of sales on most days for the papers in this sample and historically comprised a much larger percentage.

The Data Set

I construct a new data set of newspaper prices for this study. The data were collected from the six newspapers whose complete records are available at the University of Michigan: *The Detroit Free Press* (started in 1831), *The Chicago Tribune* (1849), *The New York Times* (1851), *The Detroit News* (1873), *The Washington Post* (1877), and *The Wall Street Journal* (1889).[4] The sample consists of data on cover prices, mail subscription prices, and carrier delivery prices. For the *Free Press*, *Tribune*, *Times*, *News*, and *Post*, the cover price series consist of two sets of weekday quotes—paper prices inside and outside the home metro area typically form two distinct series—and two corresponding sets of Sunday quotes. The *Journal* has a single set of weekday cover prices for the New York City metro area. The mail subscription series for all six newspapers are for one year, as are the carrier delivery series that are available for the *Free Press*, *Tribune*, *News*, and *Post*. (A complete description of the data can be found in the Data Appendix.) I collect quarterly data using prices from the first week of January, April, July, and October. This method was preferred to annual quotes because some price series change more than once in a year, and most price series do not change simultaneously, thus preserving this heterogeneity.

Few authors have utilized the newspaper industry's paper trail to study price dynamics. This is likely because newspaper prices are sticky and require lengthy time series or highly inflationary environments to display interesting behavior. Mussa (1981) and Weiss (1993) briefly examine newspaper prices during the German hyperinflation and Israeli high inflation, but this is primarily to show that even under extreme circumstances prices do not change daily for some goods. Fisher and Konieczny (1995, 2000, 2003) use an irregularly sampled data set to study facets of the Canadian newspaper industry. Annual magazine cover prices from 1953 to 1979, another media series, are used by Cecchetti (1986) and Willis (2000, forthcoming).

[4] The *Free Press* and *News* began a Joint Operating Agreement effective November 27, 1989. Between that date and the end of the sample in 2004Q2, all Saturday, Sunday, and holiday papers were issued under the single name *The Detroit News and Free Press* while the papers maintained separate weekday editions. However, the JOA merged the business operations of the two firms.

Newspaper Prices and Advertising

A criticism of using media or publication prices to study price stickiness is that the firms have other sources of revenue, primarily from advertising. This is true in the newspaper industry, where circulation revenues are currently a fraction of advertising revenues. This has not always been the case. For the industry, circulation revenues dwarfed advertising revenues in the mid-1800s and were approximately equal to advertising revenues from 1880 to 1910, but declined to 45% of advertising revenues in the 1960s and to 25% of advertising revenues in the 1990s.[5] There is also substantial variation in recent statistics: the owners of the *Free Press*, *News*, and *Tribune* each reported circulation revenues that were 25% of advertising revenues in 2003, while the owners of the *Times* and *Journal* reported circulation revenues that were 50% of advertising revenues. Thus revenues from circulation were large during the early part of the sample period and remain significant today.

The workings of the industry suggest that newspaper prices are important for another reason: the prices set by newspaper firms are integral in determining advertising revenues. As a circulation industry, these firms sell two goods: papers to readers and space to advertisers.[6] These are not typical multi-product retailers, however, since the demand for space by advertisers is based upon the circulation of the paper. Therefore, a newspaper's circulation—both in terms of the quantity of newspapers sold and the characteristics of the customer base—is a key determinant of advertising revenues, and the paper's price is one of the determinants of circulation. Choosing the "right" price is crucial: a price that is low may increase the paper's circulation, but the additional readers may lower the average purchasing power of its audience (Corden 1953, Thompson 1989).

Newspaper sales also help smooth revenue over the business cycle. During the 2001 recession, total U.S. daily newspaper advertising expenditures fell 9% from 2000 to 2001, from $48.7 billion to $44.3 billion. Over the same time, newspaper circulation revenues rose 2%, from $10.5 billion to $10.8 billion.[7] Thus circulation revenues—which are determined by cover and subscription prices—are not completely secondary to the newspaper industry.

---

[5] Data are from Emery and Emery (1992), Owen (1993), and the Newspaper Association of America.
[6] Classic references for the newspaper industry include Corden (1953) and Reddaway (1963). To the extent that the manner in which papers are sold can be broken into differentiated goods, a firm can sell more than two products.
[7] Data are from Newspaper Association of America, "Facts about Newspapers 2003."

Summary Statistics

Table 2 presents summary statistics for the entire sample, extending from 1842Q1 through 2004Q2. The weekday and Sunday cover price series behave in a similar fashion, as do the mail subscription and carrier delivery price series. Newspaper prices are very sticky compared with most other goods: Bils and Klenow (2004) find that they fall into the stickiest 5% of consumer goods and services in their BLS data set. Cover prices change in approximately 3% of all quarters and typically remain unchanged four to seven years. Mail subscription and carrier delivery prices are more flexible, changing twice as often and lasting two to three years.[8]

Associated with these differences in frequency of changes are differences in the magnitude of changes. On average, cover price changes are twice as large as price changes for mail subscription and carrier delivery.[9] Part of this result is driven by the early part of the sample when single copies of papers cost less than a nickel—so that one-cent changes were large in percentage terms. An additional reason for the large magnitude of cover price changes is due to convenience considerations, a point taken up in Section V.[10] Both large and small price changes occurred in all the series.

Table 3 shows the longest and shortest rigidities recorded in the sample. The *Post* was a clear believer in maintaining a "customary, fixed price"—in the spirit of Levy and Young (2004)—early in the sample, keeping its Sunday cover price at a nickel for nearly sixty years (and its weekday cover price and carrier delivery price constant for slightly shorter periods). During this time, the nickel price depreciated 46% overall—appreciating 26% in real terms during 1880–96 and then depreciating 72% in real terms during 1896–1939. Rapid price changes have also occurred within the industry, even for cover prices.

[8] Newspapers run some temporary sales that are not included in my data set unless they are published in the text of the papers, but these are a minor part of total sales. For instance, the Audit Bureau of Circulations reports that for the 26 weeks ended 3/28/2004, the *Free Press* sold for 25¢ on weekdays at selected retail outlets, and these outlets sold an average of 5,850 copies—2% of daily total circulation, or 6% of daily single copies sold.

[9] Carlton (1986) finds a similar positive correlation between price rigidity and the size of price changes using industrial goods' prices.

[10] Convenience may have also been a factor for carrier delivery prices, many of which historically were collected on a weekly or monthly basis.

The Frequency and Magnitude of Price Changes

To analyze changes in the frequency and magnitude of price changes over such a long time span, I divide the sample into 13 ten-year intervals: 1875–84, 1885–94, 1895–1904, 1905–14, 1915–24, 1925–34, 1935–44, 1945–54, 1955–64, 1965–74, 1975–84, 1985–94, and 1995–2004Q2. The sample begins in 1875 since this is the first year for which Balke and Gordon (1986) report the GNP deflator used to calculate early inflation.[11]

Figure 3 shows the average frequency of price change for cover (weekdays and Sundays), mail subscription, and carrier delivery prices in each ten-year interval. There is an upward trend in price adjustment frequency since 1875 for all the series. This trend is not monotonic, as prices changed rarely during the 1930s. The most frequent price changes came during the inflationary years of World War I (1914–18) and the 1970s, suggesting a positive relationship between frequency of price change and inflation. Figure 4 displays the average absolute percentage change in nominal prices—i.e., the average size of changes—in each interval. This measure has been falling over time, especially for the cover and carrier delivery price series. There does not appear to be a clear relationship between the size of price changes and inflation.

To test how the frequency and size of price changes have been affected by inflation, I measure the latter using the GNP deflator constructed by Balke and Gordon (1986) for 1875–1947Q1 and the GNP implicit price deflator issued by the BEA for 1957Q2–2003Q4. For the period 1947Q2–1957Q1, I average their implied rates of inflation. While some authors have assessed the effects of cumulative inflation on frequency of price change using probit or logit estimates of a reduced form (*S*,*s*) model (e.g., Cecchetti 1986), I measure the relationship between inflation and price adjustment frequency directly. To do so, I consider the regression

$$\overline{\text{frequency}}_t = \alpha_f + \beta_f \pi_t + \gamma_f T + \varepsilon_t^f , \tag{4.1}$$

where $\overline{\text{frequency}}_t$ is the average frequency of price changes in period *t* across all firms, π_t is a measure of the growth of the aggregate price level in period *t*, and *T* is a time trend. I perform a similar regression for the size of price changes

[11] Weiss (1993), Taylor (1999), and Wolman (2000) present reviews of the empirical literature on price stickiness at the microdata level. To ensure that my findings are not dependent upon the choice of ten-year intervals, I divide the sample into eight intervals based upon differences in average inflation: 1875Q1–1896Q2, 1896Q3–1915Q3, 1915Q4–1920Q2, 1920Q3–1938Q4, 1939Q1–1946Q4, 1947Q1–1965Q2, 1965Q3–1982Q4, and 1983Q1–2003Q4. All graphs and regression results are similar using either method.

$$\overline{\text{size}}_t = \alpha_s + \beta_s \pi_t + \gamma_s T + \varepsilon_t^s, \tag{4.2}$$

where $\overline{\text{size}}_t$ is the average of the absolute percentage changes in nominal price in period *t* for all firms.[12] Initially, regressions for the cover, mail, and carrier price series are estimated separately. I later pool the data and estimate the equations including dummy variables for mail subscription and carrier delivery prices.

Determining the appropriate measure of movements in the aggregate price level, π_t, to include in (4.1) and (4.2) is complicated by deflation in the U.S. economy during 1875–2004. Thus using average inflation—as used, e.g., by Ball et al. (1988) when looking at the relationship between inflation and the size of the output-inflation tradeoff—is inappropriate, since within a ten-year interval inflation and deflation might offset to give the appearance of a stable aggregate price level. At the same time, symmetric two-sided (*S*,*s*) models of costly price adjustment imply that high inflation and high deflation should similarly impact the frequency of adjustment, as would low inflation and deflation. To take these factors into account, π_t is the average for each ten-year period of the absolute value of the annualized percentage growth in the price level from one quarter to the next.

Since $\overline{\text{frequency}}_t \in [0,1]$, I estimate (4.1) using two methods, ordinary least squares and weighted least squares logit estimation for grouped data. In spite of the fact that the size variable cannot go below zero, I use OLS to estimate (4.2). Because the average size in each period is not close to zero, this appears to be a reasonable assumption. Results from regressions of (4.1) and (4.2) are presented in Table 4 and Table 5, respectively.

From Table 4, the frequency of price changes is positively related to the absolute rate of inflation and the time trend for all individual price series and for the pooled regression. After controlling for time, a one percentage-point increase in average annual inflation—or a one percentage-point increase in average annual deflation—over a ten-year period corresponds to newspapers changing cover prices 0.2 percentage-point more frequently and mail subscription prices 0.7 to 0.8 percentage-point more frequently. While these numbers are small in absolute terms, this is approximately a 10% increase over the series' long run frequency averages. The coefficients on inflation are highly significant in all cases.

[12] The $\overline{\text{frequency}}_t$ and $\overline{\text{size}}_t$ measures group all newspapers, thus neither regression includes firm fixed effects. Also, these regressions only focus on general macroeconomic phenomena.

Holding inflation constant, price changes have become more frequent across time: every ten years, the frequency of price changes increases by 0.4 percentage-point for cover prices and 1.1 percentage-points for mail subscription prices. The estimates are highly significant and are not trivial over the 130-year sample: cover prices now change 5.2 percentage-points more frequently and mail subscription prices now change 14.3 percentage-points more frequently than they did in the 1870s after controlling for inflation. Pooling the data to offset the small sample sizes and take advantage of the underlying similarities of the three price series yields coefficients between the above estimates.

The finding that prices are changing more frequently today than in the late 1800s is similar to Kackmeister's (2005) finding using retail price data. However, his results come from only two 28-month periods—1889–91 and 1997–99. This study shows that this has been a long term trend. To the extent that newspaper prices have consistently been among the stickiest prices in the U.S. economy, this may have implications for other goods as well.

The positive correlation between inflation and frequency of price changes supports other papers that have reached this conclusion, but uses a different methodology. The previous convention has been to either (1) compare data from the "high inflation" 1970s and early 1980s with the "low inflation" 1960s and/or mid-1980s and beyond (Cecchetti 1986, Kashyap 1995); or (2) use data from countries that experienced sharp inflation accelerations and separate "moderate," "high," and "very high" inflation periods (Mussa 1981, Sheshinski et al. 1981, Lach and Tsiddon 1992, Weiss 1993).[13] This study shows that such findings hold across long time horizons when examining the newspaper industry, and also when deflationary periods are included in the analysis.[14]

Table 5 presents results from the size regression. While the coefficient on inflation is negative in three of the four regressions, it is only statistically significant in one. This is similar to Cecchetti (1986) (magazines) and Kashyap (1995) (retail catalogue data), who found no significant relationship between inflation and the size of price changes (though their analyses did not control for time). The time trend coefficient is negative in all regressions and statistically significant at the 1% level in three of them. Every ten years, the average size of price changes

[13] Using a different sample period, Young and Blue (2005) do not find the same positive correlation between inflation and frequency of price changes.

[14] The results are robust to the inclusion of other explanatory variables, such as a measure of changes in the persistence of the inflationary process during the sample period, the standard deviation of nominal GNP growth in each ten-year period, and the standard deviation of inflation in each ten-year period.

falls 0.6 percentage-point for mail subscription prices and 3.8 percentage-points for cover prices. This implies that, after controlling for inflation, the sizes of cover price changes have decreased by 49 percentage-points on average over the last 130 years while the sizes of mail subscription price changes have only decreased by eight percentage-points. These results are opposite those presented by Kackmeister (2005); using a select group of retail goods, he found that nominal changes in price were larger in absolute percentage terms during 1997–99 than 1889–91.

V Model Simulations and Discussion

I simulate the model of convenience developed in Section III and compare its performance with data from weekday newspapers sold at the cover price. The simulations reveal three important phenomena—periods of rigidity interspersed with price flexibility, rapid switching between convenient prices, and adherence to the most convenient prices—that can arise depending on the sensitivity of profits to convenience. When profits are affected by convenience and price adjustment is costly, the model is able to match key characteristics of the data.

Calibration

The central equations in the simulations are the general real profit function,

$$\Pi\left(p_t, \mathrm{P}_t\right) = \mathrm{K} - b\left(\frac{p_t}{\mathrm{P}_t} - 1\right)^2 - z\left[n(p_t) - 1\right], \quad \mathrm{K}, b > 0, z \geq 0, \tag{5.1}$$

and the equations associated with the firm's decision problem, equations (3.4) through (3.6). While newspaper firms generate a large portion of their revenue from advertising, I subsume this in b—e.g., advertising revenues can reduce profits' sensitivity to deviations of the firm's actual price from its frictionless optimal price, P_t. Each period is one quarter, and the constant real interest rate with which the firm discounts the future is 0.75% on a quarterly basis. The firm's level of maximal quarterly profits, K, is normalized to one.

The frictionless optimum is the only stochastic process the firm faces; all other parameters are constant and known by the firm. While the inclusion of additional shocks or a larger role for advertising in the model would be desirable, data limitations, considerations of the

state space, and computational constraints drove this decision. The frictionless optimal price, which is exogenous to the firm, follows

$$\ln \mathrm{P}_t = \mu + \ln \mathrm{P}_{t-1} + \xi_t . \tag{5.2}$$

Shocks to the rate of frictionless optimal price inflation are i.i.d. normal with mean zero and standard deviation σ_ξ. I assume that $\mu + \xi_t$ can be approximated by economy-wide inflation between $t-1$ and *t*, so movements in P are similar to movements in the aggregate price level. This suggests calibrating μ=0.9% and $\sigma_\xi = 0.02$ to broadly match U.S. data over the period 1904Q3–2004Q2, which was chosen to avoid weekday cover price decreases.

The parameters of interest from the model are the inconvenience sensitivity parameter, *z*, and the size of any potential menu costs, Φ, that the firm must pay to change its price.[15] I analyze these parameters in two parts. First, I calibrate *z* and Φ to provide a graphical depiction of their role in a firm's pricing problem. Without prior evidence on the size of the inconvenience sensitivity parameter, *z* takes on values from the set {0, 0.002, 0.02, 0.2}; these can roughly be interpreted as "no inconvenience," "slight inconvenience," "some inconvenience," and "substantial inconvenience." Given K=1, these values have a natural interpretation. If the number of pieces of money in a transaction were reduced by one—by the introduction of a new monetary unit, for instance—then the firm's real quarterly profits will be unchanged when *z*=0; rise 0.2% when *z*=0.002; rise 2% when *z*=0.02; and rise 20% when *z*=0.2. (Table 6 shows the change in profits that occurs when a firm reduces its price from 26¢ to the more convenient 25¢ for the various values of *z*, when the frictionless optimal price P is 26¢.) For each value of *z*, the model is simulated in two ways: with Φ=0, so that the firm can costlessly change its price; and with Φ=0.3, so that price changes are costly.[16]

In the second part of the analysis, I estimate the structural parameters *z* and Φ through indirect inference. The Simulation Appendix describes details of the simulations.

[15] While the term "menu costs" is used extensively, these costs should be construed more broadly to include not only the physical cost of changing the printed price on a newspaper, but also implementation costs, customer antagonization costs associated with changing a price, and the like.

[16] With K=1, this calibration implies that menu costs are 30% of maximal quarterly profits. If the firm changed its price every period, this would be similar to estimates from recent studies that have measured menu costs in the range of 20% to 35% of annual net margins; see Levy et al. (1997) (using data on supermarket price changes), Dutta et al. (1999) (drugstores), and Zbaracki et al. (2004) (an industrial firm). Less frequent changes imply that menu costs would be a smaller percentage of annual profits, depending on the realized level of profits.

Simulation Results

Central to this discussion are what I refer to as *monetary convenience points*. The price p is a monetary convenience point if the relative inconvenience $n(p)$ associated with that price is a local minimum—i.e., changing the price by one cent would cause relative inconvenience to increase. Thus a monetary convenience point is a multiple of a nickel and relatively inconvenient prices do not require the use of pennies. One cent is a monetary convenience point. Some monetary convenience points are more convenient than others—25¢ requires one coin, whereas 20¢ requires two—but the statistics below do not distinguish between the two. The firm endogenizes this problem through its choice of p and thereby $n(p)$. I look at two measures of the use of convenience. The first measures the percentage of the time that a firm charges a price that is a monetary convenience point. The second measures the percentage of the time that, given that a firm changes its price, it decides to change its price to a convenience point.

The six weekday cover prices for each paper's primary metro area for 1904Q3–2004Q2 are plotted in Figure 5.[17] Table 7 presents moments of interest from these prices along with the simulation results. Sample pricing plots from one simulation for each set of parameters are depicted in Figure 6. These figures include the simulated frictionless optimal price P that the firm would like to charge at time t before menu costs and inconvenience are taken into account. By itself, this simple analysis provides strong support for the model of inconvenience presented above combined with denomination constraints imposed by the monetary system at low prices.

Consider first the scenario in which there are no fixed costs to adjust prices (Φ=0) and inconvenience does not affect profits (z=0). The average firm changes its price once per year and follows the frictionless optimal price closely. Since nearly all price changes are a penny, the primary culprit for price rigidity is denomination constraints—i.e., times when the firm would like to charge 1.3¢ or 25.7¢ but it cannot. At prices below 10¢, the firm is highly constrained by the fact that the monetary system does not have a unit smaller than one cent, changing its price 8% of quarters. Beyond the 10¢ threshold, periods of rigidity are shorter and prices change 41%

[17] Note that these are *transaction* prices—i.e., the amount required to completely execute a transaction—and not only list prices. Newspapers have historically been exempt from sales tax, a tradition carried on to the present in the sales tax laws of Michigan, Illinois, and New York. Thus the prices for the *Free Press*, *News*, *Tribune*, *Times*, and *Journal* are the same at newsstands and vending machines. Because Washington, DC, recently instituted a sales tax on newspapers sold at newsstands while exempting vending machines, I use the vending machine price for the *Post*. Vending machines are discussed in more depth below; for more on sales tax and convenience, see Knotek (2005).

of quarters. Price changes average 7% in size and convenient prices are completely unimportant, occurring approximately as frequently as they would if prices were selected at random.

The average firm's behavior when convenience has an impact on profits is decidedly different. Including some inconvenience (z=0.02) alone goes a long way toward matching the moments from the data. Prices now change in 9% of all quarters, roughly one-third as frequently as the case in which convenience does not matter. Price changes are three times as large, averaging 20% in size. In addition, firms pay attention to monetary convenience points in a manner similar to that in the data, using convenient prices 69% of the time (61% in the data) and changing to convenient prices 61% of the time (70% in the data).

With only these statistics, it might appear that inconvenience yields pricing-setting behavior similar to menu costs. However, the figures illustrate three important differences in terms of pricing dynamics. In Figure 6(c), we see evidence of rapidly changing prices interspersed with periods of longer rigidities: if a firm is able to set and maintain a convenient price, it does so for a while; when P is between convenient prices, a firm's price becomes quite flexible. This is apparent around 15¢ and 25¢. If inconvenience has a larger impact on profits, rapid "switching" between adjacent convenient prices is possible. This occurs in Figure 6(e), in particular between quarters 300 and 325. Finally, if inconvenience has an extreme impact on profits, firms will rely on the most convenient prices—those that require a single unit of exchange to complete the transaction—as much as possible, as in Figure 6(g).

The results from introducing menu costs into the model are contrasted with those from pure inconvenience considerations in Table 7 and Figure 6. For all values of the inconvenience sensitivity parameter z, the introduction of menu costs reduces the frequency of price adjustment. This is partly due to the fact that when firms are forward-looking, they will not engage in the rapid switching that occurs when only inconvenience impacts behavior. Thus, intuition, the figures, and the table combined suggest that a moderate amount of inconvenience sensitivity along with a menu cost is necessary to accurately match the empirical data.

It is worth pointing out that menu costs alone cannot match key aspects of the historical behavior of these prices. While the case in which there are menu costs but no inconvenience sensitivity (z=0) resembles the data in terms of frequency and magnitude of price changes, these simulations cannot reproduce the firms' choices of convenient prices. This is apparent in Figure 6(b), which shows a price path for a representative firm in one of the simulations. Beyond 10¢,

the firm never selects a price that is a multiple of a nickel. This starkly contrasts with real-world firm behavior. In addition, menu costs and inconvenience have different impacts on firm behavior on either side of the 10¢ threshold. From the table, we see that—for reasonable parameterizations of z—convenience does not really begin to alter firm behavior until after prices reach 10¢. Compared with the case in which there are neither menu costs nor convenience considerations, menu costs reduce the frequency of adjustment by nearly 70% when prices are less than 10¢, but by more than 90% when prices are greater than 10¢. This suggests that firm behavior is constrained by the available monetary denominations and menu costs at low prices, and by a combination of convenience considerations and menu costs at higher prices.

Statistical and Direct Comparisons with the Data

While the above exercise informally demonstrates that both convenience considerations and menu costs are necessary to match the pricing history of the newspapers in this sample, I provide formal estimates of these structural parameters using indirect inference. This procedure seeks the z-Φ combination that best "fits" the data, in that the weighted difference between moments estimated from the data and average moments estimated via simulated data is minimized; see the Simulation Appendix for details. Based on the preceding analysis, I identify nine moments from the data that the model should seek to match.

(1–3) Moments of interest in the price rigidity literature: the average frequency of price changes; the average size of price changes, in absolute value; and the standard deviation of the size of price changes.

(4–5) Moments relating to the use of convenience points: the percentage of time spent charging a price that is a monetary convenience point; and the percentage of the time that, given that a firm decides to change its price, it changes it to a monetary convenience point.

(6–9) The coefficients that measure the responsiveness of the frequency and size of price changes to inflation and a time trend, as captured by equations (4.1) and (4.2), respectively, for the cover price data: $\hat{\beta}_f$, $\hat{\gamma}_f$, $\hat{\beta}_s$, and $\hat{\gamma}_s$.

As the Simulation Appendix notes, one drawback to the simplicity of the model is that it is impossible to separate b, the sensitivity of profits to deviations of the firm's actual price from its frictionless optimal price, from z and Φ. Thus indirect inference implicitly estimates

$\widehat{z/b} = 3.00*10^{-3}$ (with standard error $3.68*10^{-4}$) and $\widehat{\Phi/b} = 0.777$ (with standard error 0.005). There is not a simple interpretation of these parameter estimates, such as menu costs stated as a percentage of profits; nor is there a simple way to directly compare them, since inconvenience affects profits in every period whereas menu costs are "paid" infrequently; see Table 8. Nevertheless, the results are highly significant. To the extent that *b* is a small positive number—a prudent assumption for newspapers—this exercise provides statistical evidence that both convenience and menu costs are important factors in the prices set by these newspaper firms.

Armed with these estimates, I perform a contrived experiment to see how well $\widehat{z/b}$ and $\widehat{\Phi/b}$ match the firms' pricing history directly. I run six simulations, one for each of the sampled newspapers. Each firm begins the simulation with the actual price it charged going into 1904Q3. In that quarter, I assume that each firm's actual price was as close to its frictionless optimal price as denomination constraints would allow. After that point, each frictionless optimum grows with the GNP deflator inflation rate realized in the U.S. economy from 1904Q3 to 2004Q2. Figure 7 presents the historical price data and the prices predicted by the model for the newspapers.

While the model is broadly consistent with the historical data, it encounters difficulty matching the prices exactly. This is due, among other things, to the facts that (1) the equation governing movements in the frictionless optimal price is poorly specified given actual inflation realizations; (2) the model assumes that frictionless optimal prices *only* change with the rate of inflation;[18] and (3) the model assumes that all firms are identical with the exception of their starting price. In general, the worst fit comes during the dramatic inflation acceleration associated with World War I and the subsequent deflation that extended through the Great Depression. The model predicts initial price increases followed by price reductions during this time, yet such behavior did not occur in the data. In fact, none of the papers in the sample decreased its cover price following World War I.

[18] This is especially problematic for the *Times*, whose price becomes unhinged from that predicted by the model in the late 1960s and beyond. Historical evidence points to an explanation: there were six competing daily papers in New York City at the beginning of 1966; by the end of 1967, there were only three. The model is not designed to handle the pricing effects of rapid changes in market concentration.

Convenience, Binding Denomination Constraints, and Sunday Cover Prices

Binding denomination constraints play an important role in price-setting during the early part of the sample. It is not until prices are greater than ten cents that changing the price by a penny is less than a 10% nominal change; while 5¢ is more convenient than 4¢, this price is 22% higher. If customers and the firm are only slightly inconvenienced (z is small) by using multiple pieces of money, it is clearly in the firm's best interest to charge an inconvenient price rather than a more convenient but substantially higher one. By contrast, a price of 25¢ (or 75¢) is more convenient than 24¢ (74¢) but is only 4% (1%) higher. Now, causing even minor inconvenience can be worse than charging a modestly higher price and firms will avoid superfluous units. At higher prices, the firm's choice is not whether to use pennies or not; it is between using one convenience point ($1) that is more convenient than another (90¢).

I formalize the above by arbitrarily dividing the sample period in half (1904Q3–1954Q2 and 1954Q3–2004Q2) and re-estimating the inconvenience sensitivity parameter and the fixed cost of price adjustment for each sub-period. Table 8 presents the results. With very low nominal prices during the early period, we should expect to see firms spending a considerable amount of time on relatively inconvenient prices because more convenient prices were too distant in percentage terms. This should lead to low estimates of z. In the later period, once nominal prices are higher and the penny is not such a binding constraint on pricing, firms have more flexibility to set convenient prices and inconvenience sensitivity should be higher. This is exactly what we see for the weekday cover prices: for the early period, $\widehat{z/b}$ is $2.92*10^{-4}$ and statistically insignificant; for the late period, it is $9.00*10^{-3}$ and highly significant.[19]

Sunday cover pricing presents an interesting contrast to weekday pricing. Once again, convenience considerations and menu costs are both essential components of price-setting. However, the exact opposite phenomenon as was found above occurs: inconvenience sensitivity was higher during the early period than during the late period for Sunday cover prices. This is due to the following. All of the Sunday papers cost 5¢ in 1904. After this, many jumped directly

[19] If b is the same in both periods, then obviously z is larger in the late period. However, if one assumes that b decreased from the early period to the late period—a reasonable assumption, given that advertising revenues were a greater component of profits in the late period—it would require an implausibly large decrease in b to have the inconvenience sensitivity parameter z fall from the early to the late period. For Sundays, z must be smaller in the late period compared with the early period whether b remained constant or decreased.

to 10¢—and some spent nearly the entire 50-year period charging these two prices. The inordinately high use of the most convenient of prices—those requiring a single piece of money—produces this very high estimate of the inconvenience sensitivity parameter.

Discussion

It is important to note the crucial roles that convenience *and* costly price adjustment play that allow the model to match the data. Convenience by itself is not capable of matching the data, even after extensively searching among possible values for the inconvenience sensitivity parameter z. In the absence of costly price adjustment, when a firm is precisely between two convenient prices it may undertake rapid switches between the nearest monetary convenience points. The cover price data reject this behavior. Similarly, not considering any inconvenience cannot match the data either, even after extensively searching among possible sizes of the menu cost Φ. If there is only a cost to changing prices, firms will not spend nearly as much time on multiples of a nickel as they do in the data. In short, the model predicts that firms choose the "wrong" prices compared with reality. Thus convenience considerations and menu costs are both essential in explaining the price dynamics of newspaper cover prices.[20]

The novel feature of the model is the direct inclusion of convenience in the profit function, allowing it to potentially affect supply and demand. A priori, it is not irrational of consumers to demand slightly more of a product when the price leads to a convenient transaction than when the price is less but the transaction is more inconvenient. This is especially true if the transaction is replicated frequently—or everyday for single-copy weekday newspapers. For goods sold in a queue, charging inconvenient prices can increase transaction times and therefore waiting times. Longer waiting times may induce consumers to not enter the queue. At the same time, charging inconvenient prices can impose real costs on sellers, requiring them to spend more time and resources making transactions than if they had set a convenient price. Obviously, this type of transaction convenience only matters for cash transactions: with credit and debit cards, relatively inconvenient prices are not an issue (but waiting for payment authorization is).

[20] Furthermore, this is true even if one excludes the moments specifically dealing with convenient prices. Indirect inference produces positive and statistically significant coefficients for both convenience sensitivity z and menu costs Φ whether one considers only the first three moments (those relating to frequency and size of price changes), only moments six through nine (the four coefficient estimates), or the combination of those seven moments.

Implementing convenience in this way models one of the reasons for the seventy-plus year rigidity of the Nickel Coke suggested by Levy and Young (2004). There, the authors note that Coca-Cola executives were concerned about the inconvenience costs to consumers of changing the price to something that required more than a single coin and point out the company's request to have the U.S. Treasury mint a 7½¢ piece.[21] The authors do not model this idea, however, nor do they extensively document subsequent price movements to lend further support to the single-coin theory.

At the same time, considering convenience on the demand side was only one of several ideas proposed to explain Coke's sticky price. A second factor was that the company's vending machines were equipped to handle a single nickel and did not return change.[22] Collecting larger denomination coins instead of many smaller denomination coins from vending machines would simplify the collection process and is one reason why convenience may factor into the supply side in general; in Coke's case, converting vending machines would have been a large one-time menu cost to depart from the nickel price. By contrast, modern newspaper vending machines were not invented until 1954 and did not take on their near-ubiquitous status until the 1980s (Leonard 1995). Thus requiring firms to only set prices that do not call for pennies to facilitate vending machine transactions is not appropriate for the present study.[23]

Thinking about convenient versus inconvenient prices has other applications than newspapers, and the model can be applied to a number of goods purchased with cash: cab, subway, and bus fares, turnpike tolls, and a variety of other small-ticket items that are purchased as a stand-alone transaction on a frequent basis; and such items as movie tickets, concession purchases, alcoholic drinks at a bar, and other items sold in queues. The prices of items sold in vending machines are another possibility if the machines include the ability to accept pennies; if they do not, convenience and additional adjustment costs for charging penny prices would apply.

---

[21] The authors call the desire to charge a single-coin price a "monetary transaction technology" constraint, which might be confusing in the context of this paper, as they are really talking about convenience constraints and not true monetary (denomination) constraints as experienced by the newspapers between 1¢ and 2¢, for instance.

[22] The inability of early vending machines to give change was not a binding constraint on the prices that others charged. Backman (1940) and Segrave (2002) point out the common practice among cigarette vendors of charging a price such as 17¢ and taping pennies to the package as change. Levy and Young (2004) cite one case in which a vendor tried to charge 8¢ using a similar technique and the experiment "fizzled miserably." Whether the Coca-Cola company, which extensively promoted the nickel price, assisted with this failure is unclear.

[23] Even though virtually all newspapers charge prices that are a multiple of a nickel, imposing this restriction on <u>all</u> papers is simply not true. For 2002, the Newspaper Association of America reported that 1% of weekday paper cover prices required pennies.

Nevertheless, the fact that some machines are built so as to not accept pennies—or to only accept quarters, for instance—suggests that convenience is partly responsible for these prices. Magazine sales at newsstands might also fall into this category, especially for weekly magazines. Yet papers that examine price stickiness in this industry—Cecchetti (1986), Willis (2000, forthcoming)—do not include convenience or pricing points in their analyses.[24]

One implication of the model is the possibility for "tokenization." If inconvenience is large and using a single unit of exchange for each transaction is imperative, firms may decide that the monetary system does not suit their needs and will issue tokens to simplify transactions. For instance, if a firm would like to charge $1.15 for each transaction, it may sell customers a packet of ten tokens for $11.50 rather than forcing them to use at least three pieces of money in every transaction.[25]

While many of the items that would take convenience into account are relatively inexpensive, the fact that they are purchased frequently amplifies their importance. The data on expenditure shares from the Consumer Expenditure Survey presented in Bils and Klenow (2004) indicate that convenience may affect items that sum to more than 5% of consumer spending. Moreover, convenience appears to affect many of the consumer goods and services with the stickiest prices in the U.S. economy. This suggests that studies focusing on very sticky prices must be cognizant of convenience's role in effecting above-average price rigidity, a point that Knotek (2005) explores using cross-sectional data.

Nevertheless, the above-average price stickiness—as measured by the length of time between price changes—at the firm level that comes about partly as a result of convenience considerations may *not* ensure price rigidity at a more aggregate level. This is a result of the fact that, when prices do change, they tend to change by a large amount. (For weekday newspaper cover prices, nominal prices change by an average of more than 35%.) With sufficient heterogeneity, scenarios in which large price changes by a small minority of firms offset inaction by the vast majority become possible, leading to the type of monetary neutrality illustrated by Caplin and Spulber (1987). Incentives to charge convenient prices may thus overwhelm desires to restrain price changes so as to be more in-line with competitors' prices.

---

[24] A sample of 74 magazine cover prices (13 weekly, 61 monthly) at the Borders store in Ann Arbor, Michigan, on August 16, 2004, revealed that 62% of the weekly magazines and 46% of the monthly magazines charged convenient prices; pricing points—prices ending in 99¢—were used the remainder of the time.

[25] I thank Andrew Coleman for highlighting this point. See also Daly (1970) and Sargent and Velde (2002).

Even without convenience considerations and menu costs, prices are relatively inflexible in the model simulations. The addition of more shocks to the model, for instance, would generate more price changes if there were no rigidities. However, the fact that firms must charge prices that are possible under the available currency denominations would cause price rigidity even in these environments, especially when prices are extremely low and the binding constraint is the monetary system rather than menu costs or convenience considerations.

While monetary denominations are not likely a tremendously binding constraint today, this has certainly not always been the case. The fact that none of the newspapers in the sample lowered its cover price—either weekday or Sunday—during the Great Depression raises the question: should the U.S. *Mint* bear some of the blame for the severity of the output loss during the Great Depression? During that time, most weekday papers cost 3¢ and most Sunday papers cost 10¢. Myriad other goods were similarly low-priced, as the price level was approximately one-tenth what it is today. Had there been a half-cent coin—or, in the case of the newspapers, a two-and-a-half-cent coin or even a nine-cent coin (the latter to maintain the relative convenience of the Sunday price)—would more goods have lowered their prices and maintained sales? Binding denomination constraints, perhaps in combination with convenience considerations, may thus have important macroeconomic implications.

VI Conclusion

This paper takes seriously the idea that some firms consider the convenience of the prices that they charge. I propose a model that incorporates relative inconvenience and show the implications of such behavior. In spite of the fact that convenience only impacts a firm's problem in a static fashion, interesting pricing dynamics can arise. If profits are only slightly affected by relatively inconvenient prices, prices can exhibit periods of rigidity alternating with flexibility. If sensitivity to inconvenience is higher, longer periods of rigidity and rapid switching between convenient prices can occur. Finally, if sensitivity to inconvenience is extreme, firms spend inordinate amounts of time charging the most convenient prices—those requiring a single unit of exchange.

I compile new time series data on newspaper cover prices to empirically assess the significance of convenience. In the empirical data, firms set prices that were more convenient

than adjacent prices 61% of the time. Using model simulations, I show that traditional menu costs alone cannot replicate this behavior. This suggests that a price's convenience is a consideration that newspaper firms take into account. Because convenience appears to affect many of the consumer goods and services with the stickiest prices in the U.S. economy, studies focusing on very sticky prices must be cognizant of convenience's role in effecting above-average price rigidity.

While this paper has empirically demonstrated the importance of convenience in newspaper cover prices, a natural question to ask is the extent to which the results hold for other items. Many of the goods listed in Section V as viable candidates are based upon casual observation or because they fit the criteria for convenience established above. More empirical evidence on these items and other items for which convenience matters is desirable, some of which is undertaken in Knotek (2005). In addition, the measure of the level of relative inconvenience $n(p)$ in the model is dependent upon the monetary denominations available when a firm sets its price. Performing a similar experiment using data from a foreign country with a distinct monetary system, or examining pricing decisions immediately before and after a country changes the denominations it offers, would help to check the robustness of such a measure. I leave these questions for future research.

VII Works Cited

Adda, Jérôme and Russell Cooper (2003) *Dynamic Economics: Quantitative Methods and Applications* Cambridge, MA: The MIT Press.

Backman, Jules (1940) "The Causes of Price Inflexibility" *Quarterly Journal of Economics* 54(3): 474–89.

Balke, Nathan S. and Robert J. Gordon (1986) "Appendix B: Historical Data" in Robert J. Gordon, ed. *The American Business Cycle: Continuity and Change* Chicago: University of Chicago Press.

Ball, Laurence, N. Gregory Mankiw, and David Romer (1988) "The New Keynesian Economics and the Output-Inflation Trade-Off" *Brookings Papers on Economic Activity* 1988(1): 1–65.

Barro, Robert J. (1976) "Integral Constraints and Aggregation in an Inventory Model of Money Demand" *Journal of Finance* 31(1): 77–88.

Bils, Mark and Peter J. Klenow (2004) "Some Evidence on the Importance of Sticky Prices" *Journal of Political Economy* 112(5): 947–85.

Blinder, Alan S., Elie R.D. Canetti, David E. Lebow, and Jeremy B. Rudd (1998) *Asking About Prices: A New Approach to Understanding Price Stickiness* New York: Russell Sage Foundation.

Caplin, Andrew S. and Daniel F. Spulber (1987) "Menu Costs and the Neutrality of Money" *Quarterly Journal of Economics* 102(4): 703–25.

Carlton, Dennis W. (1986) "The Rigidity of Prices" *American Economic Review* 76(4): 637–58.

Cecchetti, Stephen G. (1986) "The Frequency of Price Adjustment: A Study of Newsstand Prices of Magazines" *Journal of Econometrics* 31: 255–74.

Corden, W.M. (1953) "The Maximisation of Profit by a Newspaper" *Review of Economic Studies* 20(3): 181–90.

Daly, Herman E. (1970) "Some Observations on the Causes and Consequences of the Shortage of Change in Northeast Brazil" *Journal of Political Economy* 78(1): 181–84.

Dutta, Shantanu, Mark Bergen, Daniel Levy, and Robert Venable (1999) "Menu Costs, Posted Prices, and Multiproduct Retailers" *Journal of Money, Credit and Banking* 31(4): 683–703.

Emery, Michael and Edwin Emery (1992) *The Press and America: An Interpretive History of the Mass Media* 7th ed. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Fisher, Timothy C.G. and Jerzy D. Konieczny (1995) "The Relative Rigidity of Oligopoly Pricing" *Economics Letters* 49(1): 33–38.

----- (2000) "Synchronization of Price Changes by Multiproduct Firms: Evidence from Canadian Newspaper Prices" *Economics Letters* 68(3): 271–77.

----- (2003) "Inflation and Costly Price Adjustment: A Study of Canadian Newspaper Prices" Wilfrid Laurier University School of Business and Economics Working Paper 2003–07 EC.

Galbraith, John Kenneth (1936) "Monopoly Power and Price Rigidities" *Quarterly Journal of Economics* 50(3): 456–75.

Goffe, William L., Gary D. Ferrier, and John Rogers (1994) "Global Optimization of Statistical Functions with Simulated Annealing" *Journal of Econometrics* 60(1–2): 65–99.

Gouriéroux, Christian and Alain Monfort (1996) *Simulation-Based Econometric Methods* New York: Oxford University Press.

Kackmeister, Alan K. (2005) "Yesterday's Bad Times Are Today's Good Old Times: Retail Price Changes in the 1890s Were Smaller, Less Frequent, and More Permanent" Federal Reserve Board Finance and Economics Discussion Series working paper 2005–18.

Kashyap, Anil K. (1995) "Sticky Prices: New Evidence from Retail Catalogs" *Quarterly Journal of Economics* 110(1): 245–74.

Knotek, Edward S., II (2005) "Connecting Convenient Prices and Price Rigidity: Cross-Sectional Evidence" working paper.

Lach, Saul and Daniel Tsiddon (1992) "The Behavior of Prices and Inflation: An Empirical Analysis of Disaggregated Price Data" *Journal of Political Economy* 100(2): 349–89.

Lee, Manjong, Neil Wallace, and Tao Zhu (2005) "Modeling Denomination Structures" *Econometrica* 73(3): 949–60.

Leonard, Thomas C. (1995) *News for All: America's Coming-of-Age with the Press* New York: Oxford University Press.

Levy, Daniel and Andrew T. Young (2004) "'The Real Thing': Nominal Price Rigidity of the Nickel Coke, 1886–1959" *Journal of Money, Credit and Banking* 36(4): 765–99.

Levy, Daniel, Mark Bergen, Shantanu Dutta, and Robert Venable (1997) "The Magnitude of Menu Costs: Direct Evidence from Large U.S. Supermarket Chains" *Quarterly Journal of Economics* 112(3): 791–825.

Mussa, Michael (1981) "Sticky Individual Prices and the Dynamics of the General Price Level" *Carnegie-Rochester Conference Series on Public Policy* 15: 261–96.

Owen, Diana (1993) "The Commercialization of Newspapers" *The World and I* 8(December): 393.

Reddaway, W.B. (1963) "The Economics of Newspapers" *The Economic Journal* 73(290): 201–18.

Sargent, Thomas J. and François R. Velde (2002) *The Big Problem of Small Change* Princeton, NJ: Princeton University Press.

Segrave, Kerry (2002) *Vending Machines: An American Social History* Jefferson, NC: McFarland & Company, Inc.

Sheshinski, Eytan, A. Tishler, and Yoram Weiss (1981) "Inflation, Costs of Adjustment, and the Amplitude of Real Price Changes" in M. June Flanders and Assaf Razin, eds. *Development in an Inflationary World* New York: Academic Press.

Sumner, Scott (1993) “Privatizing the Mint” *Journal of Money, Credit and Banking* 25(1): 13–29.

Taylor, John B. (1999) “Staggered Price and Wage Setting in Macroeconomics” in John B. Taylor and Michael Woodford, eds. *Handbook of Macroeconomics* vol. 1B New York: Elsevier Science B.V.

Telser, L.G. (1995) “Optimal Denominations for Coins and Currency” *Economics Letters* 49(4): 425–27.

Thompson, R.S. (1989) “Circulation Versus Advertiser Appeal in the Newspaper Industry: An Empirical Investigation” *Journal of Industrial Economics* 37(3): 259–71.

Van Hove, Leo (2001) “Optimal Denominations for Coins and Bank Notes: In Defense of the Principle of Least Effort” *Journal of Money, Credit, and Banking* 33(4): 1015–21.

Watkins, G.P. (1911) “Street-Railway Rates, with Especial Reference to Differentiation” *Quarterly Journal of Economics* 25(4): 623–49.

Weiss, Yoram (1993) “Inflation and Price Adjustment: A Survey of Findings from Micro Data” in Eytan Sheshinski and Yoram Weiss, eds., *Optimal Pricing, Inflation, and the Cost of Price Adjustment* Cambridge, MA: The MIT Press.

Willis, Jonathan L. (2000) “Estimation of Adjustment Costs in a Model of State-Dependent Pricing” Federal Reserve Bank of Kansas City Research Working Paper No. 00–07.

----- (forthcoming) “Magazine Prices Revisited” *Journal of Applied Econometrics*.

Wolman, Alexander L. (2000) “The Frequency and Costs of Individual Price Adjustment” Federal Reserve Bank of Richmond *Economic Quarterly* 86(4): 1–22.

Young, Andrew T. and Alexander K. Blue (2005) “Retail Prices During a Change in Monetary Regimes: Evidence from Sears, Roebuck Catalogs, 1938–1951” working paper.

Zbaracki, Mark J., Mark Ritson, Daniel Levy, Shantanu Dutta, and Mark Bergen (2004) “Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets” *Review of Economics and Statistics* 86(2): 514–33.

VIII Data Appendix

The following describes in detail the quarterly data available for the present study.[26]

Cover Price Series

Cover prices form a unique series in that each paper has different prices for its weekday and Sunday editions, and throughout much of the sample the papers had different cover prices depending on whether the paper was sold inside the primary metro area or outside of it.[27] Thus there are four cover price series: weekday cover prices within the primary metro area, weekday cover prices outside the primary metro area, Sunday cover prices within the primary metro area, and Sunday cover prices outside the primary metro area.[28] In some cases, a newspaper provided even more pricing breakdowns—e.g., one price for the metro area, another for a distance of less than 75 miles from it, another for a distance greater than 75 miles but less than 150 miles from it, etc. For the sake of comparison, only one cover price outside the metro area was considered.

The Detroit Free Press and *The Detroit News* have continuous weekday cover prices for inside and outside the Detroit metro area 1884Q1–2004Q2 and 1873Q4–2004Q2, respectively, and continuous Sunday cover prices for both series 1884Q1–2004Q2 and 1885Q1–2004Q2, respectively, with the exception of missing observations for 1964Q4 and 1968Q1–1968Q3. During these four quarters, strikes stopped publication at both papers. These missing data points do not contain any missing price changes, since no paper was published during this time.

Strikes briefly stopped printing at *The New York Times* in 1963Q1, 1965Q4, and 1978Q4, thus these data points are missing.[29] Otherwise, the *Times* has continuous cover price series 1851Q1–2004Q2 for weekdays and 1861Q3–2004Q2 for Sundays. Because the *Times* occasionally used multiple prices based upon distance from New York City, the cover price series outside the metro area uses prices for the New York edition in Upstate New York.

The Chicago Tribune has complete cover price series for weekdays and Sundays 1876Q3–2004Q2, both within the Chicago metro area and outside of it. Within the Washington, DC, metro area, *The Washington Post* has complete cover price series for weekdays and Sundays from 1878Q1 and 1880Q3, respectively, to 2004Q2. For *Post* cover prices outside the metro area, I use those for Maryland and Virginia outside the metro area. While these weekday and Sunday series begin at the same time as their metro area counterparts, they both end with the 1993Q4 observation. After that time, the paper stated that they varied by location and did not contain a written record of them; hence these observations are missing starting with 1994Q1.

As a financial paper, *The Wall Street Journal* does not have any Sunday cover prices. At only one point—1942Q1 through 1948Q1—did the paper list a separate price for outside the

[26] The analysis assumes that there are no missed price changes, i.e., that the probability of a price changing more than once in a quarter is zero. This is based upon a thorough documentation of the pricing history of the *Free Press*, which found that only at one time—1905Q1—did the paper change its carrier delivery price twice within the quarter, and this was for a special, one-time sale that was quickly undone. (Since my analysis is on prices that are posted in the paper, this study already abstracts away from very temporary sale and special prices.)

[27] Nearly all Saturday papers have the same price as the weekday papers. However, there is one exception—the *Tribune* from 1960Q1 to 1964Q3—and as such I omit Saturday papers in this analysis.

[28] Sunday prices are generally not a multiple of the weekday price, and their pricing behavior differs enough from that of weekday papers to truly constitute a separate series.

[29] To deal with these strikes, the *Times* circulated its Western edition in New York City. Since this is not a direct substitute for the normal paper, however, I treat these as missing observations.

New York City metro area. Thus I only consider the weekday price series in the New York metro area for the *Journal*; this runs continuously 1889Q4–2004Q2.

One Year Mail Subscription Price Series

The one year subscription length for mail subscription prices was chosen due to the fact that it is the most common price quoted. The subscription price was a full subscription to the newspaper, whatever was published.[30] While some papers published separate mail subscription rates based upon distance from the primary metro area, only one series for each paper—the one that was the least changed in its description over time—was used. Unlike the multiple cover price listings, differentiated mail subscription price series moved in lockstep.

One year mail subscription series for the *Post* and the *Journal* run uninterrupted 1878Q1–2004Q2 and 1889Q3–2002Q3, respectively. The *Times* printed a one year mail subscription rate 1851Q3–2004Q2, with three exceptions owing to strikes in 1963Q1, 1965Q4, and 1978Q4. Since the price was the same before and after the missing observations, and since the newspaper was not available during this time, these missing observations do not affect the analysis.

Data for the other three newspapers were not available in some cases. The *Tribune* has one year mail subscription prices continuously 1855Q1–1883Q3, 1886Q2–1974Q1, and 1979Q1–1991Q4. From 1883Q4 to 1886Q1, the paper does not list a one year price. It does list a one month mail subscription price of $1. Since the one year price in 1883Q3—the last observation before the missing points—was $12, I annualize the monthly price to $12 to fill in the missing data points. The *Tribune* did not list mail prices 1974Q2–1978Q4, when the one year price went from $40 (1974Q1) to $80 (1979Q1). These points are treated as missing observations.[31] Starting with 1992Q1, the *Tribune* did not publish a one year price: from 1992Q1 to 1994Q1 it published a 13 week mail subscription price, and from 1994Q2 onward it published a 12 week mail subscription price. In each case, I annualized the price to continue the series. I justify this assumption as follows. First, the fact that previously the paper had only listed an annual price and thereafter only listed thirteen or twelve week prices is strongly suggestive that a price change had occurred for subscribers interested in buying an entire year's subscription. Second, the one year price was $217 for 1991Q4, at which point the 13 week price became $73.19 for 1992Q1—or $292.76 at an annual rate. Even if the paper did give a discount for buying an entire year's subscription at that time instead of paying in four 13-week installments, it is doubtful that it gave a 35% discount. Third, changing the terms of subscription very slightly—from 13 to 12 weeks in this case—is typical across newspapers as a means of disguising price changes.

The *Free Press* has continuous one year prices 1842Q1–1944Q1 and 1946Q2–2004Q2. The latter period is missing four quarters because of strikes: 1964Q4 and 1968Q1–Q3. The newspaper was not published on account of strikes at the *Free Press* and the *News*, hence these are missing observations. For 1944Q2 to 1946Q1, the *Free Press* did not publish any mail prices and the price went from $15 (1944Q1) to $22.50 (1946Q2). It is reasonable to assume that the price changed one time, in 1944Q3. There are several justifications for this belief. First, the *Free Press* changed its weekday and Sunday cover prices and carrier prices during this quarter.

[30] For the *Journal*, this is a subscription for weekdays except for legal holidays after 1953, and everyday except Sundays and legal holidays prior to 1953. For the other five papers, this is for 365-day mail delivery; before Sunday editions were printed, it was a subscription for everyday except Sundays and legal holidays.

[31] For comparison, carrier delivery prices changed three times during this time span.

Second, the *News* also changed its mail subscription price in this quarter. Finally, between 1920 and 1961, all other mail subscription prices of the *Free Press* and the *News* were identical. In spite of this suggestive evidence, I do not interpolate these missing observations.

The *News* has continuous one year mail subscription prices 1873Q4–1883Q2 and 1889Q1–2004Q2. The latter series is missing the same four observations as the *Free Press*; as such, it is treated identically. From 1883Q3 to 1888Q4, a number of observations are missing for this series. All indications are that prices only changed one time during this span, but due to lack of certainty this period is excluded from the analysis.

One Year Carrier Delivery Price Series

The price series for cover prices and one year mail subscription prices are remarkably intact, whereas the price series for carrier delivery are not.[32] The first problem is one of data availability. The *Times* only published carrier delivery prices on a regular basis from 1851 to 1861 and thus is not included in the carrier delivery statistics. The *Journal* also was omitted from these statistics, on account of ambiguity over whether its subscription price was the same for mail and carrier delivery. (The "subscription" price was marked "postage paid" for more than 75 years, which explains its inclusion in the mail delivery statistics.) In addition, all papers except for the *Post* did not print any carrier delivery price quotes during some time, though the lengths of these intervals vary. These missing observations may skew some statistics, as there is no way to ascertain whether there were no price changes or—if the price before and after the missing observations are different—if there were multiple price changes. The bias could easily run in either direction: a price may not have been listed because it had been the same for a long time, because it was changing relatively frequently, or because it was determined by distributors.

Missing observations aside, the largest complicating factor with carrier delivery prices is that the length of the term for the quoted price—one year, one month, one week, etc.—varies widely among newspapers and over time. Changing the length of the term instead of changing the price of the term directly is common with carrier delivery prices. An illustration of this is helpful. From 1880Q3 through 1933Q3, carrier delivery for the *Post* for one month was 70¢; the cost for one year carrier delivery, which was published 1919Q1–1933Q3, was $8.40.[33] In 1933Q4, the monthly price was eliminated, but the one year price fell to $7.80. At the same time, the *Post* began publishing a one week carrier delivery price for 15¢.

Because of this complication, I calculate two statistics for carrier delivery prices. In the first, I compute an annualized carrier delivery price based upon available quotes and calculate statistics of interest from that. This is not a perfect price. The annualized monthly or weekly prices do not always equal the yearly price (when it is available); as a result, the level of the annualized prices is not always correct, nor is the percentage change in the price. However, this does serve as a good measure of price changes: when multiple series are listed concurrently and do not "disappear," all price changes are simultaneous, and the sizes of the price changes are comparable—within several percentage points. In the second method, I compute all statistics using all listed prices, then take averages across these statistics. Both methods yield nearly identical results, so I use the constructed annualized series for ease of comparability with the one year mail subscription series. Because of the fragmented nature of these data sets, the exact

[32] Carrier delivery is access to a six or seven day paper, depending on what was available, similar to mail subscriptions above.

[33] While in this case the one year price was the same as the monthly price annualized, this is not always the case.

dates for these series are listed in Table A1 along with dates for all other series. In addition, the analysis in the text is more focused on the cover and mail subscription price series.

IX Simulation Appendix

For the simulations, the central equations are the firm's general real profit function,

$$\Pi\left(p_t, \mathrm{P}_t\right) = \mathrm{K} - b\left(\frac{p_t}{\mathrm{P}_t} - 1\right)^2 - z\left[n(p_t) - 1\right], \quad \mathrm{K}, b > 0, z \geq 0, \tag{9.1}$$

and the equations associated with the firm's decision problem from Section III.

$$V\left(p, \mathrm{P}\right) = \max\left\{V^K\left(p, \mathrm{P}\right), V^C\left(p, \mathrm{P}\right)\right\} \tag{9.2}$$

$$V^K\left(p, \mathrm{P}\right) = \Pi\left(p, \mathrm{P}\right) + \beta E_{\mathrm{P}'|\mathrm{P}} V\left(p, \mathrm{P}'\right) \tag{9.3}$$

$$V^C\left(p, \mathrm{P}\right) = \max_{\tilde{p}} \ \Pi\left(\tilde{p}, \mathrm{P}\right) - \Phi + \beta E_{\mathrm{P}'|\mathrm{P}} V\left(\tilde{p}, \mathrm{P}'\right) \tag{9.4}$$

The model is solved numerically using value function iteration. The firm's optimal frictionless price, P, evolves according to

$$\ln \mathrm{P}_t = \mu + \ln \mathrm{P}_{t-1} + \xi_t. \tag{9.5}$$

The following calibrations are common across all simulations: 1 period=1 quarter; $\beta = (1+r)^{-1}$; $r = 0.0075$; $\mu = 0.009$; $\xi \sim$ i.i.d. $N(0, \sigma_\xi^2)$; and $\sigma_\xi = 0.02$.

Allowing for exponential growth in the firm's frictionless optimal price poses computational challenges since the state space for P, and thereby *p*, is potentially infinite. To form an approximate solution, I truncate the problem even though this makes the value function near the boundaries of the (truncated) state space imprecise. In the results presented, the state spaces for P and *p* are large enough so that the results are not sensitive to the truncations. In an alternative model, I assume that P follows an AR(1) process such that it is always an element of a compact set, so that the value function is well-defined even at the boundaries of the state space. Broadly speaking, the results are similar for both cases. Thus any imprecision of the solution technique appears to be unimportant for the current analysis.

For the first set of simulations from Section V, K and *b* are normalized to one. The inconvenience sensitivity parameter *z* is set to one of {0, 0.002, 0.02, 0.2}. The cost of price adjustment Φ is set to one of {0,0.3}. For each *z*-Φ combination, I run 100 simulations of 400 quarters. Each simulation consists of one set of exogenous inflation realizations—which are assumed to approximate $\mu + \xi_t$ in each firm's frictionless optimal price equation—and six individual firm price series, one for each of the six firms in the empirical data sample. Each simulated firm's starting price is set to the corresponding actual price charged by a firm in 1904. The moments presented in Table 7 are averages across the 100 simulations.

Before undertaking estimation of the structural parameters *z* and Φ via indirect inference, note that one can divide (9.1)–(9.4) by *b*, which measures the sensitivity of profits to deviations of the firm's actual price from its frictionless optimal price. Thus the model can be rewritten in terms of K/*b*, *z*/*b*, and Φ/*b*. The ratio K/*b* does not affect the firm's price-setting problem (and thus will not affect the estimation of *z*/*b* and Φ/*b*) and is normalized to one.

Indirect inference seeks to find the *z*/*b*-Φ/*b* combination that best "fits" the data, in that the weighted difference between moments estimated from the data and average moments

estimated via simulated data is minimized. See, e.g., Gouriéroux and Monfort (1996) or Adda and Cooper (2003). I identify nine moments that the model should attempt to match.

(1–3) Moments of interest in the price rigidity literature: the average frequency of price changes; the average size of price changes, in absolute value; and the standard deviation of the size of price changes.

(4–5) Moments relating to the use of convenience points: the percentage of time spent charging a price that is a monetary convenience point; and the percentage of the time that, given that a firm decides to change its price, it changes it to a monetary convenience point.

(6–9) The coefficients that measure the responsiveness of the frequency and size of price changes to inflation and a time trend, as captured by equations (4.1) and (4.2), respectively, for the cover price data: $\hat{\beta}_f$, $\hat{\gamma}_f$, $\hat{\beta}_s$, and $\hat{\gamma}_s$.

These nine moments are estimated from the empirical data and called $\hat{\theta}$. For each z/b-Φ/b combination, I run S=100 simulations of six firms' price-setting for 400 quarters. Each simulation yields a similar set of moments based upon simulated data that is a function of the choice of z/b and Φ/b, $\tilde{\theta}_s(z/b, \Phi/b)$. The indirect inference parameter estimates are given by

$$\widehat{\frac{z}{b}}, \widehat{\frac{\Phi}{b}} = \arg\min_{\frac{z}{b}, \frac{\Phi}{b}} \left[\hat{\theta} - \frac{1}{S} \sum_{s=1}^{S} \tilde{\theta}_s \left(\frac{z}{b}, \frac{\Phi}{b} \right) \right]' \Omega \left[\hat{\theta} - \frac{1}{S} \sum_{s=1}^{S} \tilde{\theta}_s \left(\frac{z}{b}, \frac{\Phi}{b} \right) \right], \tag{9.6}$$

where Ω is a positive definite weighting matrix, which is the inverted bootstrapped variance-covariance matrix for the moments estimated from the data. The results are presented in Table 8. The search for (9.6) was carried out by simulated annealing; see, e.g., Goffe et al. (1994). Five starting points were selected to insure convergence to global as opposed to local minima. After identifying $\widehat{z/b}$ and $\widehat{\Phi/b}$, standard errors were found using numerical derivatives.

For the sub-samples, 200 quarters were simulated. Five firms were simulated for the Sunday indirect inference exercise. Starting prices for the simulated firms were always set equal to one of the weekday or Sunday papers at the beginning of the time period.

The parameters z/b and Φ/b do not have simple interpretations, such as menu costs stated as a percentage of profits. A further complication preventing an easy comparison of the estimates is the fact that inconvenience affects profits in every period whereas menu costs are only "paid" infrequently—i.e., when a firm decides to change its price. As a relatively simple way to gauge the importance of inconvenience considerations relative to menu costs and to effectively eliminate b, Table 8 takes the estimated values $\widehat{z/b}$ and $\widehat{\Phi/b}$ and, together with the actual historical prices set by the I firms, uses them to report the average ratio of profits lost due to inconvenience to profits lost due to menu costs

$$\frac{\text{Profits lost due to inconvenience}}{\text{Profits lost due to menu costs}} = \frac{1}{I} \sum_{i=1}^{I} \frac{\widehat{z/b} \sum_{t=1}^{T} [n(p_{it}) - 1]}{\widehat{\Phi/b} \sum_{t=1}^{T} D_{it}}, \quad D_{it} = \begin{cases} 1 \text{ if } p_{it} \neq p_{it-1} \\ 0 \text{ otherwise} \end{cases}, \tag{9.7}$$

I is six for weekday prices and five for Sunday prices. T is 400 for the whole samples and 200 for the sub-samples.

Figure 1: Small Inconvenience Loss

Figure 1(a): Profits earned for various values of the frictionless optimal price

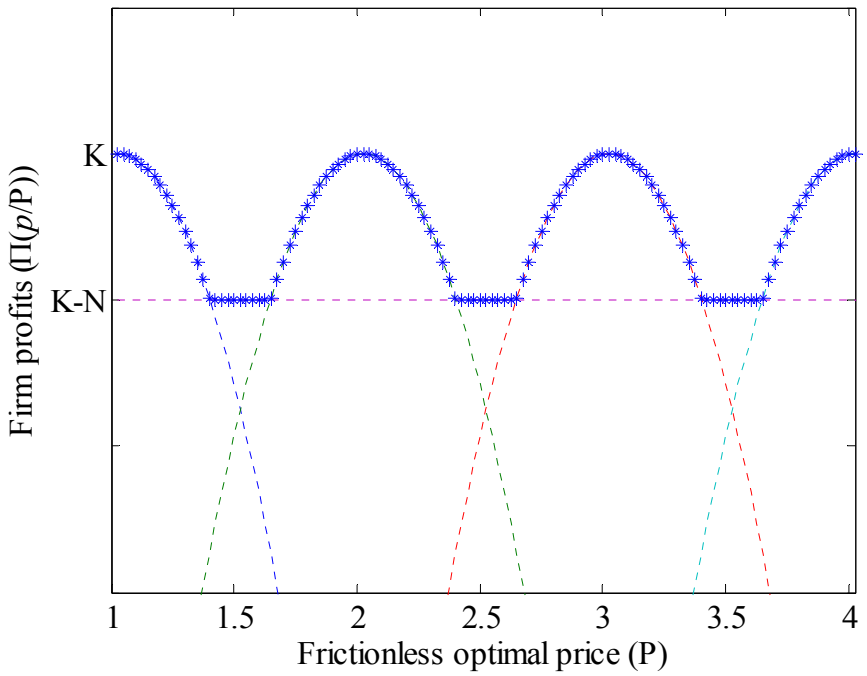


Figure 1(b): The firm's reaction function

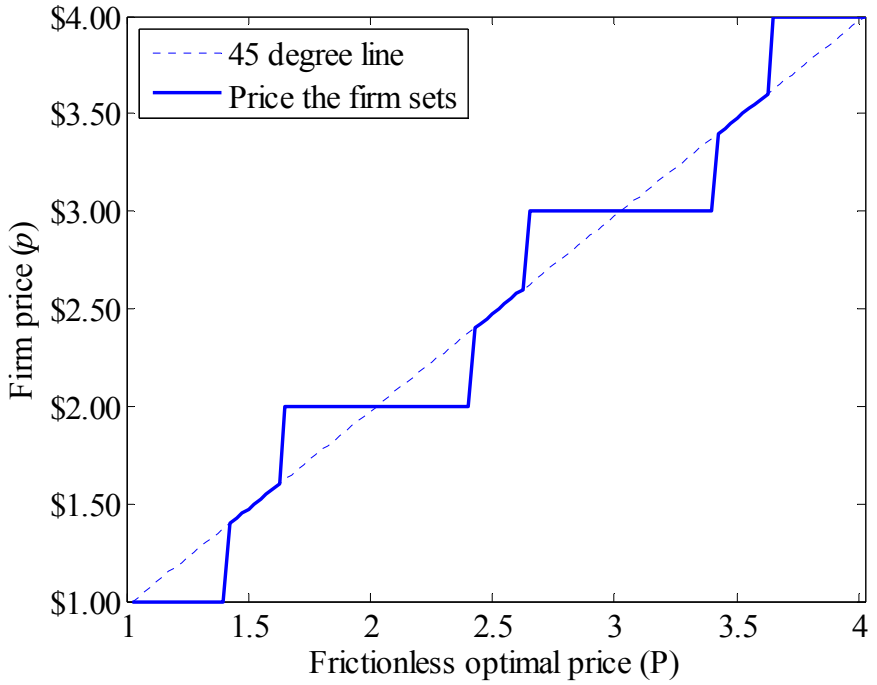


Figure 2: Large Inconvenience Loss

Figure 2(a): Profits earned for various values of the frictionless optimal price

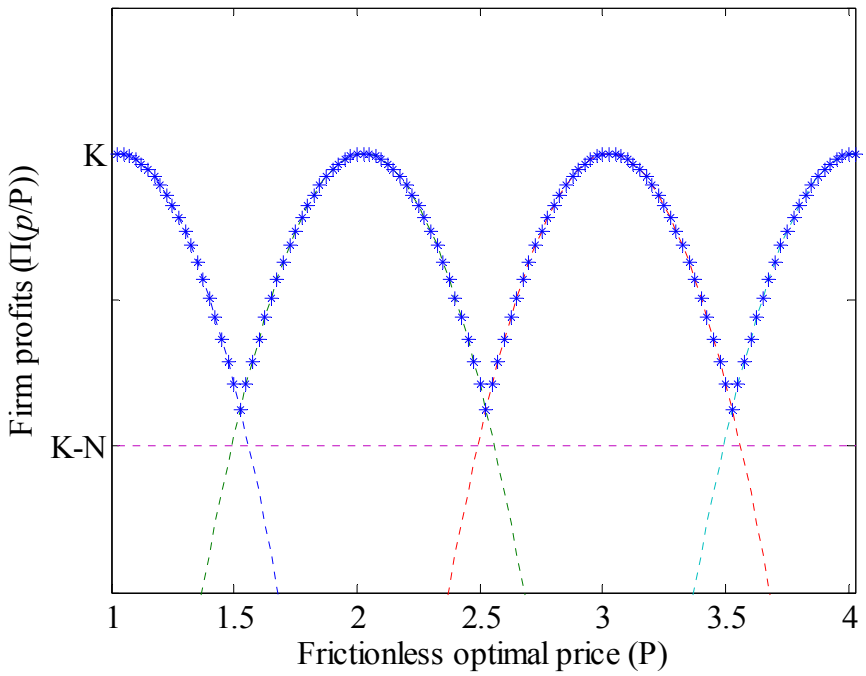


Figure 2(b): The firm's reaction function

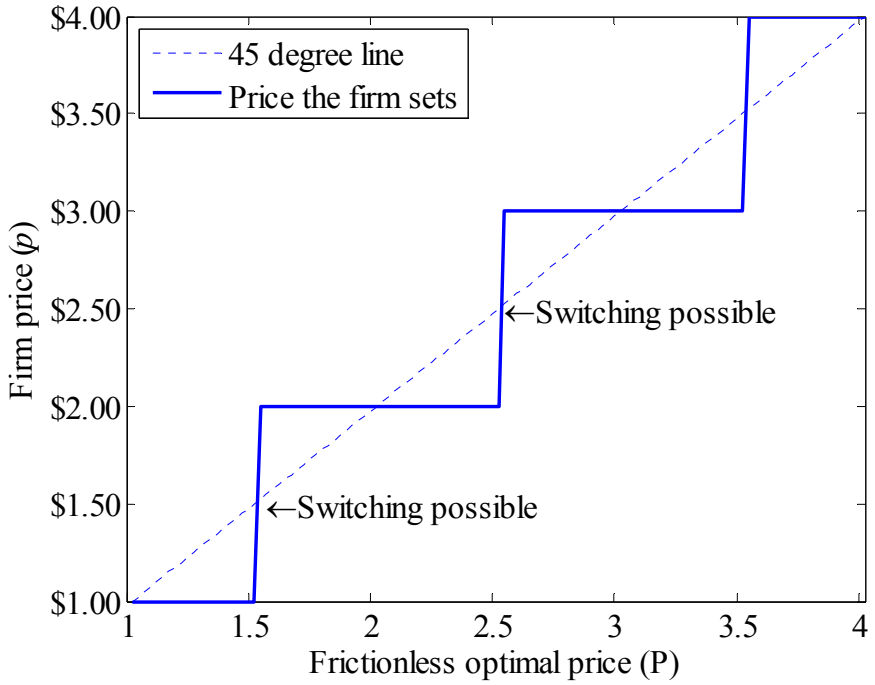
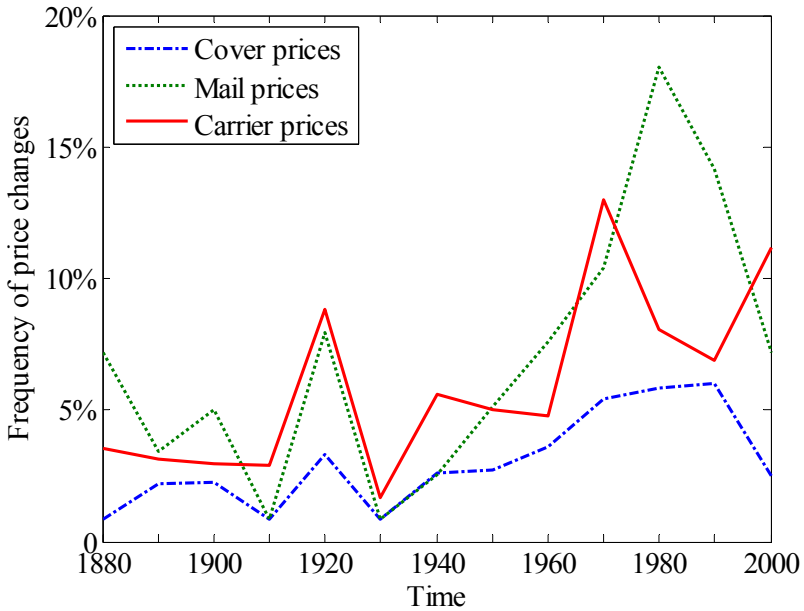
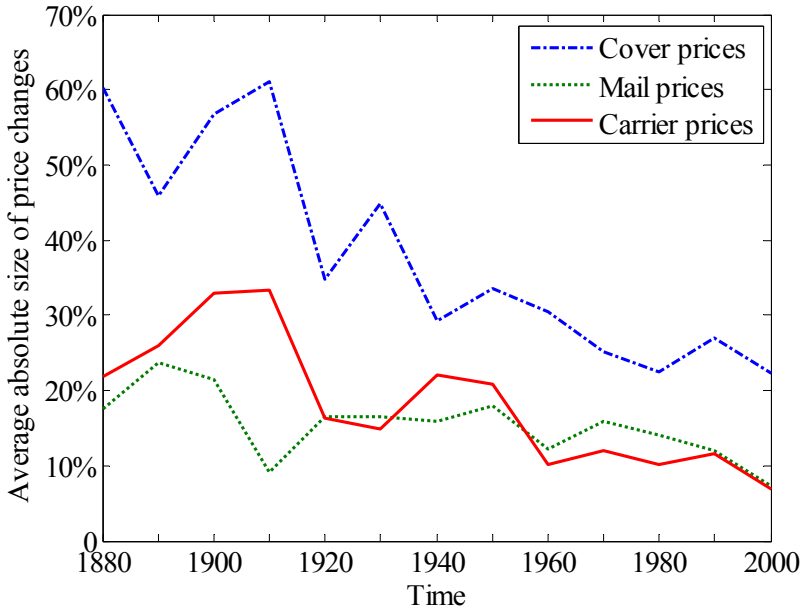


Figure 3: Average Frequency of Price Changes in Each Period



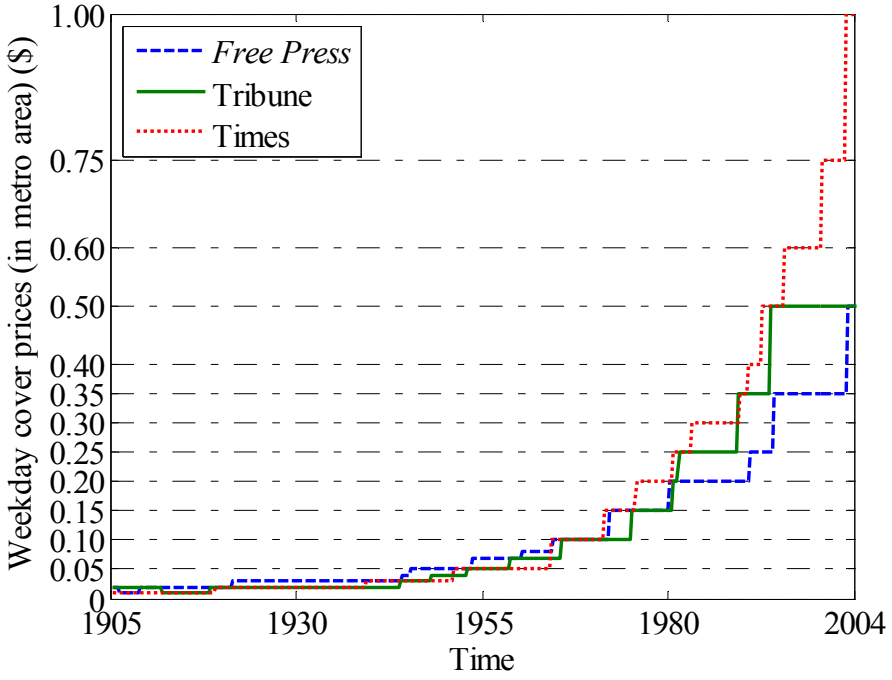
Notes: Dates on the horizontal axis are the midpoints of each ten-year interval.

Figure 4: Average Absolute Nominal Size of Price Changes in Each Period



Notes: Dates on the horizontal axis are the midpoints of each ten-year interval.

Figure 5: Weekday Cover Prices for Six Newspapers, 1904–2004



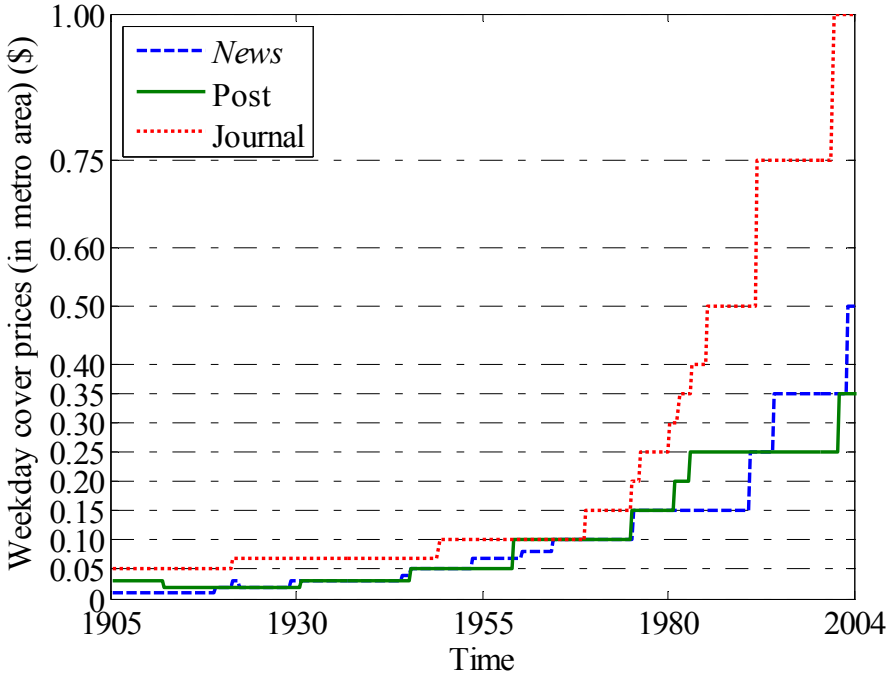


Figure 6: One Simulation: A Firm's Actual Price and Its Frictionless Optimal Price

Figure 6(a) Results for z=0, Φ =0

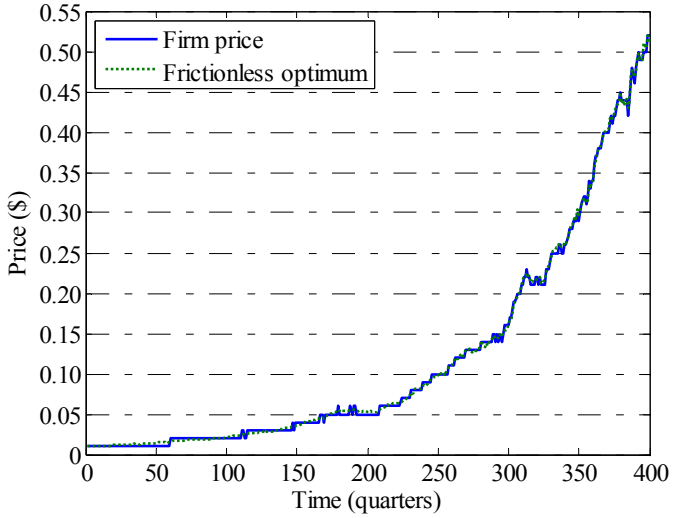


Figure 6(b) Results for z=0, Φ =0.3

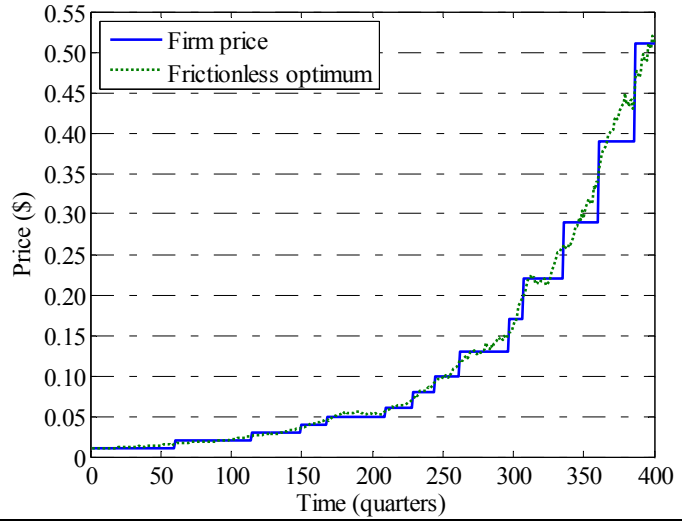


Figure 6(c) Results for z=0.002, Φ =0

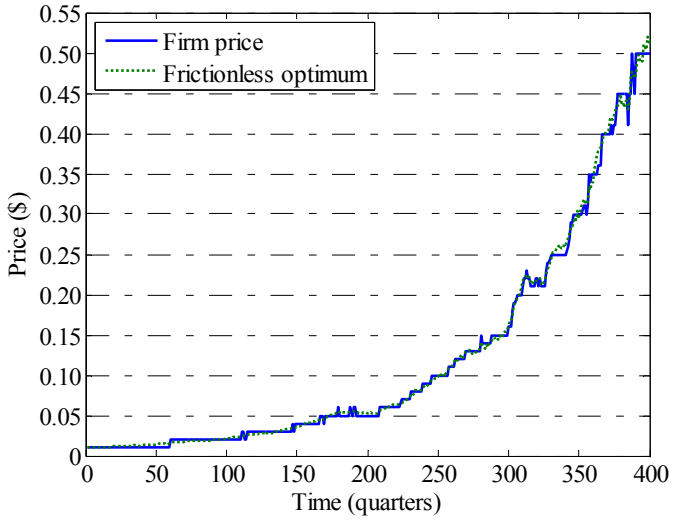


Figure 6(d) Results for z=0.002, Φ =0.3

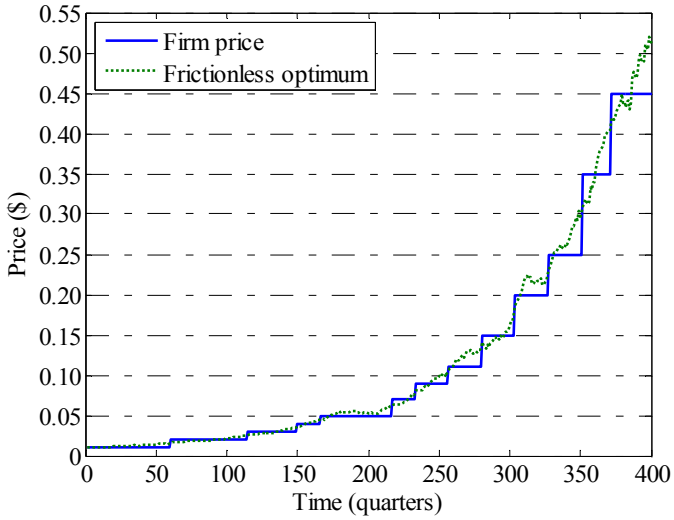


Figure 6(e) Results for z=0.02, Φ =0

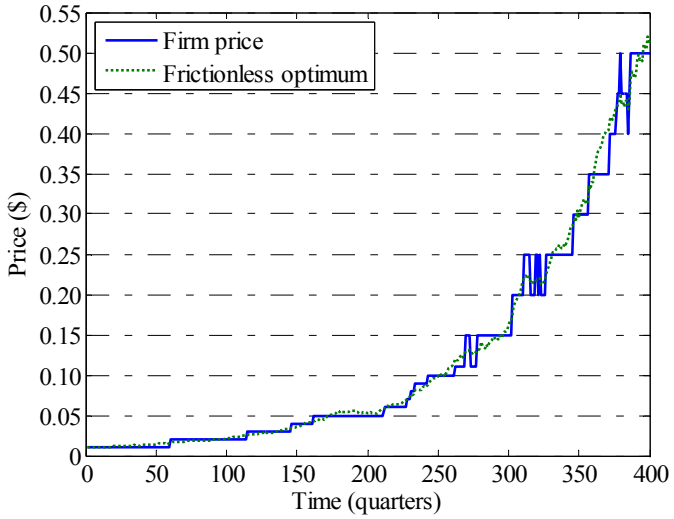


Figure 6(f) Results for z=0.02, Φ =0.3

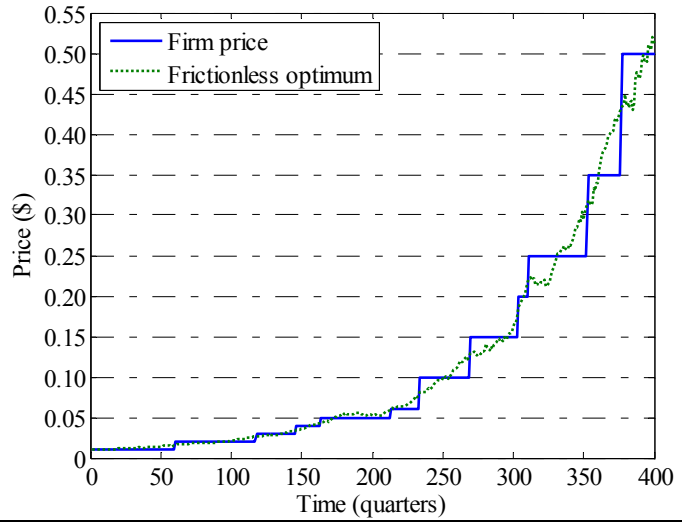


Figure 6(g) Results for z=0.2, Φ =0

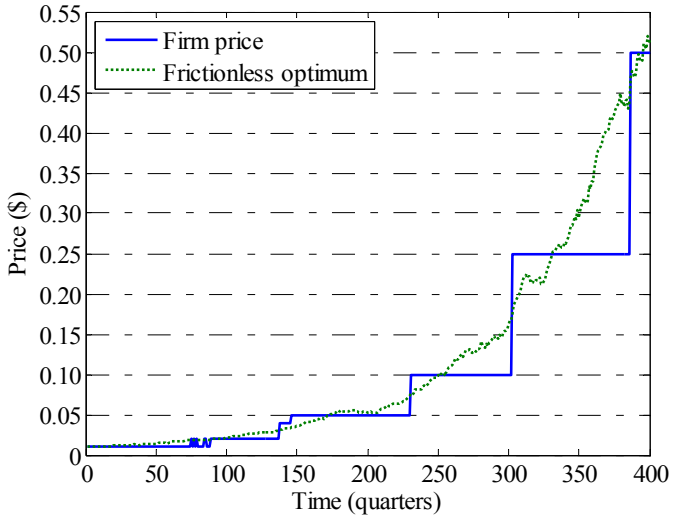


Figure 6(h) Results for z=0.2, Φ =0.3

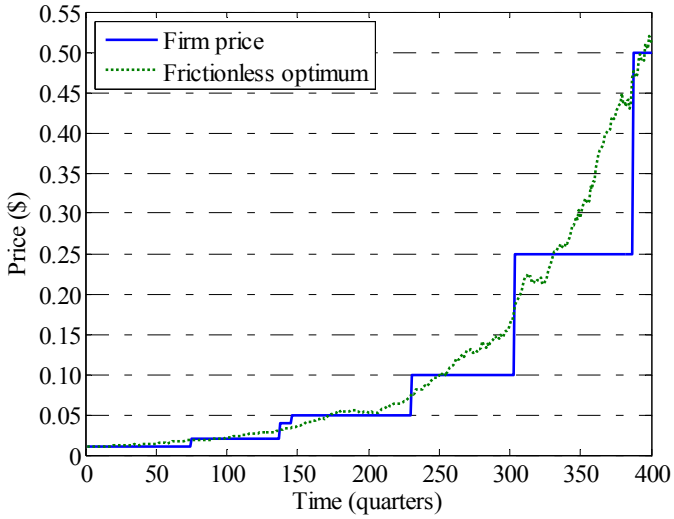


Figure 7: Direct Comparisons between the Historical and Predicted Prices

Figure 7(a): *The Detroit Free Press*

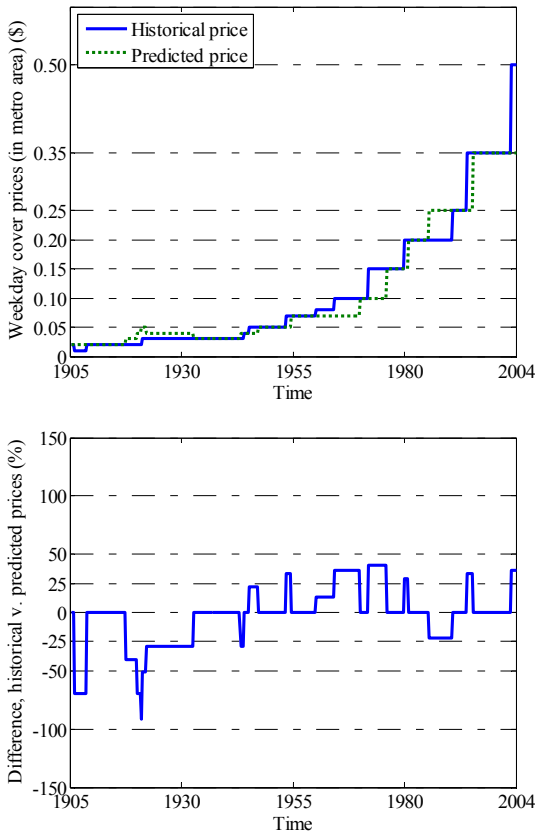


Figure 7(b): *The Detroit News*

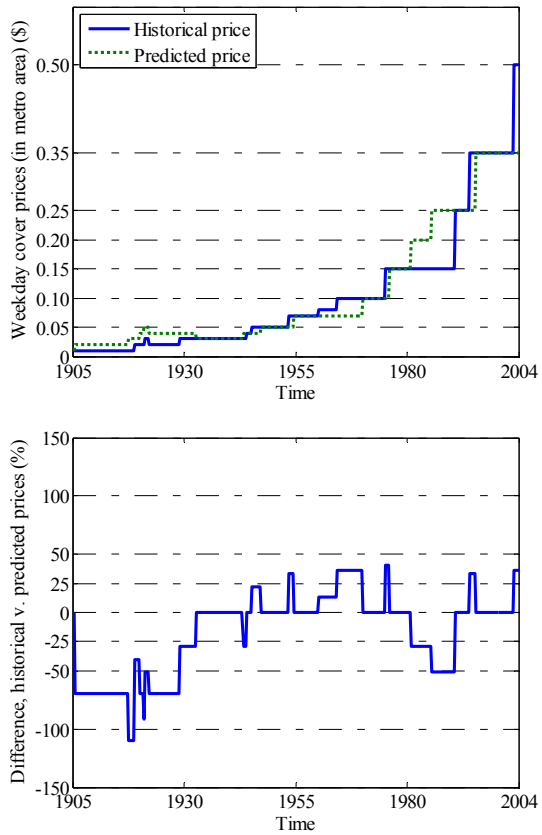


Figure 7(c): *The Chicago Tribune*

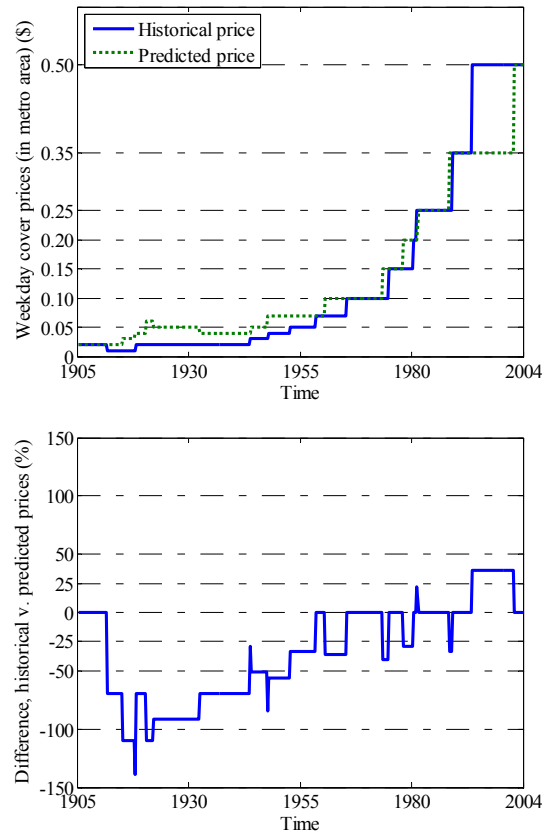


Figure 7(d): *The New York Times*

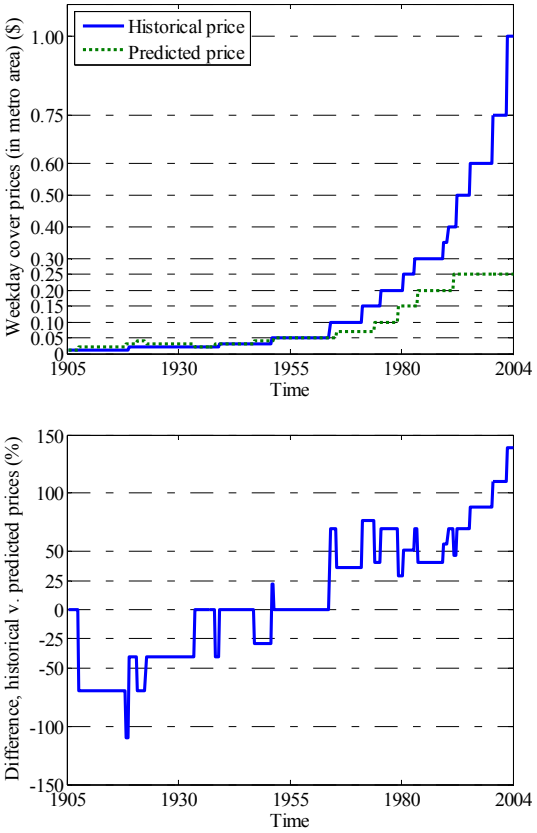


Figure 7(e): *The Washington Post*

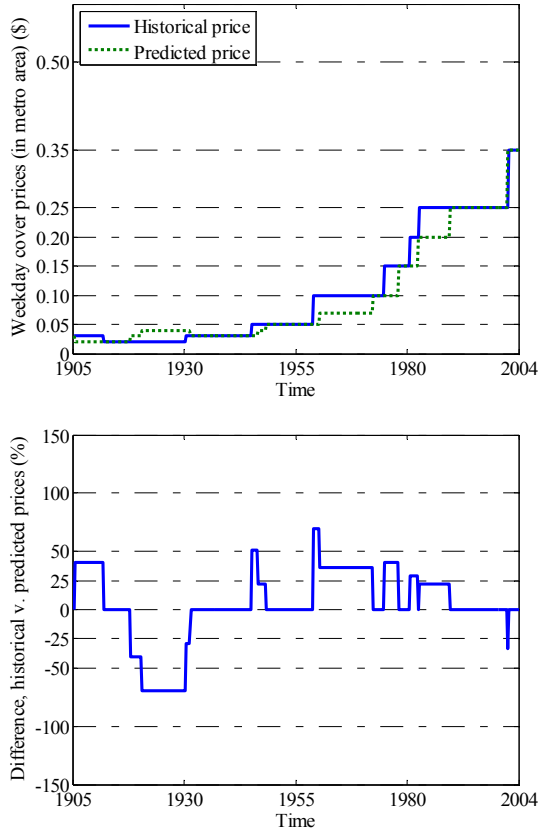
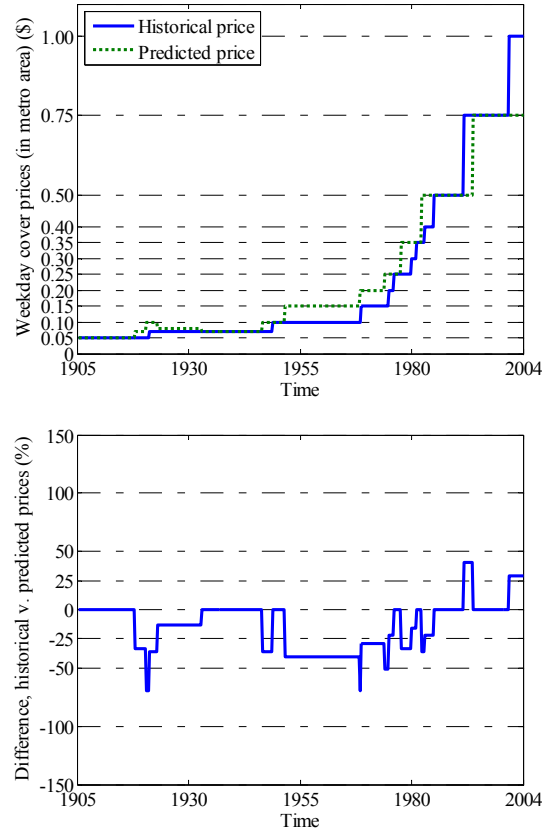


Figure 7(f): *The Wall Street Journal*



Notes: Predicted prices are generated (1) using the estimated parameters from indirect inference, $\widehat{z/b} = 3.00 * 10^{-3}$ and $\widehat{\Phi/b} = 0.777$; (2) starting the predicted price series at the price each firm actually charged as of 1904Q2; and (3) subjecting the firm to the actual inflationary shocks of the period 1904–2004. See the text for details.

Table 1: Calculating Relative Inconvenience *n*(*p*)

p	*n*(*p*)
\$0.25	1
\$0.29	3
\$0.83	5
\$0.96	3
\$4.73	4

Notes: Relative inconvenience *n*(*p*) is the minimum number of common coins and/or common bills that can be used, in any combination, to form price *p*, allowing for the possibility that the buyer can receive change from the seller.

Table 2: Whole Sample Statistics, 1842–2004

	Frequency of price changes (% of quarters)	Duration between price changes (quarters)		Absolute nominal size of price changes (%)[34]		Largest positive/negative nominal price change (%)	Smallest absolute price change (%)
		Median	Mean	Median	Mean		
Weekday cover	2.70	28	35.2 (29.8)	35.7	39.0 (17.3)	69.3 / –109.9	13.4
Sunday cover	3.48	15	27.3 (35.8)	22.3	26.0 (11.8)	69.3 / –51.1	2.3
Mail subscription	6.94	8	14.0 (18.0)	13.4	15.3 (9.7)	47.0 / –47.0	1.7
Carrier delivery	6.03	10	15.0 (22.0)	12.5	15.4 (10.1)	58.8 / –43.5	2.4

Notes: See Section IV for specifics. Numbers in parentheses are standard deviations. The frequency of price changes (as a percentage of the number of quarters) is defined as the number of price changes that occurred in the sample divided by the number of possible price changes. New prices—e.g., the points at which the first cover price occurred—are not regarded as changes. Possible price changes corrects for the fact that not all data are available for all dates.

[34] All percentage change measures for price changes and inflation use $(\text{Percentage change in } x) = \ln(x_{new}) - \ln(x_{old})$.

Table 3: Longest and Shortest Rigidities

	Duration (quarters)	Paper (m=metro price, o=outside metro price)
Longest rigidities:		
Weekday cover	133	*The Washington Post* (m & o), 1878Q1–1911Q1
Sunday cover	238	*The Washington Post* (m & o), 1880Q3–1939Q3
Mail subscription	111	*The Wall Street Journal*, 1920Q3–1948Q1
Carrier delivery	213	*The Washington Post*, 1880Q3–1933Q3
Shortest rigidities:		
Weekday cover	1	*The Detroit News* (o), 1908Q1
Sunday cover	1	*The Detroit News* (o), 1885Q1
Mail subscription	1	(9 occurrences)
Carrier delivery	1	(3 occurrences)

Table 4: Regression Results for $\overline{\text{frequency}}_t = \alpha_f + \beta_f \pi_t + \gamma_f T + \varepsilon_t^f$

	Covers	Mail subscription	Carrier delivery	Pooled
Estimates from OLS Regressions				
α_f	-0.012	-0.055	-0.030	
	(0.01)	(0.04)	(0.01)	
β_f	0.233**	0.844*	0.566***	0.548***
	(0.10)	(0.44)	(0.13)	(0.15)
γ_f	0.004***	0.011**	0.008***	0.008***
	(0.001)	(0.004)	(0.002)	(0.001)
$\bar{R}^2$	0.49	0.40	0.54	0.53
Estimates from Weighted Least Squares Logit Regressions for Grouped Data [Marginal effects at mean values in brackets]				
	Covers	Mail subscription	Carrier delivery	Pooled
α_f	-4.900***	-4.325***	-4.501***	
	(0.52)	(0.70)	(0.49)	
β_f	6.995	11.017	10.416**	8.852***
	(4.64)	(6.20)	(4.21)	(2.79)
	[0.20]	[0.72]	[0.56]	[0.42]
γ_f	0.146***	0.162***	0.162****	0.153***
	(0.039)	(0.050)	(0.036)	(0.02)
	[0.004]	[0.011]	[0.009]	[0.007]
$\bar{R}^2$	0.50	0.41	0.60	0.69

Notes: $\overline{\text{frequency}}_t$ is the average frequency of price change (as a percentage of the number of quarters) during time period *t*, π_t is the average for each ten-year period *t* of the absolute value of the annualized percentage growth in the price level from one quarter to the next, and *T* is a time trend. Standard errors in parentheses (robust standard errors for OLS regressions); *, **, *** denotes significant at the 10%, 5%, or 1% level, respectively. There are 13 observations in the sample: 1875–1884, 1885–1894, 1895–1904, 1905–1914, 1915–1924, 1925–1934, 1935–1944, 1945–1954, 1955–1964, 1965–1974, 1975–1984, 1985–1994, 1995–2004. The pooled model is estimated using dummies for the mail and carrier series; the coefficients, while not reported, are significant at the 1% level in all cases.

Table 5: Regression Results for $\overline{\text{size}}_t = \alpha_s + \beta_s \pi_t + \gamma_s T + \varepsilon_t^s$

	Covers	Mail subscription	Carrier delivery	Pooled
α_s	0.720***	0.174**	0.379***	
	(0.08)	(0.06)	(0.06)	
β_s	-1.363**	0.384	-0.848	-0.608
	(0.58)	(0.47)	(0.48)	(0.38)
γ_s	-0.038***	-0.006	-0.021***	-0.022***
	(0.006)	(0.004)	(0.005)	(0.004)
$\bar{R}^2$	0.80	0.34	0.63	0.78

Notes: $\overline{\text{size}}_t$ is the average absolute nominal percentage change in price during time period t, π_t is the average for each ten-year period t of the absolute value of the annualized percentage growth in the price level from one quarter to the next, and T is a time trend. Robust standard errors in parentheses; *, **, *** denotes significant at the 10%, 5%, or 1% level, respectively. There are 13 observations in the sample: 1875–1884, 1885–1894, 1895–1904, 1905–1914, 1915–1924, 1925–1934, 1935–1944, 1945–1954, 1955–1964, 1965–1974, 1975–1984, 1985–1994, 1995–2004. The pooled model is estimated using dummies for the mail and carrier series; the coefficients, while not reported, are significant at the 1% level in all cases.

Table 6: The Effects of Inconvenience

z	Change in profits from charging 25¢ instead of 26¢ when P=26¢	
0	–0.15%	No inconvenience
0.002	0.05%	Slight inconvenience
0.02	1.87%	Some inconvenience
0.2	22.17%	Substantial inconvenience

Table 7: Comparing Moments between the Data and the Simulations

		Φ=0				Φ=0.3			
	Data	z=0	z=0.002	z=0.02	z=0.2	z=0	z=0.002	z=0.02	z=0.2
Frequency of price changes	2.96	25.68	18.36	9.10	2.96	3.23	3.10	2.65	1.48
Average (absolute) size of price changes	34.93	7.1	9.8	19.9	60.4	27.67	28.95	33.54	65.39
Standard deviation of size of changes	15.42	8.9	9.7	11.5	22.6	8.3	8.6	11.7	20.7
Time spent on convenience points	61.21	22.8	42.9	66.8	88.0	19.7	56.7	71.6	88.1
Changes to convenience points	70.42	21.1	40.0	61.4	75.5	19.3	59.0	72.7	73.9
Frequency | price <10¢	2.46	7.66	7.66	8.11	3.18	2.65	2.49	2.31	1.65
Frequency | price ≥ 10¢	3.50	40.61	27.36	9.83	2.82	3.72	3.66	2.91	1.38

Notes: All numbers are percentages. Monetary convenience points are local minima of the relative inconvenience measure. Moments from the data are estimated using the six weekday newspaper series from 1904Q3 to 2004Q2. Moments from the simulated data are averages over 100 simulations and use the z-Φ combination given. See Section V and the Simulation Appendix for specifics of the simulations.

Table 8: Parameter Estimates for *z*/*b* and Φ/*b* from Indirect Inference

	Weekdays (1904–2004)	Weekdays, 1904–1954	Weekdays, 1954–2004	Sundays (1904–2004)	Sundays, 1904–1954	Sundays, 1954–2004
$\widehat{z/b}$	3.00E-03	2.92E-04	9.00E-03	5.52E-02	5.52E-02	2.15E-02
(Standard error)	(3.68E-04)	(3.39E-04)	(7.18E-04)	(4.28E-04)	(3.69E-04)	(2.26E-03)
$\widehat{\Phi/b}$	0.777	0.727	0.149	0.026	0.073	0.015
(Standard error)	(0.005)	(0.104)	(0.010)	(0.003)	(0.002)	(0.001)
$\frac{\text{Profits lost due to inconvenience}}{\text{Profits lost due to menu costs}}$	0.12	0.02	1.14	41.15	9.86	31.89

Notes: Standard errors computed via numerical derivatives. (Profits lost due to inconvenience)/(Profits lost due to menu costs) combines $\widehat{z/b}$ and $\widehat{\Phi/b}$ with the actual historical prices set by the firms to derive an approximate measure of the importance of inconvenience considerations relative to menu costs over the sample period in question.

$$\frac{\text{Profits lost due to inconvenience}}{\text{Profits lost due to menu costs}} = \frac{1}{I}\sum_{i=1}^{I}\frac{\widehat{z/b}\sum_{t=1}^{T}\left[n(p_{it})-1\right]}{\widehat{\Phi/b}\sum_{t=1}^{T}D_{it}}, \quad D_{it} = \begin{cases} 1 \text{ if } p_{it} \neq p_{it-1} \\ 0 \text{ otherwise} \end{cases}$$

See Section V and the Simulation Appendix for details.

Table A1: Data Available for Study

	Start Date	End Date
The Detroit Free Press		
Weekday cover price (metro Detroit)	1884Q1	2004Q2
Weekday cover price (outside Detroit)	1884Q1	2004Q2
Sunday cover price (metro Detroit)	1884Q1	2004Q2
Sunday cover price (outside Detroit)	1884Q1	2004Q2
One year mail subscription price	1842Q1	1944Q1
	1946Q2	2004Q2
One year carrier delivery price	1847Q4	1901Q4
	1905Q1	2004Q2
The Detroit News		
Weekday cover price (metro Detroit)	1873Q4	2004Q2
Weekday cover price (outside Detroit)	1873Q4	2004Q2
Sunday cover price (metro Detroit)	1885Q1	2004Q2
Sunday cover price (outside Detroit)	1885Q1	2004Q2
One year mail subscription price	1873Q4	1883Q2
	1889Q1	2004Q2
One year carrier delivery price	1873Q4	1883Q2
	1893Q1	1901Q4
	1908Q1	1937Q1
	1949Q4	2004Q2
The Chicago Tribune		
Weekday cover price (metro Chicago)	1876Q3	2004Q2
Weekday cover price (outside Chicago)	1876Q3	2004Q2
Sunday cover price (metro Chicago)	1876Q3	2004Q2
Sunday cover price (outside Chicago)	1876Q3	2004Q2
One year mail subscription price	1855Q1	1974Q1
	1979Q1	2004Q2
One year carrier delivery price	1855Q1	1905Q4
	1908Q1	1918Q4
	1957Q4	1978Q4
	1988Q3	2004Q2
The New York Times		
Weekday cover price (metro New York City)	1851Q1	2004Q2
Weekday cover price (outside New York City)	1851Q1	2004Q2
Sunday cover price (metro New York City)	1861Q3	2004Q2
Sunday cover price (outside New York City)	1861Q3	2004Q2
One year mail subscription price	1851Q3	2004Q2
The Washington Post		
Weekday cover price (metro Washington, DC)	1878Q1	2004Q2
Weekday cover price (outside Washington, DC)	1878Q1	1993Q4
Sunday cover price (metro Washington, DC)	1880Q3	2004Q2
Sunday cover price (outside Washington, DC)	1880Q3	1993Q4
One year mail subscription price	1878Q1	2004Q2
One year carrier delivery price	1878Q1	2004Q2
The Wall Street Journal		
Weekday cover price (metro New York City)	1889Q4	2004Q2
One year mail subscription price	1889Q3	2002Q3