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ABSTRACT

The present study gathers prices for firewood and estimates the premium paid for dry fuel, relative to green wood, on a monthly basis from 1922 to 1935. This premium conveys consumers' willingness-to-pay for a good available for immediate consumption relative to the same good ready for use after roughly one year. Embedded in this premium are consumers' time preferences. The paper documents time series variation in the dry fuel premium and associated time preference spanning the macroeconomic shocks before, during, and after the Great Depression. The dry fuel premium increased by a factor of four during the recession of 1923 to 1924, and fell by a factor of two following the Great Crash of October 1929. Key factors in determining the premium for dry fuel were variation in wages, inflation, stock market returns, and bond yields. This paper supports the uncertainty hypothesis as an explanation for the precipitous fall in consumption expenditures following the Great Crash of 1929.

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1. Introduction.

This paper brings together two topics that have individually received considerable attention in the economics literature, but have not yet been explored together: the Great Depression and intertemporal choice. New primary data on the relative prices of seasoned and green firewood between the years 1922 and 1935 facilitates this synthesis. These two goods are nearly perfect substitutes in all respects except that dry fuel is ready for current consumption, whereas green wood must cure before use. The relative prices of dry and green fuel reflects the value placed on consumption at different points in time. The differential embodies time preferences. For most types of fuel wood, the time required for proper seasoning is about one year. Thus, the comparison of dry and green fuel prices in any given time period is one between willingness-to-pay (WTP) for consumption in the present relative to WTP for consumption delayed by one year.

The novel approach to gleaning information about rates of time preference from market data over this particular time-period affords a series of unprecedented empirical exercises. First, temporal stability in time preference is tested by estimating premiums for dry fuel on a monthly basis from 1922 to 1935. Second, the paper examines the sensitivity of apparent time preferences to macroeconomic shocks such as the Great Crash of October 1929, the Banking Crises of 1931 and 1932, and the recessions that occurred earlier in the 1920's. Third, the paper tests associations between dry fuel premiums and indicators of financial conditions such as bond yields, returns on equity, and inflation as well as microeconomic measures including local wages, coal prices and costs-of-living. Doing so over such a long time series during a period of macroeconomic and social upheaval is also new. Finally, the paper qualitatively contributes to the literature probing causes and factors that exacerbated the Great Depression by framing the discussion of time preference in the broader "uncertainty hypothesis" developed by Romer (1990).

The present paper exploits a newly constructed dataset of historic energy fuel prices. Price data for firewood are gathered from classified advertisements in the *Portland Oregonian* from 1922 to 1935 (*Oregonian*, various). In all, the data consist of over 14,000 price quotes from 168 months spanning 1922 to 1935. All price quotes from one day in the middle of each month are included in the data. The ads often specify the following fuel attributes: cut, type, and species of wood, quantity for sale, and whether the wood is dry or green. It is the last attribute that the paper uses to elicit time preferences. It is important to note that the present paper cannot control for all possible confounding factors that may affect the relative prices of dry and green fuel[1]. However, typical usage patterns of green fuel (namely, buying the fuel, storing the fuel until it is seasoned, and then consuming it) suggest that rates of time preference are central to the WTP for dry relative to green fuel.

There are three reasons why this empirical setting is a fortuitous context in which to study intertemporal choice. First, fuel wood comprised a significant share of household budgets. Purchases of fuel, electricity, and ice comprised 6.2 percent of household expenditures in the 1930's (BLS, 1941). Second, firewood was the dominant source of energy at this time.

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[1] The claim that the dry fuel premium offers an estimate of consumers' time preference is tempered by consideration of the cost of storage. Clearly purchasing green fuel and stockpiling it for, say, a year until it seasons requires the use of space. Use of scarce space by homeowners comes at some opportunity cost, especially given that the fuel must be kept in a dry location. Because storage comes at cost, the true premium paid for dry fuel is likely *lower* than the price differential gleaned from market data.

In 1935, over 20 percent of energy consumption in the United States was derived from firewood (Schurr et al., 1960). And, in 1940, over 70 percent of households in Oregon relied on wood as the primary heating fuel (U.S. Census, 2000). Clearly, purchases of wood as a home heating and cooking fuel were central to home production and welfare. As such, consumers likely weighed such decisions heavily. That households devoted considerable thought to their fuel wood purchases strengthens the link between the relative prices for dry and green fuel and market participants' time preferences. Third, from the times of early European settlement (and even among Native American communities) until the period under study, in a timber-rich region like the Pacific Northwest, wood was the historically dominant source of energy. Household choice with respect to firewood reflected years of accumulated knowledge. Well-formed habits would have included how much wood to purchase and when to buy it, what type of wood to purchase, how to season firewood, and from whom to procure it. This accumulated knowledge permeated the markets observed in the present analysis. It would reduce uncertainty about the quantity of fuel needed, how to season wood, and pricing dynamics. Mitigating household uncertainty enhances the present analysis' ability to recover time preferences.

In this fortuitous context, the paper conducts three sets of empirical exercises. First, a series of hedonic pricing models estimate the marginal implicit price of dry fuel relative to green fuel. Second, the fitted dry fuel premiums are regressed on a series of controls and indicators for macroeconomic shocks that occurred between 1922 and 1935. Third, to assess conditions on the supply side of the market, convenience yields are estimated, and the effect of timber harvests on convenience yields is explored.

1.1 Hedonic Estimation of Time Preferences.

The hedonic models describe prices of firewood as a function of fuel attributes and the models estimate the implicit price of these attributes (Griliches, 1961; Rosen, 1974). Firewood is comprised of several characteristics including the cut, species, and season status. Provided sufficient variation within the product class (that is, assuming there are many different types of firewood with different bundles of attributes) it is possible to recover the hedonic price function. Then, the partial derivative of the hedonic price function with respect to an attribute provides its marginal implicit price (Rosen, 1974).

A critical assumption undergirding this estimation strategy is that the prices observed and collected in this study reflect equilibrium outcomes in firewood markets. Equilibrium prices in the hedonic framework reflect tangencies between buyers bid curves, suppliers offer curves, and the double envelope between them that is the hedonic price function. As such, the hedonic price function and prices depend on both supply side and demand side characteristics. The empirical analysis that follows explores both supply and demand side conditions, though most of the empirical analysis interpret the relative prices through the lens of consumers' intertemporal choice and time preferences.

Central to the hypothesis tests in this paper is the estimate of the marginal implicit price of dry fuel, expressed relative to green fuel. It is important to ask what the dry premium measures. At one end of the spectrum is the argument that the premium paid for dry fuel relative to green fuel reveals the consumers' pure rate of time preference. At the other is the position that there are too many confounding factors inherent in the hurly burly of market activity to claim elicitation of time preference from the firewood price data. The paper adopts a circumspect stance between these two extremes; while rates of time preference are surely embedded in consumers' WTP for dry fuel, other factors on both the supply and demand side of the market are quite likely at play. This position also prompts the emphasis on variation in the dry fuel premium over the 168 months covered by the analysis rather than the level of the dry fuel premium. Concern about factors confounding the elicitation of consumers' time preferences motivates the exploration of the supply side of the market and the inclusion of other covariates in the hedonic models that are potentially pertinent to individual time preference, consumption decisions and market conditions, more generally.

1.2 Determinants of Estimated Time Preferences.

Data spanning 168 months from 1922 to 1935 uniquely enable tests of how time preferences vary according to both discrete macroeconomic shocks and continuously measured variables. Specifically, dry fuel premia are estimated by month-of-sample. These parameter estimates are regressed on indicators for discrete events and other controls that may plausibly affect the dry fuel premium. In terms of events, the paper tests whether time preferences were affected by the recessions of 1923 – 1924 and 1926 – 1927, the stock market Crash of October 1929, and the Banking Crises of 1931 through March 1933. The paper also examines how time preferences respond to general measures of inflation (such as the Consumer Price Index – CPI), returns on stocks, using monthly returns on the Dow Jones Industrials Index, and yields on 10-year U.S Treasury Bonds. In addition, these descriptive regressions control for monthly wages using data gathered from classified ads in the *Portland Oregonian*.

The regressions described above position the paper to inform the literature on the causes and exacerbating forces of the Great Depression. Prior authors examined the effect of uncertainty over future economic conditions on consumption decisions during the 1920's and 1930's (Bernanke, 1983; Romer, 1990). The argument undergirding Romer's (1990) uncertainty hypothesis leveraged Bernanke's (1983) intuition regarding the irreversibility of certain investments; uncertainty in income may cause consumers to delay purchases, especially of durables. One interpretation of this is a temporary increase in patience. To enable a test of Romer's (1990) uncertainty hypothesis in the context of a household staple, the regressions include both means and standard deviations of income, inflation, cost-of-living, returns on equity, and bond yields. Bernanke (1983) and Romer (1990) argued such uncertainty was pivotal in explaining the sustained downturn that following the Crash of October 1929. The present paper tests this hypothesis.

1.3 Convenience Yields.

To provide a more complete analysis of the firewood markets, this paper estimates convenience yields for producers of firewood. Convenience yields are typically defined as the return to investors of holding inventory of a storable commodity (Pindyck, 1994). This return may stem from the ability of investors to reap profits during shortages (when prices are high) and to avoid costly disruptions to production processes (stock-outs), Pindyck (1994). Convenience yields depend on relative spot and futures prices: the analysis treats green fuel prices as forward fuel prices and dry wood prices as spot prices.

Residuals from the lumber industry primarily supplied the markets for firewood in Portland, Oregon. Whether and precisely when lumber companies decided to sell fuel wood depended on firms' expectations about price movements in both the lumber and firewood markets as well as storage costs. Thus, the return to firms holding inventories relative to bringing wood to market may be an important time-varying factor affecting both fuel prices and the relative prices of dry and green wood. Convenience yields, described in more detail in section 2.3, are estimated on a month-of-sample basis.

1.4 Related Literature.

Frederick, Loewenstein, and O'Donoghue (FLO, 2002) provides the benchmark reference for laboratory and field studies on empirical discount rates. As noted above, the present analysis focuses on how rates of time preference vary over time, rather than their level. As such, this summary of the literature focuses on papers exploring temporal stability in time preferences. Intertemporal stability in time preferences comprises a gap in the otherwise well-trodden ground of studies on discount rates and time preference, (FLO, 2002). Absent entirely from this literature are studies over as long a time series as featured in the present paper. For example, a recent paper examining intertemporal stability in time preference explored just three years of data (Krupa and Stephens, 2013). Importantly, Giglio et al., (2015) estimate long-run discount rates using variation in housing prices driven by differential lengths in leasing structures. A distinguishing feature of the present analysis is the focus on relatively high-frequency variation in estimates of time preference as opposed to long-run discount rates extracted over a long time series.

Extant papers in this space yield conflicting results as to whether individual discount rates respond to changing financial circumstances. For example, Harrison et al., (2002) report that discount rates are not affected by economic outcomes, either at the household level or in terms of respondents' expectations. Similarly, Meier and Sprenger (2015) find that discount rates are not responsive to changes in household income or the provision of unemployment benefits. In contrast, Krupka and Stephens (2013) report that discount rates systematically vary over time. These authors argue that discount rates are positively correlated with measures of inflation and negatively related to household income (Krupka and Stephens, 2013). Giglio et al., (2015) report declining discount rates with the length of cash flow maturities. Any paper focusing on the estimation of individual discount rates in a field setting builds on the work of Hausman (1979), who exploited differences in the revealed preference for purchase prices and capital costs of air conditioners to estimate discount rates.

As noted above, the specific time period over which pricing data was gathered implicitly links this paper to work that probes the causes of, and behavior during, the Great Depression. These include but are not limited to Romer, (1990) who offers the uncertainty hypothesis regarding the stark drop in consumption of durable goods; Bernanke (1983) who posited the intuition for the link between uncertainty and investment at the crux of Romer (1990); Hall and Ferguson (1998) who summarize events and extant arguments as to the roles of the Federal Reserve, consumers, and firms during the Depression; and Friedman (1956) and Friedman and Schwartz (1963) who focus on the role of monetary policy.

1.5 Summary of Results.

Over all months and wood types, the estimated premium for dry fuel is about 13 percent. The dry fuel premiums are sensitive to macroeconomic shocks that occurred between 1922 and 1935. During the recession that occurred from 1923 to 1924, dry fuel premiums rose by a factor of between three and four. Following the stock market Crash of October 1929, dry fuel premiums *fell* by one-half. The analysis finds that uncertainty in economic conditions, as measured by inflation, wages, returns on equity investments and bond yields, are significant determinants of the dry fuel premiums. As such, the findings herein provide empirical support for Romer's uncertainty hypothesis (Romer, 1990). On the supply side of the market, convenience yields differ significantly before and after the Crash. Holding inventories after the Crash produced positive returns, implying greater scarcity, whereas convenience yields were negative prior to the Crash. Convenience yields are negatively associated with local timber harvests because such harvests produce copious amounts of residual biomass which comprises fuel wood.

The remainder of the paper is structured as follows. Section 2 focuses on the data and empirical methodology. Section 3 presents the empirical results and section 4 concludes.

2. Data and Methods.

The primary data used in the empirical econometric analyses consist of price quotes in classified ads for fuelwood in Portland, Oregon, USA. The data were gathered from the *Portland Oregonian* online archives over the period 1922 through 1935 (*Oregonian,* various). An example of classified ads that contain price quotes is found in figure A1. The data consist of over 14,000 price quotes. Many of the advertisements list attributes of the fuel including cut, type, and species of wood, amount of wood for sale, and the extent to which the fuel is raw or seasoned. The data are monthly, with ads sampled from the 15th day of each month from 1922 through 1935. (If the images are illegible for the 15th, data are gathered from the nearest day with suitable imagery.) All advertisements from each sampled day are included in the estimation dataset – provided the images on the archives were legible. Figure A2 in the appendix reports the total number of price quotes across the 14 years. The figure indicates that the number of price quotes grew from about 50 per day in 1922 up to over 200 per day during the Great Depression. After 1932, the number of quotes then fell back to between 50 and 100 per day.

Table 1 displays the summary statistics for the price data. While there are many types of fuel wood contained in the sample of advertisements, table 1 reports summaries for those that comprise 1 percent of the sample or more[2]. These types of fuel collectively account for the majority of all price quotes in the sample. The largest share of price quotes were for slab wood: a residual from lumber production (see figure A3 in the appendix). The average price per cord of slab was about $5. Nearly 30 percent of the advertisements for this wood type were for dry (seasoned) fuel, another 18 percent were for partially seasoned fuel, and 3 percent of ads were for green, or raw, fuel. The remaining 50 percent of price quotes did not specify the fuel's seasoning status. Another 8 percent of price quotes were for old-growth fuel. The price of old growth fuel averaged about $5.9. Approximately one-quarter of prices for old growth specify that the fuel was seasoned. Much smaller percentages of ads denote either partially seasoned fuel or raw fuel. Table 1 indicates that about 8 percent of the price quotes were in ads that did not designate the type of wood. Despite not reporting type, about half of these ads did specify that the fuel was seasoned,

[2] The large number of different wood types lends credence to the claim that an hedonic model applied to the data identifies the hedonic price function and the marginal implicit prices of fuel attributes.

approximately 4 percent were for partially seasoned wood, and 3 percent were for raw fuel. Ads for block wood contributed another 7 percent of observations. Block wood is also a residual from sawmills. This wood type was about 20 percent more expensive than slab. Just under 20 percent of the price quotes were for dry fuel, 11 percent were for partially seasoned wood, and 3 percent were for raw fuel. Fuel specified as fir comprised another 6 percent of ads. Average prices for fir were about $7 per cord, the second highest average price of all types in table 1. About one-quarter of prices for fir were for seasoned fuel, and between 4 and 5 percent were for partially dry and raw fuel.

Table 1 contains several additional types of wood that reveal that fuel was often derived from other uses of wood. For example, ads for "mill" and "planer" fuel indicate by-products of the lumber industry. (Planer ends are the unusable last few inches of boards that have been planed down to specific dimensions for use in building or woodworking.) Ads for "wreckage" often specify that the fuel came from demolished structures. Other wood types refer to specific uses, such as "furnace" or "range" fuels. The only hardwood species that contributes more than 1 percent of observations was oak. This fuel, presumably due to its high energy content, had the highest average price at just over $8 per cord. For all types with the exception of wreckage wood, the majority of advertisements did not specify whether the fuel was raw or seasoned. Those ads that did report seasoning status most commonly reported dry fuel. Fuel advertised as green was the least common of the categories of seasoning status.

Figure 1 presents the ratios of concurrent prices for dry to green fuel. The left panel includes all wood types. The right panel focuses on slab wood – the fuel type for which there were the greatest number of price quotes. For all wood types, dry fuel sold for about 25 percent more than green fuel, on a concurrent basis. For a small number of months (mostly in the 1920's) green fuel prices exceeded those of dry. However, it is important to note that, by including all price quotes, the left-hand panel of figure 1 may compare green and dry prices for very different products: oak and fir, for example. As such, the right panel of figure 1 focuses on the dry fuel premium for just slab wood. One observes fewer cases in which green fuel prices exceeded those of dry fuel. The relative prices rise through the 1920's before falling during the early 1930's. Prices reflect equilibrium outcomes in fuel markets. This figure reveals that consumers were willing to pay a premium for dry fuel available for current consumption.

Figure A4 presents monthly average firewood prices ($1982) for both green and dry fuel. The figure provides evidence of a fundamental change in the Portland firewood markets after the Crash. First, this figure clearly shows the dry fuel premium both before the Crash and after the banking crises. However, between 1931 and 1933, the dry fuel premium breaks down. Second, the price level for both types of firewood rises, and it remains higher until the end of the sample.

Table 2 reports summary price statistics for the different seasoning grades of fuel for all wood types, slab, old-growth, and all other wood types, conditional on there being a fuel type specified in the price quote. This table provides further evidence of the premium for dry fuel embodied in market prices. Across all wood types, dry fuel averaged about $5.9 per cord, whereas green fuel averaged just $5.3. This suggests a dry fuel premium relative to green fuel of about 10 percent. Dry fuel was also more expensive than either partially dry fuel or that without seasoned status denoted in the advertisement. Neither partially seasoned fuel nor prices without information about seasoning status were priced differently than green fuel.

The average price for dry slab was $5.7 per cord, which is about 22 percent higher than the average price for green slab wood. Dry fuel also was about 23 percent more expensive than partially seasoned fuel. The price for dry slab was 20 percent higher than prices for slab in ads that did not specify whether the fuel was seasoned or green. The mean price of raw slab wood is not statistically different from either partially seasoned wood or ads selling wood without seasoning information.

The premium for dry old growth wood was considerably smaller in percentage terms. The average price of dry old growth wood was just 8 percent higher than for green old growth wood. The price of dry old growth wood was 3 percent smaller than fuel without reported seasoning status. Counterintuitively, dry old growth fuel was 6 percent *less expensive* than partially dry fuel, though this difference is not statistically significant. This may be due to the timing of when the ads for partially dry old growth wood were posted – during times of relatively higher prices, generally, for fuel wood. The right-hand column of table 2 suggests that consumers were willing-to-pay a 7 percent premium for dry fuel for all types of fuel, when the type of fuel is specified. The average price of dry wood was about 7 percent higher than green wood, excluding all price quotes when there is no wood type information in the advertisement. While just presenting price summaries, table 2 provides redolent evidence of consumers' WTP for dry fuel that provides immediate gratification, relative to green fuel that requires seasoning before use. Thus, these average prices are suggestive of consumer's time preferences.

Additional data gathered and used in the analysis include the monthly Consumer Price Index (CPI), (McCusker, 1992), and monthly values for the Dow Jones Industrial Index (Measuring Worth). Monthly yields on U.S. government bonds are provided by the U.S. Federal Reserve (Federal Reserve, 1943). Cost-of-living indices (COLI) for Portland, Oregon are provided by the Bureau of Labor Statistics (BLS, 1941). Included in the analysis are COLI indices for food, rent, and clothing. Hourly wages for occupations in the trades were also gathered from classified advertisements in the *Portland Oregonian* (*Oregonian*, various). Weather data, specifically temperature and precipitation anomalies, are provided by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), (NOAA, 2018). These are cumulative monthly temperature and precipitation anomalies. These measures are the sum of differences between monthly temperature (precipitation) and average temperatures (precipitation) for each month of year. The sum is calculated beginning in June of each year and it runs through May of the following year. Data on timber harvests in the state of Oregon are provided by the Oregon State Department of Forestry (2005).

Monthly retail prices of anthracite and bituminous coal are provided by the Federal Reserve Economic Data (FRED, 2018a; 2018b). Figure A5 shows monthly average coal prices plotted with firewood prices from 1922 to 1935. Both coal series are expressed in $/U.S. short ton. Anthracite prices were higher than bituminous coal prices, presumably because of its higher heat content. Both the bituminous coal and firewood series exhibit strong seasonality: the anthracite series less so. While firewood prices rose immediately after the Great Crash, neither coal series did so. Tables A3 and A4 in the appendix reports results from models that regress firewood prices on coal prices characterize the relationships among these price series.

2.1 Estimation of Time Preferences.

The primary regression used to elicit time preference is a hedonic price model that describes fuel prices as a function of attributes of the fuel. The specification of the hedonic models begins with model (1) which includes seasonal fixed effects, denoted S_j, a time trend, $f(t)$, year (γ_t) and fuel type (T_i) fixed effects, and controls for seasoned status of the fuel ($\varphi_{i,t}^{s}$). The default model also controls for the CPI, monthly yields for U.S. Treasury bonds, the Dow Jones Industrials Index, monthly coal prices, and hourly wages (expressed as monthly averages), and cost-of-living indices for rent, food, and clothing (BLS, 1941) for Portland, Oregon. These covariates are subsumed into ($\mu_t F_t$), in (1). Also included is the quantity of fuel for sale in each ad ($Q_{i,t}$). Finally, the temperature (A_t) and precipitation anomaly (Pre_t) are encompassed by the models.

$$ln(P_{i,t}) = \beta_0 + \beta_q Q_{i,t} + \sum_{i=1}^{N} \beta_i T_i + \sum_{s=1}^{4} \alpha_s \varphi_{i,t}^{s} + f(t) + \gamma_t \ldots$$

$$+ \sum_{j=1}^{4} \theta_j S_j + \mu_t F_t + \omega_1 A_t + \omega_2 Pre_t + \varepsilon_{i,t} \qquad (1)$$

The specification in (2) augments that in (1) with interactions between the linear and quadratic functional forms fit to the month-of-year controls and temperature and precipitation. Rather than re-writing (1), (2) simply shows the additional weather terms.

$$\omega_1 A_t + \omega_2 Pre_t + \omega_3 A_t M_t + \omega_4 Pre_t M_t + \omega_5 A_t M_t^2 + \omega_6 Pre_t M_t^2 \qquad (2)$$

Finally, the expression in (2) is enhanced by the addition of interaction terms between the temperature anomaly and season status of the fuel. Note that the summation operators below reflect the four different season status indicators.

$$\sum_{s=1}^{4} \alpha_s \varphi_{i,t}^{s} + \sum_{s=1}^{4} \pi_s \varphi_{i,t}^{s} A_t \qquad (3)$$

The parameter estimates of interest in models (1) and (2) are the $\{\alpha_s\}$ terms, the marginal implicit prices of season status. In (3), the combination of the $\{\alpha_s\}$ terms together with the $\{\pi_s\}$ coefficients are of interest since these parameters jointly reflect the implicit price of seasoned wood. To facilitate interpretation of the parameter estimate for dry fuel as a *rate* of time preference, the indicator for green (raw, unseasoned) fuel is the excluded case among the four seasoned classes: dry, partially-dry, green, and no seasoned data. Given the natural log form of price as the dependent variable, the parameter estimate corresponding to the indicator for dry, seasoned fuel reveals the equilibrium percentage premium for dry fuel. One interpretation is that the dry fuel coefficients reflect consumers' time preference.

2.1.1. Time Preferences and the Timing of Fuel Procurement.

Because hedonic models reveal equilibrium conditions, it is difficult to cleanly identify demand-side versus supply-side forces at play in the determination of the marginal implicit prices. Therefore, it is useful to attempt to invoke complementary approaches to the elicitation of time preferences. One such strategy proposed here leverages the weather data to obtain a sense of the timing or flow of fuel purchases throughout the year.

This paper contends that a typical wood consumption pattern for households features a lump sum purchase of fuel well in advance of the projected time of use. Time preferences are embedded in such behavior; pre-season lump sum fuel procurement balances the risk of running out of fuel against the opportunity cost of allocating funds that could be put to some other productive use. Larger quantities of fuel obtained in advance of anticipated use suggest a greater willingness to trade off current consumption against future liquidity risk, ceteris peribus.

Consumers' expectations regarding fuel use for the coming season and liquidity risk at season's end are likely to depend on cumulative temperature anomalies rather than the month-of-sample temperature levels. Presumably, consumers making a lump sum acquisition of fuel prior to use procure an amount of fuel appropriate for expected conditions. The hypothesis is that households' expectations are conditioned on past experience and on information about whether the coming season will be abnormally warm or cold. Such updating likely depends on weather between the end of the previous heating season and the time of lump sum purchases. Intuitively, liquidity risk at season's end depends on whether the heating season manifest as especially warm or cold, a phenomenon captured by the cumulative temperature anomaly. To explore whether market participants make lump sum purchases, the analysis tests whether prices are especially sensitive to temperature during these two times of the year.

2.2 Estimation of Temporal Stability in Time Preferences.

As stated above, equilibrium prices reflect supply and demand-side forces. Causally eliciting changes in either demand or supply over time in this context is difficult. The present section focuses on estimation of changes in demand side forces. Section 2.3 explores supply-side factors.

Few empirical contexts in the literature facilitate testing for time series heterogeneity in rates of time preference. The richness of the data employed herein enables tests of the stability of time preferences over 14 years and 168 months, a scope of research not yet conducted in the field or experimental literature. Further, probing whether there is time series variation in time preferences is motivated by the fact that the sample period, 1922 – 1935, spans several macroeconomic shocks: the stock market Crash of October 1929, the banking panics of 1931 through 1933, and the recessions in 1923 – 1924 and 1926 – 1927.

To this end, in addition to the estimation of the hedonic models across the entire sample period, a series of regressions fit model (2) to subsamples of the data to test whether and how the parameter estimates of interest vary across time. This is executed in two ways. First, dry fuel premiums are estimated by month-of-sample. The analysis conducts t-tests of the fitted dry fuel premiums in "treatment" and "control" periods. For example, the full sample (168 months' worth) of estimated dry fuel premiums are decomposed into two groups: the months before (control) and after (treatment) the stock market Crash of October 1929. T-tests are performed on the dry fuel coefficients to ascertain whether the dry fuel premiums fitted to data before the Crash differ from those fitted to data afterwards. This approach is repeated for each of the macroeconomic shocks listed above.

The month-of-sample estimated dry fuel premiums are then used in a regression-based test of how macroeconomic covariates affect time preferences. Model (4) frames these tests, by regressing the estimated dry fuel premiums, by month-of-sample, on a collection of covariates including: a time trend ($g(t)$), month-of-year fixed effects (M_t), wages (W_t) in

Portland, Oregon, the CPI, U.S. Treasury yields (*Bond*), the Dow Jones Industrials Index (*Dow*).

$$\hat{\alpha}_{dry,t} = \beta_0 + \theta_0 M_t + g(t) + W_t + \theta_0 CPI_t + \theta_1 Bond_t + \theta_2 Dow_t + \epsilon_t \quad (4)$$

All covariates are included in concurrent and lagged values up to six-months. Both the means and the standard deviations (over concurrent and lagged values) are included.

The second strategy used to test for temporal stability in time preference leverages the temperature-price relationships described in section 2.1. Empirical evidence of bulk purchases is found in heightened reactivity of prices to temperature during the late fall and late spring months. To test for temporal heterogeneity in time preferences, the analysis calculates the partial effect of temperature anomalies on prices by month-of-year before and after the Crash. Differences in the responsiveness of prices to temperature throughout the year may provide evidence of changes in intertemporal choice induced by the Crash.

2.3 Supply Forces: Estimating Convenience Yields.

The literature on commodity prices identifies the return to investors of holding inventory of a commodity as a convenience yield (Pindyck, 1994). This return may stem from the ability of investors to reap profits during shortages (when prices are high) and to avoid costly disruptions to production processes (stock-outs), (Pindyck, 1994). Convenience yields are relevant in the present context: firewood is a storable commodity.

Consider that residuals from the lumber industry primarily supplied the markets for firewood in Portland, Oregon; slab wood comprises the most common wood type for sale from 1922 to 1935, and slab is just wood left over from the conversion of saw logs into dimensional lumber. Whether and when lumber companies decide to sell fuel wood depended on firms' expectations about price movements in both the lumber and firewood markets as well as storage costs. Thus, the return to firms holding inventories relative to bringing wood to market may be an important time-varying factor affecting both fuel prices and the relative prices of dry and green wood.

To frame the analysis of convenience yields, note that the price of a futures contract of maturity (T), for a commodity ($F_{f,t}$) is defined as a function of spot prices ($S_{f,t}$), the cost of storage (K_t), convenience yield (c_t), and the risk-free interest rate as shown in (5).

$$F_{f,t} = S_{f,t}e^{(r-K_t-c_t)T} \qquad (5)$$

Rearranging (5), and assuming storage costs are negligible produces an expression for the convenience yield at time (t):

$$c_t = r - \frac{1}{T} ln\left(\frac{F_{f,t}}{S_{f,t}}\right) \qquad (6)$$

While there were not (to the author's knowledge) futures markets for firewood in Portland during the 1920's and 1930's, the green fuel price in period (t) is a suitable proxy for the *forward* price; green fuel is the same commodity as dry fuel, just separated by the time needed to season wood – about one year. The utility in estimating the convenience yields lies primarily in determining the periods of time when suppliers would have earned positive returns, that is, when convenience yields were positive (backwardation), and when convenience yields were negative (contango).

These conditions reflect scarcity and abundance of the commodity. When inventories are high, expected levels of scarcity in the near term are low, relative to some future period. In this case, the convenience yield is low: $r > c_t$. Conversely, when present inventories of the commodity are low, scarcity is relatively high. This suggests $S_{f,t} > F_{f,t}$ and that c_t may exceed r.

Because the 1922 to 1935 period featured considerable variation in macroeconomic conditions, it is useful to test for temporal stability in convenience yields. The framework for convenience yields is essentially the same as that used to test for temporal heterogeneity in consumer time preferences. The paper conducts t-tests of the estimated convenience yields in the "treatment" and "control" periods defined above. These tests are also intended to assess how supply side forces influenced fuel prices, and specifically the relative prices of dry and green fuel.

To concretize the dynamics between inventories, convenience yields, and fuel prices, the paper explores associations between estimated convenience yields and timber harvests in Oregon. The analysis regresses the estimated convenience yields on county level timber harvests and a series of temporal fixed effects.

Expression (7) depicts the regression specification that explores the determinants of convenience yields. The model includes wood type fixed effects, (μ_i), controls for local timber harvests (defined as west of the Cascade Mountains), (H_t^L), non-local timber harvests, (defined as east of the Cascade Mountains), (H_t^N), and season, (S_j), and year (γ_t)

fixed effects[3]. The model also includes interactions between the season and harvest controls.

$$c_{i,t} = \beta_0 + \beta_1 H_t^L + \beta_2 H_t^N + \sum_{j=1}^{4} \beta_j S_j + \sum_{j=1}^{4} \theta_j H_t^L S_j + \sum_{j=1}^{4} \alpha_j H_t^N S_j + \mu_i + \gamma_t + \varepsilon_{i,t} \quad (7)$$

3. Empirical Results.

Table 3 presents the estimated dry fuel premiums using prices for four categories of wood: all wood types, all types of wood fuel *conditional on some type being reported,* slab, and old growth. Green fuel is the excluded case. The parameter estimate for dry fuel, inclusive of all wood types, across all 14 years of data is 0.127 ($p < 0.01$). This result suggests that consumers' are willing-to-pay about 13 percent more for fuel, on a btu-adjusted basis, that is marketed as being dry and ready for immediate use relative to raw fuel. While there may be unobservable confounding factors that affect the relative price of dry-to-green fuel, given typical usage patterns, (green fuel is usually bought and held until it is seasoned) consumers' time preferences likely play an important role in driving this premium for dry fuel. Importantly, this estimate of the dry fuel premium controls for the monthly temperature and precipitation anomalies and the interaction between the anomalies and month-of-year. This model also includes wages, bituminous coal prices, the current CPI, lagged measures of inflation, COLIs for Portland and alternative uses of funds (the Dow Jones and bond yields). As noted in section 2, the models in table 3 also contain season,

[3] The data for timber harvest in Oregon is provided by: Oregon Department of Forestry (2005).

month, and year fixed effects and a quadratic time trend. The model in the first column includes wood type fixed effects.

The first column of table 3 also reports that prices for partially seasoned fuel are not distinguishable from green fuel. This could stem from consumers' uncertainty over actually how seasoned the fuel is when marketed as partially dry. Fuel without any information about seasoning sells at a small (under 5 percent) premium over green fuel.

The second column of table 3 restricts the estimation sample to advertisements that report some type of fuel. With this subsample, the coefficient on dry fuel falls to 0.110 ($p < 0.01$). Partially seasoned fuel sells at a modest discount (3 percent) with respect to green fuel. Prices for fuel without information on its seasoning status are not distinguishable from green fuel. The coefficient for dry fuel, restricting the sample to prices for slab wood, is 0.170 ($p < 0.01$). The prices for partially seasoned fuel are indistinguishable from prices for green fuel. Prices for slab wood without any seasoning information were about 2 percent higher than green fuel ($p < 0.10$).

When the sample is restricted only to ads for old-growth fuel, table 3 reports that consumers are willing to pay a 12.2 percent premium for dry fuel ($p < 0.01$). In contrast to slab wood, prices for partially seasoned old-growth fuel are significantly higher than green fuel. And, further, prices for old-growth fuel reported in advertisements without seasoning information are also higher than for green fuel.

3.1 Price Sensitivity to Temperature and Time Preference.

Table 4 explores different specifications with a focus on how the weather data are modeled. Note that column (3) corresponds to the default specification reported in table 3. While table 4 controls for bituminous coal prices, tables A5 and A6 in the appendix explores different specifications of coal prices, and the inclusion of anthracite rather than bituminous coal prices, respectively.

Each specification in table 4 contains the full array of non-weather controls. The focus here is on treatment of weather covariates for two reasons. First, temperature and precipitation are critical determinants of the demand for heating fuel. Second, the paper argues that lump sum purchases of fuel provide information relevant to consumers' time preferences and that a typical consumption pattern for households involved a bulk procurement of green fuel well in advance of the intended time of use. If many market participants behaved in this way, fuel prices should be most sensitive to temperature prior to the heating season when making large purchases and late in the heating season when household stocks are dwindling and liquidity risk is high. This conjecture is tested below by examining the interactions between temperature anomalies and months of year controls.

In column (1), no weather covariates are included. In this naïve specification, the premium for dry fuel is 12.5 percent ($p < 0.01$). In column (2), temperature is inversely associated with fuel prices ($p < 0.01$). Positive anomalies suppress prices; the equilibrium prices for heating fuel are lower when the temperature is abnormally warmer, and vice versa. The coefficient for precipitation is positive ($p < 0.05$). The dry fuel premium remains effectively unchanged (0.128, $p < 0.01$), from column (1), as does the small premium on fuel without seasoning information (0.044, $p < 0.01$).

Column (3) includes the temperature and precipitation anomalies and interactions between each of these controls with month of year, which enters in both linear and quadratic forms. The temperature anomaly-by-month interaction is significant in both the linear (negative, $p < 0.01$) and quadratic (positive, $p < 0.05$) terms. Figure A6 facilitates interpretation of the partial effects of temperature. The left panel of figure A6 plots the fitted quadratic interaction between temperature and month of year. This shows that the effect of temperature on price maximizes (in absolute value) in late spring and summer; a one-unit increase in the cumulative temperature anomaly in May reduces price by about 0.3 percent. Intuitively, higher than typical temperatures reduce fuel prices, presumably through an inward shift in demand for heat. The left-hand side of figure A6 suggests fuel prices are least responsive to temperature anomalies during the months of January, February, and March. This despite the fact that these are typically among the coldest months of the year with high heating demand.

The right-hand panel of figure A6 evaluates the fitted quadratic function at the average temperature anomaly by month of sample across the 14 years of data included in the analysis. This plot indicates that temperature has the largest effect on the price of fuel at two times of the year: during April and May when liquidity risk is high and in the late fall prior to the start of the heating season.

One interpretation of this dual sensitivity of prices to temperature is as evidence of consumers making bulk purchases of firewood prior to the heating season. Figure A6 shows that during years with lower than average temperatures from June through November, prices in the late fall tend to be high[4]. Market participants appear to have reacted to temperature anomalies during the summer and fall as they stockpiled fuel in the fall for anticipated use. Prices are also reactive to temperature in late spring. For years with negative temperature anomalies throughout the winter, consumers' fuel stocks would dwindle earlier. Facing a binding fuel constraint, consumers' only option was to dip into the spot market to replenish fuel supplies. If many consumers behaved in this manner, prices would respond as shown in figure A6. Had consumers participated in spot markets all winter (not stockpiling fuel), one would expect a more homogenous degree of sensitivity of prices to temperatures, by month. The right-hand side of figure A6 provides evidence supporting the hypothesis that households make lump sum purchases of firewood.

In column (3) of table 4, the precipitation interaction with the linear month-of-year term is positive and significant ($p < 0.01$). The interaction with the quadratic term is significant and negative ($p < 0.05$). To facilitate interpretation, figure A7 in the appendix displays the fitted coefficients for the precipitation controls. The left-panel displays the fitted quadratic; it shows that the cumulative precipitation anomaly has the greatest effect on fuel prices in late spring and summer. As with temperature, this plot suggests prices are most sensitive to weather conditions late in the heating season. When evaluated at the average precipitation anomalies by month-of-year, the right-hand panel shows that prices are most sensitive to the cumulative precipitation anomaly in late spring. The figure reveals that low-moisture heating seasons suppress prices. One reason for this relationship is that drier

[4] Since the fitted quadratic is negative, negative anomalies produce the positive price effect observed in November.

winters may allow for timber harvests through the winter, whereas wetter winters with greater snowfall likely limits access to timberlands.

Column (4) of table 4 adds interactions among the fuel season status controls and the temperature anomaly. The coefficients on temperature and precipitation and interactions with month-of-year remain basically unchanged, though the quadratic term on the temperature-by-month interaction is no longer significant. Intuitively, warmer weather realizations suppress the differential between seasoned fuel and green fuel (the excluded case). For warmer months and heating seasons, consumers are willing to pay a smaller premium for dry fuel ($p < 0.10$). Temperature anomalies do not affect the relative prices of partially dry fuel. However, temperature does attenuate the price differential between green fuel and fuel without seasoning information ($p < 0.01$). These interaction terms reveal that market participants are willing to pay a smaller premium for firewood relative to green wood when it is abnormally warm. The coefficient on the direct control for dry fuel exhibits a small reduction from 0.127 in column (3) to 0.120 (se = 0.013; $p < 0.01$). As such, even when accounting for the differential effect of temperature through season status of the fuel, the premium paid for dry fuel remains between 12 and 13 percent.

3.2 Annual Variation in Time Preferences.

Figure 3 shows the estimated dry fuel premiums, by year, for all wood types (left panel) and for slab wood (right panel) from 1922 to 1935. To construct the figures, observations are restricted to a particular year, and the dry fuel premium is computed using the specification in column (3) of table 4. Estimated dry fuel premiums for all wood types rose from a statistical zero in 1922 to over 20 percent in 1924. From 1925 through 1928, the dry fuel premiums fell to about 10 percent before rising in 1929 to about 20 percent. In 1930, following the stock market Crash, and with the onset of deflation, the dry fuel premium fell to zero. Then, the estimated premiums climbed back to 10 percent before falling to zero again in 1935. Of particular note is the collapse in the premium paid for dry fuel between 1929 and 1930. The right hand side of figure 3 presents the dry fuel premium for slab wood. It suggests that consumers increasingly valued the immediate gratification derived from purchasing dry fuel from 1922 through 1929. The estimated premium increased (albeit non-monotonically) from about 10 percent in 1922 to 25 percent in 1929. Then, after 1929, the estimated premium dropped to under 10 percent from 1930 to 1935.

Although the estimated premiums are not direct estimates of time preference, consumers' rates of time preference are likely to be a primary driver of the WTP for fuel available for immediate consumption, relative to fuel that requires one year of seasoning. As such, figure 3 provides suggestive evidence that consumers became *more patient* from 1929 to 1930. That is, the extra value to market participants of having fuel for present consumption, relative to fuel for future consumption effectively went away between 1929 and 1930. The paper explores factors that may help to explain these changes in section 3.3.

3.3 Responsiveness of dry fuel premiums to macroeconomic shocks.

Figure 4 plots the month-of-sample dry fuel premiums derived from pricing data for all wood types. (These estimates derive from the specification in column (3) of table 4.) The vertical lines demarcate both recessions during the 1920's, the stock market Crash of 1929, and the banking crises in the early 1930's. During the first recession of 1923-1924, dry fuel premiums spiked to over 60 percent. In the second recession, the estimated dry fuel premiums gyrated from below zero to over 20 percent. Then, following the Crash both the level and the month-to-month variation in the dry fuel premiums declined.

Table 5 employs the month-of-sample dry fuel premiums to test whether and how the relative prices respond to the severe macroeconomic shocks that occurred during the 1922 to 1935 period. The first and second rows of table 5 decompose the results according to the first recession (May, 1923 to June, 1924), and the second recession (October, 1926 to November, 1927). The estimated dry fuel premiums during the 1923-1924 downturn were nearly four-times greater ($p < 0.01$) than dry fuel premiums estimated in months *not during this recession.* The same comparison for the second recession reveals no statistically significant difference in dry fuel premiums. Both of the recessions explored here are, ex post, considered to have been mild recessions (Zarnowitz, 1992).

Table 5 also splits the sample into the months prior to and after the stock market Crash of October 1929. The dry fuel premiums estimated using pricing data from before the Crash average 11.8 percent. For the months after the Crash, consumers' impatience falls; the dry fuel premium is estimated to be just about 5 percent during the months after the Crash ($p < 0.01$).

The final test in table 5 focuses on dry fuel premiums for months during the Banking Crises. The estimated dry fuel premiums are *lower* during the Banking Crises months than for other months. This contrasts with the months during both recessions in which the dry fuel premiums were *higher* than for non-recessionary months. However, the t-test fails to reject the null hypothesis of equivalent means for months during the Banking Crises and all other months.

If, the equilibrium prices for green and dry fuel reflect time preferences, both the 1923 to 1924 recession and the stock market Crash appear to have affected consumers' patterns of intertemporal choice. However, the manner in which these disruptive events did so differs. The paper now turns to the literature characterizing key events and policy changes during the 1920's and 1930's to delve more deeply into potential causes, or explanations, for the results in table 5: in particular, the apparently radical change in time preferences during the recession of 1923-1924 and after the Crash.

One candidate explanation for the jump in rates of time preference during the recession of 1923-1924 is the hypothesized inversely oriented relationship between personal income and impatience. This recession, although mild, was an adverse shock to income. Hence, consumers responded by emphasizing consumption in the present over considerations of future conditions. Many economists dating back to Fisher (1930) have argued this position. More recently, Lawrance (1991) finds rates of time preference that are significantly lower for higher income households than for households toward the bottom of the income distribution. Extrapolating Lawrance's (1991) result from cross-sectional differences in income to intertemporal income shocks suggests periods of lower income would yield higher discount rates.

The reduction in the dry fuel premium after the Crash revealed in table 5 is more difficult to parse. Hall and Ferguson (1998) note that following the Crash household consumption expenditures fell because of the decline in household wealth. This fact, in and of itself, would not explain a drop in individual discount rates. Temin (1976) and Romer (1990) argue that uncertainty in future economic conditions[5] fueled this reduction. These authors, particularly Romer (1990), press this case by noting that consumption of durable goods decreased by a much larger percentage share than perishables. And, Hall and Ferguson (1998) contend that purchases of durables, by nature of the goods, can be delayed. Connecting this line of argument to the present context: if consumers' expectations about future economic conditions changed due to perceptions of elevated uncertainty, and their response was to reduce consumption of *those goods the acquisition of which could be delayed*, this could show up as heightened demand for less expensive green fuel because this essentially delays consumption of dry wood.

The results from table 5 herein certainly support this position. The Great Crash induced a reduction in the extra amount consumers were willing-to-pay for fuel immediately available relative to that which would become available after one year. The literature cited above provides a possible explanation for this behavior. Consumers feared what the future held. They elected to purchase less expensive green fuel and allowed it to season. By stockpiling fuel that required seasoning, their measureable patience increased.

The stunning rate of deflation evident from 1929 through 1930 is also likely to have played an important role in explaining the results in table 5. Hall and Ferguson (1998) propose mechanisms that link deflation to reduced consumer expenditure: the rising burden of household debt, the transfer of income (or wealth) from relatively poor borrowers to relative rich lenders, and consumers' expectation about continued deflation. It is the third

[5] Temin (1976) and Romer (1990) employed volatility in stock prices as a measure of uncertainty in future economic conditions, especially income.

channel that is most relevant to the results in table 5. If consumers' expected the price level to continue to fall, they are more likely to hoard cash so that they can consume later when the cash that they currently hold increases in value. In the present context, purchasing green fuel facilitates saving the extra cash that would be needed to consume dry fuel. That saved increment of money appreciates in a deflationary environment. Many consumers adopting this position would diminish the measurable premium for dry fuel, as observed in table 5.

3.4 Price Sensitivity to Temperature and Macroeconomic Events.

The discussion above posits a change in time preference induced by the macroeconomic shocks of the late 1920's. This section probes whether macroeconomic events affected the sensitivity of fuel prices to temperature and if such changes provide information related to time preferences. Figure 5 plots the sensitivity of prices to temperature, by month-of-year. What distinguishes figure 5 from figure A6 is that figure 5 decomposes the sensitivities for dry fuel and green fuel. The left-hand panel limits the estimation sample to all months prior to the Great Crash. The right side includes months of the sample after the Great Crash.

Both panels suggest that dry fuel prices were most sensitive to temperature shocks during the late spring, when liquidity risk was high. Before the Crash, temperatures were colder than average during the winter and spring months (see Figure A8). Intuitively, this caused dry fuel prices to increase; when faced with a liquidity constraint consumers participated in the spot market. After the Crash, temperatures were warmer. The unusual warmth meant consumers had ample fuel throughout the season, which negatively affected dry fuel prices.

That dry fuel prices were most reactive to temperature in April and May further bolsters the case that households made bulk fuel purchases prior to the heating season. Because temperatures deviated from normal, actual fuel consumption over the season differed from expected levels. And, the means by which households compensated for their mistakes in prior procurement was reflected in the spot market. Before and after the Crash spot market prices reveal outward and inward shifts in demand for heat, respectively, as temperatures were colder (before) and warmer (after) than average.

Green fuel prices also exhibited sensitivity to temperature during the late spring months before the Crash. However, the colder than average months induced a reduction in green fuel prices. This may suggest that cash consumers would have used to purchase green fuel for future use was instead allocated to seasoned wood for immediate consumption. Green fuel prices were also quite sensitive to temperature in December before the Crash; colder weather induced greater demand for green fuel in months when consumers stockpiled fuel.

The right panel of figure 5 shows that the reactivity of green fuel prices to temperature changed markedly after the Crash. The partial effect of temperature was ten-times larger after the Crash (than before) during the month of September, five-times larger in October and November, two-times larger in December, and orders of magnitude greater in January. The responsiveness of raw fuel prices to temperature then fell from February through June despite a rising temperature anomaly.

Why would market participants behave in such a manner? Recall that temperatures during the winter months after the Crash were warmer than average (see Figure A8). With less liquidity risk, consumers may have purchased green fuel during the months of the year when they normally would purchase seasoned fuel to manage liquidity risk. Doing so does not necessarily mean that households consumed unseasoned fuel to produce heat. Rather, households may have bought more green fuel in advance of the intended time of consumption. If demanders were substituting to an inferior good (raw fuel) because of an adverse income shock, with the intent of consuming the fuel *while still unseasoned*, raw fuel prices would exhibit greater sensitivity in late spring as liquidity risk rises. Instead, figure 5 reveals declining sensitivity of unseasoned fuel to temperatures in the late spring. Further, if the market for dry fuel were dormant due to a wholesale substitution to green fuel, dry fuel prices would not respond to temperatures. This was not the case. The right hand side of figure 5 suggests consumers held a surplus of dry fuel after the Crash; dry fuel prices fell due to warm weather in the winter and spring months. The continued reactivity of dry fuel prices to temperature in late spring and the heightened responsiveness of green fuel prices after the Crash supports the hypothesis that consumers changed the relative amounts of dry and green fuel procured but that short-run demand was met with dry fuel. This speaks to a change in timing and the mix of fuel purchased. Tilting the mix towards raw fuel comports with a greater willingness to delay consumption. The reduced premium paid for dry fuel after the Crash reported in table 5 also fits with this interpretation. It appears that market participants became more willing delay consumption by purchasing unseasoned fuel after the Crash.

3.5 Determinants of the dry fuel premium.

In order to test how the dry fuel premiums were affected by the various economic forces at work during the sample period, table 6 presents the results of the regression models that seek to explain the month-of-sample dry fuel premiums as a function of wage income, returns on investment in stocks and bonds, and inflation.

Table 6 displays the results from five different models. In each, the dependent variable is the estimated month-of-sample dry fuel premiums used in table 5. In addition to the variables listed above, the models control for various combinations of time trends and month-of-year fixed effects, an indicator for the stock market Crash of October 1929, the two recessions, and the banking crises. For each continuous regressor, the models include both the mean and the standard deviation over lags zero (current) through six months.

Model (1) includes only hourly nominal wages[6] (averaged across occupations, by month-of-sample) in the regression. Mean wages are not significantly associated with the dry fuel premium. In contrast, the six-month lagged standard deviation in wages is positively associated with the dry fuel premium ($p < 0.05$); a one-unit increase in the standard deviation is associated with a 0.77 percent increase in the dry fuel premium. Table 6 shows that in four out of five models, the standard deviation of wages positively affects the dry fuel premium. This result suggests that in times when consumers expect wage income to be quite variable, based on variation in wages over the previous half-year, their degree of impatience increased. They valued consumption of fuel in the present relatively more than in the future, presumably, because their level of future income was uncertain.

Although not shown in table 6, the indicator variables for the Crash of 1929, and the recession in 1926 – 1927 are not significantly associated with the dry fuel premiums. In

[6] The average wage across occupations and months of the sample is about 60 cents per hour, and the average standard deviation is about 0.15 cents per hour.

contrast, the 1923 – 1924 recession indicator is highly significant ($p < 0.01$). The coefficient ranges between 0.19 and 0.27 in models (1) through (5). The banking crisis indicator is not significantly related to the dry fuel premium.

Column (2) includes measures of inflation (mean and standard deviations over six month-lagged values of month-over-month changes in the all goods CPI). Neither the mean nor the standard deviation of inflation significantly affects the dry fuel premium. The coefficient on the standard deviation in wages remains positive and significant.

Column (3) includes means and standard deviations (again, over six month lagged values) of returns on the Dow Jones Industrials and yields on U.S. Treasury bonds. The standard deviation of returns on the Dow Industrials is significant and negatively related to dry fuel premiums ($p < 0.05$). The significance and orientation of this relationship is robust across specifications in models (3), (4), and (5). This is the same measure that Romer (1990) used to proxy for uncertainty in future economic conditions. Romer (1990) showed that fluctuations in stock prices were a primary cause of reductions in consumer expenditures on durables. In the present context, variability in stock returns is associated with a reduction in the premium for dry fuel, and likely in consumers' degree of impatience. The mean month-over-month change in the Dow Jones is significantly and positively associated with the dry fuel premium in models (3), ($p < 0.05$) and marginally significant in model (4), ($p < 0.10$).

The standard deviation in U.S. Treasury yields is positively associated with the dry fuel premiums in models (3), (4), and (5), ($p < 0.05$). One interpretation of this is that U.S. Treasury yields reflect consumer's expectations about inflation. As such, this result suggests that uncertainty about forecast inflation induces greater preference for current consumption relative to that in the future. This is an intuitive finding since holding cash during periods of high inflation effectively devalues the cash in future periods. Accordingly, uncertainty in future inflation would likely induce current spending – raising the apparent rate of time preference. The mean yields are negatively associated with dry fuel premiums in model (3), ($p < 0.05$), and marginally significant in model (4), ($p < 0.10$).

In models (4) and (5), interaction terms between wages and inflation (both means and standard deviations) are included. The mean interaction has no effect. The interaction of standard deviations in wages and inflation is significant ($p < 0.10$) and negatively associated with the dry fuel premiums. In (4) and (5), also estimated are the joint effects of wages (both means and standard deviations) through both the wage controls and the interactions with inflation. The combined effect of average wages is positive though not significant. In contrast, the joint effect of the standard deviation of wages (both directly and through inflation) is negatively related to rates of time preference in both models (4) and (5), ($p < 0.05$). The difference between the models in column (4) and (5) is the inclusion of the NVIX volatility measure gleaned from newspaper articles (Manela and Moreira, 2017). In column (5), the effect of wages, inflation, and standard deviations in the Dow and bond yields are effectively unchanged from column (4).

The results in table 6 suggest that uncertainty in economic conditions plays a central role in shaping consumers' time preferences. Variability in wages, interacted with inflation, along with returns on investment in equities suppress estimated dry fuel premiums. As noted above, Romer (1990) argues that stock market volatility was a key factor driving down consumer expenditures. Table 6 comports with Romer's argument but from a very different perspective. While Romer directly measured consumer expenditures, the present paper bolsters her argument by finding that apparent rates of time preference fall, and patience builds, during times of heightened uncertainty. This phenomenon appears to be unique to the post-Crash period in the present study. That is, apparent rates of time preference rise significantly during the recession of 1923 through 1924, in a manner that suggests the tilting of time preference toward present needs argued by economists back to Fisher (1930).

3.6 Convenience Yields.

Table 7 presents the results of a series of mean comparison tests for the estimated convenience yields. The first row tests whether the convenience yields differ for months during the 1923 – 1924 recession relative to all other months. While the signs of the average yields between the two time-periods differ in a manner that suggests higher scarcity during the recession, the t-test fails to reject the null hypothesis of equal means. This is also the case for the test pertaining to the recession of 1926 and 1927. In contrast, when the sample of estimated convenience yields is divided into the months before and after the Great Crash of 1929, table 7 indicates significantly larger convenience yields after the Crash; the average convenience yields before the Crash are -5.3 and 7.7 after the Crash ($p < 0.10$). A positive convenience yield suggests current scarcity: spot prices in excess of futures prices. This result in table 7 suggests greater scarcity in firewood markets after the Crash. This could have occurred because of an inward shift in demand for construction services after the Crash. Although the orientation of the average convenience yields during the banking crises (relative to not during the crises) is the same (higher yields during the crises), the difference is not significant. Table 7 includes an additional test: whether convenience yields estimated during the period of time when the Smoot-Hawley Tariff Act was in force (June, 1930 through 1934) differ from other months. The convenience yields are higher during this four-year period ($p < 0.10$) than in other months.

Table A1 in the appendix presents the results of the model shown in (7). Column (1) of table A1 features the most parsimonious specification in which monthly convenience yields are regressed on timber harvests. The harvest data are reported by county. Because of transportation costs, the data are subdivided into harvests local to Portland, Oregon and extraction at greater distance. In table A1, local refers to harvests in counties west of the Cascade Mountains (which is also where Portland is situated). Column (1) indicates that local timber harvests reduced convenience yields ($p < 0.05$). This is intuitive in the sense that firewood was a residual or by-product from timber production. Larger harvests would correspond with greater supply of fuel wood and less scarcity. Harvests east of the Cascades had no effect of convenience yields in this first specification. Column (2) adds season and year fixed effects. The sign of the coefficients for local and non-local harvest remain unchanged. However, local harvests no longer significantly affect yields, whereas non-local harvests increase yields. The positive relationship between non-local timber harvest and convenience yields requires some explanation. Distance, terrain, and costs suggests that it is unlikely that raw timber harvested east of Cascade Mountains was transported to mills near Portland for processing. As such, residuals from such harvests probably did not affect firewood markets in Portland either. However, timber harvests east of the Cascades may proxy for conditions in the construction sector (and housing markets).

Greater demand for wood products may reduce the portion of harvest devoted to firewood (that which is deemed waste) and thereby increase scarcity.

Column (3) adds interactions between harvests and season fixed effects. The interactions between local harvests and the season fixed effects suggest convenience yields are inversely associated with local harvest in all seasons except for winter. The largest effect manifests during the autumn months ($p < 0.01$). Larger local harvests, all else equal, likely result in more green firewood in the Portland market.

The interactions between harvests east of the Cascade Mountains suggest a positive effect of regional timber harvest on convenience yields in the firewood markets in Portland. The largest coefficient corresponds to the autumn interaction ($p < 0.01$). The parameter estimates for spring and summer are considerably smaller ($p < 0.05$).

4. Conclusions and Discussion.

Considerable research in economics explores intertemporal choice (FLO, 2002) and the Great Depression (Hall and Ferguson, 1998). The present paper brings these two literatures together by estimating the extra amount consumers were willing to pay for dry fuel wood relative to green fuel wood, by month, over 168 months from January 1922 through December 1935. The long time series of estimated dry fuel premiums provides a first-of-its-kind examination of how apparent rates of time preference respond to wages, inflation, the returns of various investments, and the macroeconomic shocks during the 1920's and 1930's.

Over 14,000 price quotes for firewood were gathered from classified ads placed in the *Portland Oregonian*. A hedonic price model for firewood is specified, and the marginal implicit price for seasoned fuel (relative to raw fuel) is estimated in a semi-log specification. Estimation in the hedonic framework necessitates interpretation of fuel prices as equilibrium outcomes between buyers and sellers. As is well known, disentangling supply side forces from demand side forces in this context is challenging. The paper does not claim to causally identify either consumers' time preferences or firms' intertemporal behavior. Rather, it conducts empirical exercises that focus on both consumers and suppliers, in turn, to provide a novel perspective on a behavior in a market for a household staple during a critical time in U.S. economic history.

Controlling for time trends, monthly, seasonal, and wood type fixed effects, a battery of microeconomic factors and macroeconomic indicators, the estimated dry fuel premium is about 13 percent. The analysis of factors that determine or affect the dry fuel premium reveals that variation, rather than mean levels, of the covariates are critical. For example, the six-month standard deviation in wages is consistently associated with the estimated rates of time preference. This is also true for monthly returns on the Dow Jones Industrials and U.S. Treasury bond yields. The results herein suggest that fluctuations in wage and capital income are critical in determining intertemporal choice. This supports the uncertainty hypothesis (Romer, 1990) that argues uncertainty over future economic conditions explains the dramatic reduction in consumer expenditures after the stock market Crash of 1929.

The paper also is in a unique position to document variability in apparent rates of time preference over the macroeconomic shocks between 1922 and 1935. For example, during the recession that occurred from 1923 to 1924 dry fuel premiums were four-times higher than in other months. Similarly, the dry fuel premiums prior to the Great Crash were about two-times larger than those estimated afterwards.

Many authors have offered explanations for the Great Depression, both in terms of its occurrence and duration (Friedman, 1956; Friedman and Schwartz, 1963; Bernanke, 1983; Romer, 1990; Hall and Ferguson, 1998). While the goals of this paper do not include an exhaustive treatment of the Depression, the time series estimation of relative fuel prices during the 1920's and 1930's provides new insights into the behavior of market participants during that time. The paper provides evidence that consumers became significantly more patient after the Great Crash of 1929.

One source of evidence supporting this claim is the two-fold reduction in WTP for seasoned fuel after the Crash. Another piece of evidence involves the interplay between prices and temperature. The data reveals that firewood prices were most reactive to temperature in late autumn when consumers made bulk purchases prior to the heating season, and in the spring months late in the heating season when liquidity risk was high. That market participants made lump-sum acquisitions of fuel is redolent of tradeoffs between current consumption against future liquidity risk; this consumption pattern strongly suggests time preference and intertemporal choice play a role in fuel purchases.

The importance of the Crash is evident in the enhanced sensitivity of prices to temperature after 1929. In particular, consumers shifted their mix of fuel toward unseasoned fuel.

Crucially, it appears they are doing so without the intention of consuming the fuel while still unseasoned. Procuring more green fuel prior to use suggests a greater willingness to tradeoff current and future consumption, or an increase in patience. Exactly why market participants became more patient remains an open question. The paper provides suggestive evidence that a central factor was uncertainty in economic futures; variability in both capital and wage income appear to have suppressed impatience. This position comports with Romer's (1990) uncertainty hypothesis. The paper augments this literature by demonstrating a behavioral mechanism undergirding the observed precipitous fall in consumption in the early 1930's.

The evidence reported here may spur further research in other cities during this period to elicit consumers' time preferences. Such broadly based research may prove critically important in deepening our understanding of the myriad forces that shaped the Great Depression. The paper also demonstrates a new approach to gathering pricing data for an energy fuel that was central to the development of the American economy. Firewood was the dominant fuel used in early American households and industry. Yet, very little empirical work exists specifically focusing on this fuel. (The informality of firewood markets is one reason for this dearth of studies: Cole, 1970). By examining ads for fuel prices placed in newspapers, the present study shows how to access these historically important markets to researchers in economics and other disciplines.

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Tables.

Table 1: Summary Statistics by Fuel Types.

Type	Count of Ads	Fraction of Ads	Price ($/cord)[A]	Fraction Dry	Fraction Partial	Fraction Green
Slab	6,782	0.4535	4.993	0.284	0.181	0.030
Old Growth	1,161	0.0776	5.894	0.237	0.023	0.003
No Type	1,126	0.0753	6.729	0.456	0.038	0.029
Block	1,074	0.0718	6.036	0.171	0.111	0.033
Fir	896	0.0599	7.366	0.265	0.049	0.042
Mill	788	0.0527	4.464	0.060	0.119	0.001
Cordwood	487	0.0326	6.154	0.472	0.025	0.004
Planer	487	0.0326	5.330	0.437	0.000	0.000
Second Growth	435	0.0291	5.228	0.198	0.018	0.002
Wreckage	413	0.0276	5.065	0.775	0.000	0.000
Box	230	0.0154	4.540	0.396	0.043	0.000
Oak	220	0.0147	8.537	0.241	0.000	0.005
Furnace	205	0.0137	5.483	0.239	0.073	0.005
Range	175	0.0117	4.877	0.337	0.137	0.000

A = prices expressed in ($1982) are adjusted for btu content by seasoned status.

Table 2: Prices by Season Status for Major Types of Wood.

	All Types	Slab	Old Growth	Other[B]
Dry	5.867	5.692	5.779	5.754
	(1.352)[A]	(1.058)	(1.195)	(1.276)
Partially-Dry	4.796	4.620	6.132	4.782
	(1.071)	(0.899)	(0.801)	(1.056)
Green	5.269	4.687	5.347	5.282
	(1.457)	(0.906)	(0.139)	(1.434)
No Season	5.467	4.751	5.926	5.369
Information	(1.521)	(0.917)	(1.112)	(1.462)

A = prices expressed in ($1982), standard deviations in parenthesis

B = Other includes all prices quotes excluding those without a wood type specified.

Table 3: Implicit Prices of Seasoned Status.

	All	Other[A]	Slab	Old Growth
Seasoned	0.127***	0.110***	0.174***	0.122***
	(0.0128)	(0.0117)	(0.0114)	(0.0329)
Partially Seasoned	-0.0119	-0.0319***	0.00266	0.112***
	(0.0131)	(0.0121)	(0.0117)	(0.0356)
No Season Data	0.0441***	0.0165	0.0216*	0.155***
	(0.0125)	(0.0114)	(0.0113)	(0.0284)
Season, Month, Year F.E.	X	X	X	X
Macro Controls	X	X	X	X
Coal Prices	X	X	X	X
Weather Controls	X	X	X	X
Weather x Month	X	X	X	X
adj. R^2	0.433	0.446	0.430	0.543
N	14363	13246	6541	1091

Standard errors in parentheses
Note: * p<0.10, ** p<0.05, *** p<0.01
Green fuel is the excluded case.
Dependent variable is natural log of price.
A = Other includes all prices quotes excluding those without a wood type specified.

Table 4: Cumulative Temperature Anomaly and Dry Fuel Premiums

	(1)	(2)	(3)	(4)
Seasoned	0.125***	0.128***	0.127***	0.120***
	(0.0127)	(0.0128)	(0.0128)	(0.0134)
Partially	-0.0145	-0.0117	-0.0119	-0.0196
Seasoned	(0.0131)	(0.0132)	(0.0131)	(0.0137)
No Season	0.0412***	0.0443***	0.0441***	0.0364***
Information	(0.0125)	(0.0126)	(0.0125)	(0.0132)
Cumulative Temp.		-0.00254***	-0.000191	0.00212
Anomaly (Temp.)		(0.000274)	(0.000830)	(0.00141)
Cumulative Precip.		0.00160**	-0.00379*	-0.00365*
Anomaly (Pre.)		(0.000677)	(0.00208)	(0.00208)
Pre. x Month			0.00198***	0.00191**
			(0.000757)	(0.000756)
Pre. x Month^2			-0.000129**	-0.000122**
			(0.0000550)	(0.0000550)
Temp. x Month			-0.000786***	-0.000622**
			(0.000297)	(0.000300)
Temp. x Month^2			0.0000486**	0.0000372
			(0.0000231)	(0.0000232)
Seasoned x				-0.00218*
Anomaly				(0.00117)
Partially Seasoned x				-0.00152
Anomaly				(0.00119)
No Season Information x				-0.00339***
Anomaly				(0.00115)
adj. R^2	0.430	0.433	0.433	0.434
N	14363	14363	14363	14363

Standard errors in parentheses
Note: * p<0.10, ** p<0.05, *** p<0.01
Dependent variable: ln(Price)

In model (4), linear combination of dry fuel coefficient plus the dry fuel x temperature anomaly interaction evaluated at the mean temperature anomaly value = 0.123 (0.013).

Table 5: Sensitivity of the dry fuel premiums to macroeconomic conditions.

Event	Dry Premium During Event[1]	Dry Premium Not During Event	T-Statistic of Difference
May, '23 – June, '24 Recession	0.246 (0.062)[2]	0.073 (0.009)	-2.752*** [0.009][3]
Oct., '26 – Nov., '27 Recession	0.101 (0.040)	0.087 (0.011)	-0.338 [0.370]
Crash of Oct., 1929	0.049[4] (0.008)	0.118 (0.017)	3.708*** [0.000]
Banking Crises	0.073 (0.013)	0.091 (0.013)	1.010 [0.158]

1 = Average partial effect of dry fuel category on price. Green fuel is the excluded case. Derived from regression model with natural log of price as dependent variable, hence coefficient of 0.25 implies dry fuel premium of 25%.
2 = Standard errors in parenthesis.
3 = p-value in brackets.
4 = For the Crash of October, 1929, during is counted as all months following October, 1929.

Table 6: Determinants of the dry fuel premium.

	(1)	(2)	(3)	(4)	(5)
Wage	0.770**	0.753**	0.314	1.758**	1.893**
SD[1]	(0.299)	(0.294)	(0.275)	(0.840)	(0.930)
Wage	0.0237	0.0312	0.0906	0.0936	0.0750
Mean[2]	(0.108)	(0.106)	(0.199)	(0.213)	(0.218)
Inflation		0.994	-1.236	-11.50	-10.68
SD		(1.611)	(2.713)	(10.62)	(11.13)
Inflation		-2.368	-0.806	24.90*	26.88*
Mean		(3.705)	(4.121)	(13.68)	(14.71)
Wage x Inflation				16.70	14.83
Mean				(20.88)	(21.99)
Wage x Inflation				-247.4*	-254.1*
SD				(128.5)	(137.0)
Dow Jones			-0.813**	-0.863**	-0.842**
SD			(0.411)	(0.407)	(0.423)
Dow Jones			1.051**	0.864*	0.760
Mean			(0.511)	(0.497)	(0.522)
U.S. Treasury Yield			4.115**	3.950**	3.383**
SD			(1.592)	(1.531)	(1.627)
U.S. Treasury Yield			-2.791**	-2.133*	-2.173
Mean			(1.371)	(1.282)	(1.336)
Quadratic Trend	X	X	X	X	X
Month of year FE	X	X	X	X	X
Macro Events			X	X	
NVIX					X
adj. R^2	0.179	0.169	0.330	0.352	0.348
N	150	150	149	149	149

Standard errors in parentheses
* p<0.10   ** p<0.05   *** p<0.01"
1 = Standard deviations over 0 to six month lags
2 = Means over 0 to six month lags.

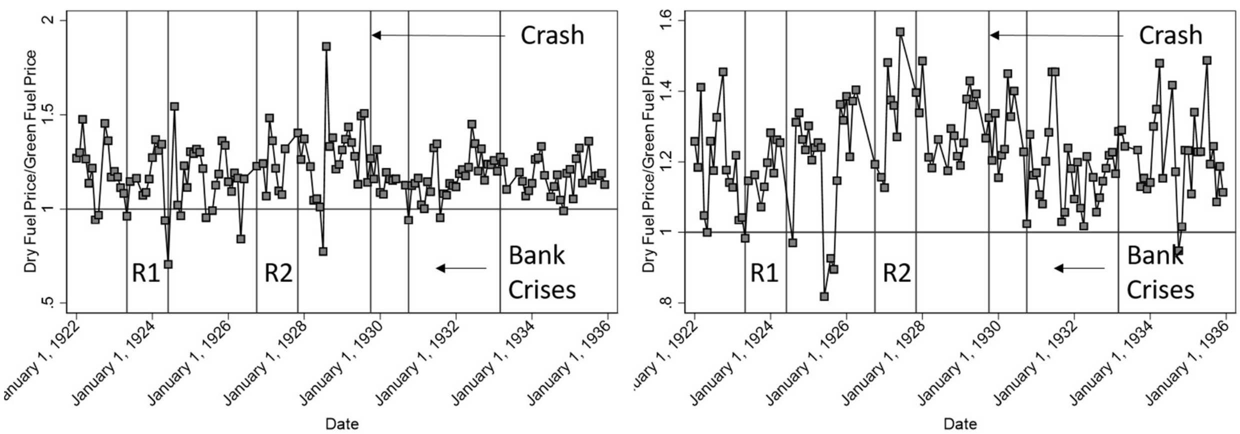
Table 7: Sensitivity of Convenience Yields to Macroeconomic Events.

Time Period	Convenience Yield During Event	Convenience Yield Not During Event	t-stat of difference
Recession of 1923 – 1924	7.043 (4.225)[1]	-2.679 (4.397)	-0.809 [0.210][2]
Recession of 1926 – 1927	-6.492 (8.839)	-1.035 (4.200)	-0.391 [0.348]
Stock Market Crash[3]	7.736 (5.677)	-5.338 (4.959)	-1.532* [0.064]
Banking Crises	9.012 (12.928)	-2.079 (4.063)	0.627 (0.266)
Smoot-Hawley[4]	11.675 (6.211)	-4.251 (4.501)	1.546* (0.062)

1 = Standard errors in parenthesis.
2 = p-value in brackets.
3 = For the Crash of October, 1929, during is counted as all months following October, 1929.
4 = Inclusive of months from passage (June, 1930) to passage of Reciprocal Trade Agreements Act of 1934 (June, 1934).

Figures.

Figure 1. Ratio of Dry Fuel to Green Fuel Prices.



Left panel: all wood types. Right panel: slab wood.

Source: *Portland Oregonian,* Various from 1922 – 1935.

Vertical lines indicate:

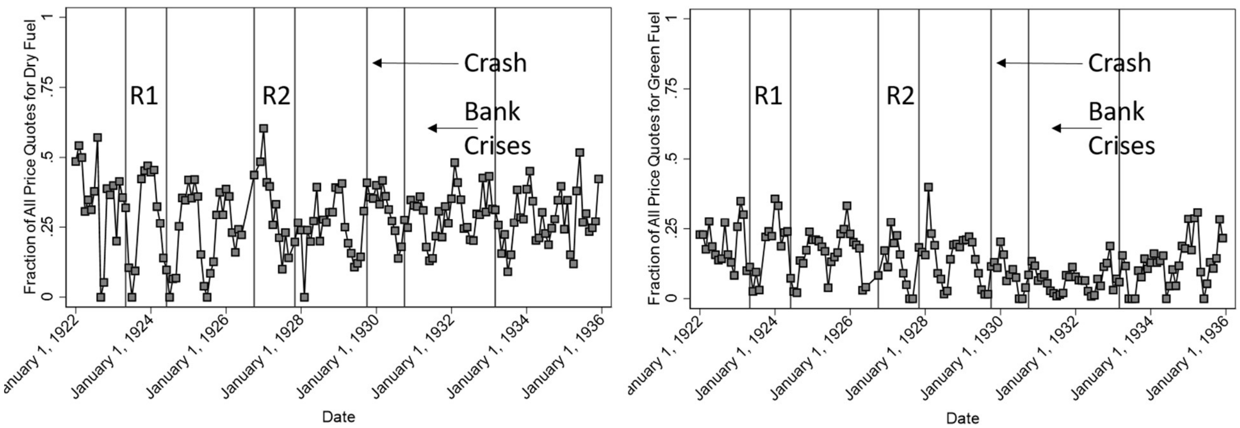
R 1 = Recession of 1923 to 1924

R 2 = Recession of 1926 to 1927

Crash = Great Crash of October, 1929

Bank Crises = Banking Crises using time demarcations from Friedman and Schwartz (1963).

Figure 2: Share of Price Quotes by Season Status.



Source: *Portland Oregonian,* Various from 1922 – 1935.

Vertical lines indicate:

R 1 = Recession of 1923 to 1924

R 2 = Recession of 1926 to 1927

Crash = Great Crash of October, 1929

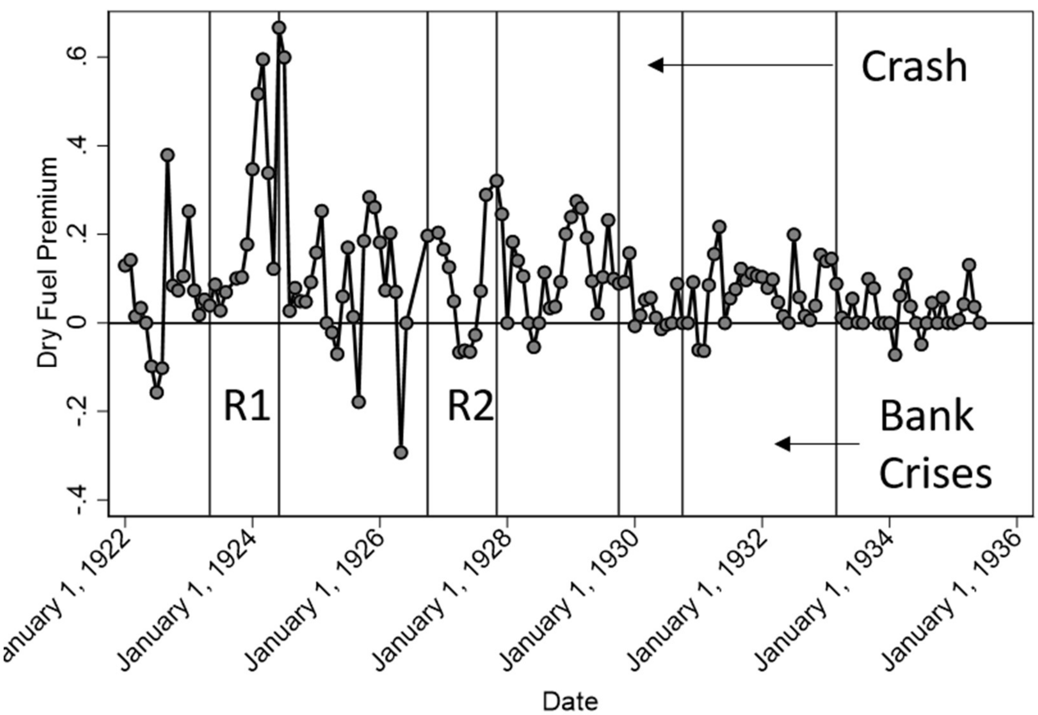
Bank Crises = Banking Crises using time demarcations from Friedman and Schwartz (1963).

Figure 3: Annual Premium for Dry Wood.

Dashed lines are 95% confidence intervals.

Source: *Portland Oregonian,* Various from 1922 – 1935. Author's calculations.

Figure 4: Dry Fuel Premium by Month of Sample.



Source: *Portland Oregonian,* Various from 1922 – 1935.

Vertical lines indicate:

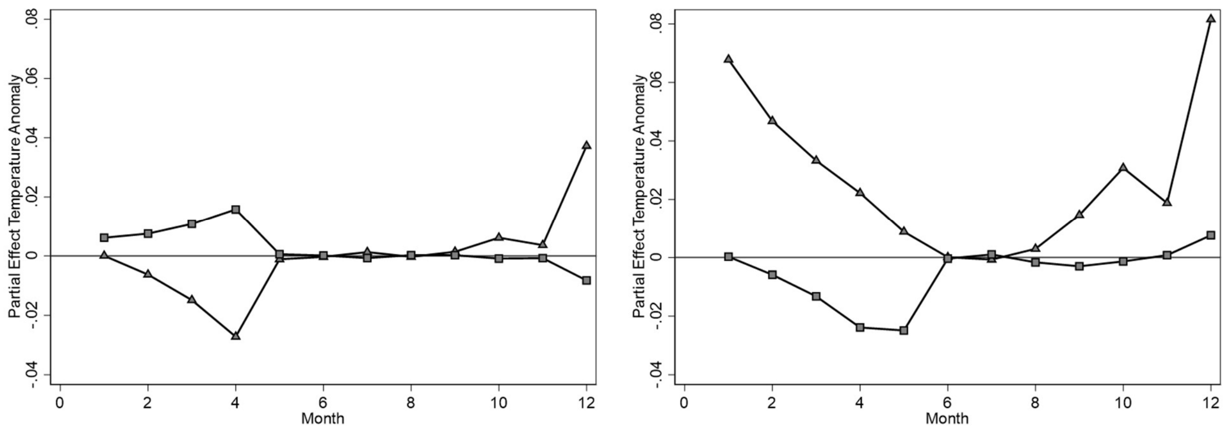
R 1 = Recession of 1923 to 1924

R 2 = Recession of 1926 to 1927

Crash = Great Crash of October, 1929

Bank Crises = Banking Crises using time demarcations from Friedman and Schwartz (1963).

Figure 5: Partial Effect of Temperature on Fuel Price for Before (Left) and After (Right) the Great Crash.



Squares: prices for dry fuel. Triangles: prices for green fuel.

Appendix.

This supplementary appendix covers three topics: a systematic comparison of the apparent rate of return on green fuel investments relative to other common investments, an exploration of the correlations between coal and wood prices, and a series of robustness exercises focusing on how coal prices are included in the hedonic models.

1. **Comparison of Yield on Purchase of Green Fuel to Alternative Investments.**

As FLO (2002) note, consumer choice regarding expenditures at different points in time may not reveal time preference, but rather consumers' ability to arbitrage through access to capital markets. Unpacking these two factors (time preference and intertemporal arbitrage) in a field setting in which only market prices are observed (along with attributes of the fuel), without any follow-up interview as to motivations for the choices made is clearly challenging. However, if consumers do have access to capital markets *and observed choices actually reflect arbitrage behavior,* then the estimated discount rates should align with the market interest rate (FLO, 2002). As stated numerous times in the main text, the paper does not claim to cleanly identify individual discount rates. Rather, the premium paid for dry fuel is argued to embody time preference along with other potential confounding attributes of green and seasoned fuel.

The following exercise compares yields on 10-year U.S. Treasuries with the dry fuel premiums. This test, assuming that the dry fuel premiums embody rates of time preference, explores convergence between market interest rates and rates of time preference of the sort hypothesized by FLO (2002). Table A2 presents the result of this comparison. What table A1 shows is that the differences between estimated discount rates, as embodied by the dry fuel premiums, and returns on alternative investments fall toward zero over the course of the 1922 to 1935 sample. The reduction in the spread is largest (in percentage point terms) and results in the spread being closest to zero for 10-year bonds. Considering the limitations of working in an empirical context some 95 years in the past, the yield on 10-year bonds is probably the best estimate of the extant market rate of interest. However, it is unclear whether the diminished spread reflects arbitrage or a reduction in time preference from the events that occurred during the Great Depression.

Figure A9 tests another potential confound to the interpretation of dry fuel premiums as revelatory about consumers' time preferences. Specifically, if households and other consumers viewed green fuel as a financial investment opportunity, returns should converge to the returns to other investments. Figure A9 reveals that, when viewed as an investment opportunity, purchasing green fuel and letting it mature for one year to be sold at the extant price for dry fuel generates very high, but quite volatile, returns; the average rate of return is over 22 percent, but the standard deviation of over 21 percent. In contrast, the average rate of interest on the 10-year bond is just 3 percent with a standard deviation of 0.3. And, the spread between the yields on these two investments grows throughout the sample. Both before and after the Crash of 1929, the return on investment in green fuel was about 24 percent. If speculative investors were capitalizing on the exorbitant returns offered by green fuel, prices for raw fuel would rise, relative to dry fuel one year hence. This would align the returns with those offered by competing investments, such as the 10-year bonds. The data reveals no convergence with bond yields falling over the 1921 to 1935 period.

2. Coal Prices.

Table A3 explores the sensitivity of wood fuel prices to bituminous coal prices. The values in table A3 are parameter estimates on the natural log of coal prices, and because the natural log form of the dependent variable (wood prices) these estimates are elasticities. The table emphasizes changes to these elasticities as a function of the macroeconomic shocks occurring between 1922 and 1935. Table A3 indicates that wood and coal prices were positively correlated and that this positive correlation is mainly between dry fuel prices and coal prices.

The first column of table A3 focuses on the 1923-1924 recession. The top panel indicates that coal and wood prices were positively correlated in months *not* during this recession. For all fuel prices, the elasticity is 0.436 ($p < 0.01$). This relationship is driven by dry fuel prices. Green fuel prices appear to be uncorrelated with bituminous coal prices in non-recession months. During this recession, the elasticity estimate increases by about five-fold. Neither dry fuel prices, nor green fuel prices are individually correlated with coal prices during the 1923 – 1924 recession.

A similar pattern manifests for the 1926 – 1927 recession: in non-recession months, wood and coal prices were positively correlated and this is primarily due to dry fuel prices. During the recession, there is no evidence of a significant correlation between wood and coal prices.

The third column of table A3 examines the months before and after the Great Crash. Prior to the Crash, wood prices were relatively inelastic with respect to coal prices (0.236, $p < 0.01$). Again, it was dry fuel prices that were responsive to coal prices. After the Crash, the elasticity increased to 1.432 ($p < 0.01$). Unlike the two recessions, after the Crash, the elasticity remains significant. This activity was concentrated in the market for dry fuel.

Table A4 employs anthracite prices rather than bituminous coal prices. For the two recessions, the results using anthracite prices are quite similar to those for bituminous coal; in non-recessionary months, wood and coal prices are significantly, positively correlated and the relationship appears to be concentrated in the market for dry wood.

Unlike table A3, in table A4, wood and anthracite coal prices are only correlated in dry fuel markets before the Crash. After the Crash, both dry and green fuel prices are significantly correlated with anthracite coal prices.

Table A5 explores different specifications in terms of how bituminous coal prices are included in the hedonic regression models. Column (1) corresponds to the results in table 4 in the main text. Across all months of the sample, the elasticity of firewood prices with respect to coal prices is 0.548 ($p < 0.01$). Column (2) includes interactions between coal prices and both the linear and quadratic month-of-year controls. Both terms are significant: the interaction between coal prices and the linear month control is positive ($p < 0.01$) while that for the quadratic term is negative ($p < 0.01$). The inclusion of these interaction terms modestly reduces the firewood-coal price elasticity from 0.548 in column (1) to 0.489 ($p < 0.01$) in column (2). In addition, the dry fuel premium increases slightly to 0.132 ($p < 0.01$). Column (3) replaces the interactions between coal prices and month-of-year with interaction between the temperature and precipitation anomalies, coal prices, and month-of-year. Only the quadratic term for temperature is significantly different from zero. In this specification, the firewood-coal price elasticity increases to 0.614 ($p < 0.01$), and the dry fuel premium is 0.129 ($p < 0.01$).

Column (4) includes both coal-by-month and coal-by-anomaly-by-month interactions. The coal-by-month interactions are significant and similar in magnitude to those in column (2). Both the linear and quadratic interactions between month, temperature, and coal prices are also significant ($p < 0.01$). In addition, the quadratic interaction between month, precipitation, and coal prices is negative and significant ($p < 0.05$). The firewood-coal price elasticity falls to 0.513 ($p < 0.01$), and the dry fuel premium is estimated to be 0.132 ($p < 0.01$).

Table A6 replicates table 4 from the main text using anthracite coal prices instead of bituminous coal prices. Column (1) indicates that using anthracite rather than bituminous coal induces a small change in the dry fuel premium from 0.125 ($p < 0.01$) to 0.127 ($p < 0.01$). Similarly, the dry fuel premium and the coefficients for temperature and precipitation in column (2) exhibit very little sensitivity to using anthracite coal when compared to those reported in table 4. This pattern also holds for the dry fuel premium reported in column (3). However, the interaction terms between month-of-year and both precipitation and temperature all are larger (in an absolute sense) when using anthracite relative to bituminous coal. This result also manifests in column (4). In contrast, the coefficients for the interactions between temperature and firewood prices by season status are quite similar whether using bituminous or anthracite prices.

Tables and Figures.

Table A1: Determinants of Convenience Yields.

	(1)	(2)	(3)
Harvest West of	-0.000181**	-0.00183	-0.00112
Cascades	(0.0000696)	(0.000933)	(0.00176)
Harvest East of	0.000173	0.00159*	0.000351
Cascades	(0.000169)	(0.000748)	(0.00152)
Spring		3.191	6.479
		(7.760)	(23.00)
Summer		4.570	-13.40
		(7.555)	(27.30)
Autumn		18.60	18.25
		(9.774)	(16.80)
Harvest West x Spring			-0.000679**
			(0.000190)
Harvest West x Summer			-0.000563***
			(0.000121)
Harvest West x Autumn			-0.000953***
			(0.000129)
Harvest East x Spring			0.00115**
			(0.000425)
Harvest East x Summer			0.00118**
			(0.000425)
Harvest East x Autumn			0.00165***
			(0.000244)
Year Fixed Effects		X	X
adj. R^2	-0.005	0.031	-0.012
N	82	82	82

Table A2: Comparison of Dry Fuel Premiums to Yields on Alternative Investments.

	Pre-Crash	Post-Crash	Full Sample
10-Year Bond	7.810***	1.405***	5.100***
	(1.648)	(0.741)	(1.030)
Dow Jones	10.432***	5.856***	8.483***
	(1.742)	(1.485)	(1.194)
Commercial Paper	11.817***	7.574***	10.022***
	(1.784)	(1.788)	(1.284)
S&P	10.407***	5.834***	8.460***
	(1.724)	(1.544)	(1.199)
N	90	67	157

Standard errors in parentheses
Note: * p<0.10, ** p<0.05, *** p<0.01
T-tests compare spread between monthly dry fuel premiums and returns (yields) on alternative investments to zero.

Table A3: Relationship Between Wood Fuel Prices and Bituminous Coal Prices.

Not During Event	1923 – 1924 Recession	1926 – 1927 Recession	Great Crash	Banking Crises
All	0.436***	0.735***	0.236***	0.562***
	(0.0649)	(0.0683)	(0.0708)	(0.0635)
Dry	0.649***	0.721***	0.272**	0.683***
	(0.115)	(0.122)	(0.132)	(0.114)
Green	0.372	0.633	0.376	0.630
	(0.461)	(0.481)	(0.513)	(0.427)
During Event	**1923 – 1924 Recession**	**1926 – 1927 Recession**	**Great Crash**	**Banking Crises**
All	2.365**	0.0304	1.432***	0.127
	(1.194)	(0.441)	(0.164)	(1.020)
Dry	-1.146	0.407	1.722***	0.967
	(1.932)	(0.874)	(0.324)	(1.240)
Green	1.500	0	0.962	0
	(1.242)	(.)	(1.822)	(.)

Values in table A3 are estimated coefficients from regression of natural log of wood prices on the natural log of monthly bituminous coal prices. Regressions include wood type fixed effects, season and year fixed effects.

Table A4: Relationship Between Wood Fuel Prices and Anthracite Coal Prices.

Not During Event	1923 – 1924 Recession	1926 – 1927 Recession	Great Crash	Banking Crises
All	0.229***	0.234***	0.00379	0.402***
	(0.0431)	(0.0445)	(0.0778)	(0.0490)
Dry	0.383***	0.432***	0.501***	0.615***
	(0.0772)	(0.0796)	(0.147)	(0.0866)
Green	-0.249	0.111	-0.160	-0.113
	(0.319)	(0.323)	(0.348)	(0.309)
During Event	**1923 – 1924 Recession**	**1926 – 1927 Recession**	**Great Crash**	**Banking Crises**
All	2.993**	0.0379	0.582***	0.373
	(1.511)	(0.548)	(0.0597)	(0.336)
Dry	-1.458	0.506	0.542***	-0.642
	(2.459)	(1.087)	(0.111)	(0.410)
Green	1.899	0	2.041***	0
	(1.571)	(.)	(0.623)	(.)

Values in table A3 are estimated coefficients from regression of natural log of wood prices on the natural log of monthly bituminous coal prices. Regressions include wood type fixed effects, season and year fixed effects.

Table A5: Specification of Bituminous Coal Prices in Hedonic Price Model.

	(1)	(2)	(3)	(4)
Seasoned	0.127***	0.132***	0.129***	0.132***
	(0.0128)	(0.0128)	(0.0128)	(0.0127)
Partially Seasoned	-0.0119	-0.00780	-0.0104	-0.00748
	(0.0131)	(0.0131)	(0.0131)	(0.0130)
No Season Information	0.0441***	0.0474***	0.0451***	0.0475***
	(0.0125)	(0.0125)	(0.0125)	(0.0125)
Ln (Coal Price)	0.548***	0.489***	0.614***	0.513***
	(0.0681)	(0.128)	(0.0728)	(0.124)
Coal x Month		0.0188***		0.0212***
		(0.00393)		(0.00389)
Coal x Month^2		-0.00193***		-0.00227***
		(0.000276)		(0.000292)
Coal x Temp x Month			0.000248	0.000524***
			(0.000193)	(0.000193)
Coal x Temp x Month^2			-0.0000687***	-0.0000625***
			(0.0000221)	(0.0000220)
Coal x Pre. x Month			-0.000729	0.000790
			(0.000558)	(0.000583)
Coal x Pre. x Month^2			0.0000567	-0.000141**
			(0.0000551)	(0.0000600)
adj. R^2	0.433	0.436	0.434	0.437
N	14363	14363	14363	14363

Standard errors in parentheses
Note: * p<0.10, ** p<0.05, *** p<0.01
Dependent variable: ln(Price)

Table A6: Cumulative Temperature Anomaly and Dry Fuel Premiums using Anthracite Coal Prices.

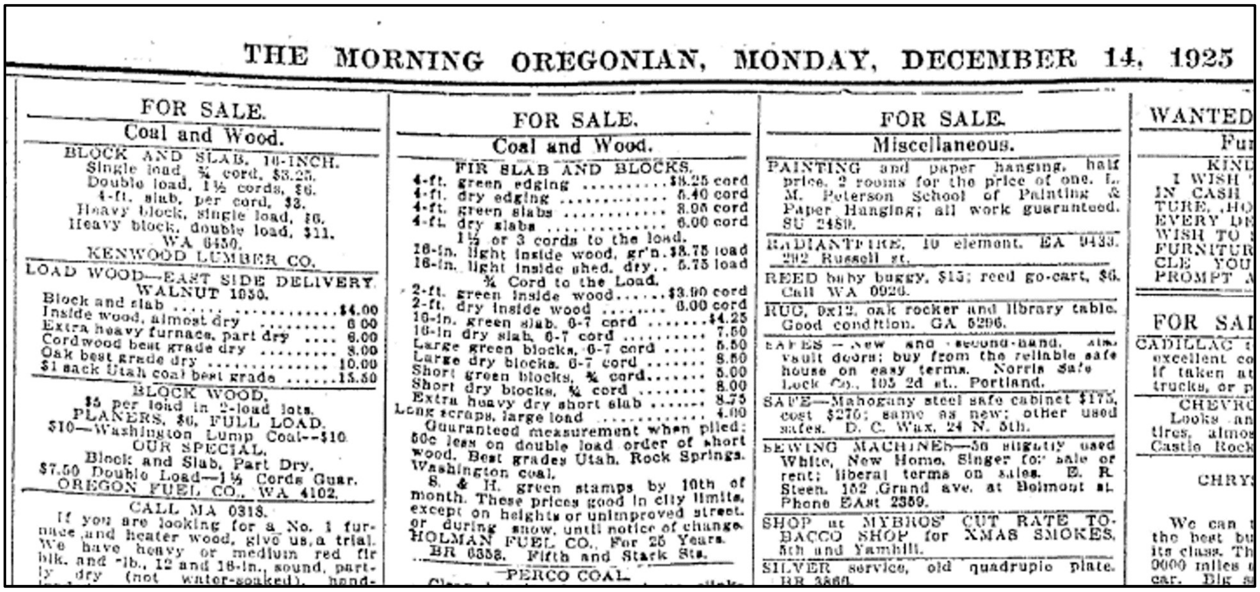
	(1)	(2)	(3)	(4)
Seasoned	0.127***	0.128***	0.128***	0.121***
	(0.0127)	(0.0128)	(0.0127)	(0.0134)
Partially Seasoned	-0.0129	-0.0114	-0.0116	-0.0192
	(0.0130)	(0.0131)	(0.0131)	(0.0137)
No Season Information	0.0427***	0.0447***	0.0442***	0.0367***
	(0.0124)	(0.0125)	(0.0124)	(0.0131)
Cumulative Temp. Anomaly (Temp.)		-0.00215***	0.000367	0.00260*
		(0.000273)	(0.000832)	(0.00139)
Cumulative Precip. Anomaly (Pre.)		0.00254***	-0.00371*	-0.00358*
		(0.000678)	(0.00208)	(0.00208)
Pre. x Month			0.00235***	0.00227***
			(0.000761)	(0.000761)
Pre. x $Month^2$			-0.000158***	-0.000151***
			(0.0000553)	(0.0000553)
Temp. x Month			0.0000677***	0.0000546**
			(0.0000230)	(0.0000232)
Temp. x $Month^2$			-0.000930***	-0.000746**
			(0.000297)	(0.000300)
Seasoned x Anomaly				-0.00211*
				(0.00115)
Partially Seasoned x Anomaly				-0.00139
				(0.00117)
No Season Information x Anomaly				-0.00342***
				(0.00113)
adj. R^2	0.428	0.431	0.431	0.432
N	14363	14363	14363	14363

Standard errors in parentheses
Note: * p<0.10, ** p<0.05, *** p<0.01
Dependent variable: ln(Price)

In model (4), linear combination of dry fuel coefficient plus the dry fuel x temperature anomaly interaction evaluated at the mean temperature anomaly value = 0.119 (0.014).

Appendix Figures:

Figure A1: Advertisement Showing Price Quotes and Grades of Wood Fuel.



THE MORNING OREGONIAN, MONDAY, DECEMBER 14, 1925

FOR SALE.

Coal and Wood.

BLOCK AND SLAB, 16-INCH.
Single load, ¾ cord, $3.25.
Double load, 1½ cords, $6.
4-ft. slab, per cord, $8.
Heavy block, single load, $6.
Heavy block, double load, $11.
WA 6450.
KENWOOD LUMBER CO.

LOAD WOOD—EAST SIDE DELIVERY
WALNUT 1050.
Block and slab $4.00
Inside wood, almost dry 6.00
Extra heavy furnace, part dry 6.00
Cordwood best grade dry 8.00
Oak best grade dry 10.00
$1 sack Utah coal best grade 15.50

BLOCK WOOD.
$5 per load in 2-load lots.
PLANERS, $6, FULL LOAD.
$10—Washington Lump Coal--$10
OUR SPECIAL.
Block and Slab, Part Dry.
$7.50 Double Load—1½ Cords Guar.
OREGON FUEL CO., WA 4102.

CALL MA 0318.
If you are looking for a No. 1 furnace and heater wood, give us a trial. We have heavy or medium red fir blk. and 4-ft., 12 and 16-in., sound, partly dry (not water-soaked), hand-

FOR SALE.

Coal and Wood.

FIR SLAB AND BLOCKS.
4-ft. green edging ....$8.25 cord
4-ft. dry edging .... 5.40 cord
4-ft. green slabs .... 8.05 cord
4-ft. dry slabs .... 6.00 cord
1½ or 3 cords to the load.
16-in. light inside wood, gr'n.$8.75 load
16-in. light inside shed, dry.. 5.75 load
¾ Cord to the Load.
2-ft. green inside wood......$3.90 cord
2-ft. dry inside wood .... 6.00 cord
16-in. green slab, 6-7 cord $4.25
16-in dry slab, 6-7 cord 7.50
Large green blocks, 6-7 cord 5.50
Large dry blocks, 6-7 cord 8.50
Short green blocks, ¾ cord....... 5.00
Short dry blocks, ¾ cord 8.00
Extra heavy dry short slab 8.75
Long scraps, large load 4.00
Guaranteed measurement when piled; 50c less on double load order of short wood. Best grades Utah, Rock Springs, Washington coal.
S. & H. green stamps by 10th of month. These prices good in city limits, except on heights or unimproved street, or during snow, until notice of change.
HOLMAN FUEL CO., For 25 Years.
BR 6353. Fifth and Stark Sts.

PERCO COAL.

FOR SALE.

Miscellaneous.

PAINTING and paper hanging, half price, 2 rooms for the price of one. L. M. Peterson School of Painting & Paper Hanging; all work guaranteed. SU 2489.

RADIANTFIRE, 10 element. EA 9433. 292 Russell st.

REED baby buggy, $15; reed go-cart, $6. Call WA 0926.

RUG, 9x12, oak rocker and library table. Good condition. GA 5296.

SAFES — New and second-hand, also vault doors; buy from the reliable safe house on easy terms. Norris Safe Lock Co., 105 2d st., Portland.

SAFE—Mahogany steel safe cabinet $175, cost $276; same as new; other used safes. D. C. Wax, 24 N. 5th.

SEWING MACHINES—50 slightly used White, New Home, Singer for sale or rent; liberal terms on sales. E. R. Steen, 152 Grand ave. at Belmont st. Phone EAst 2359.

SHOP at MYBROS' CUT RATE TOBACCO SHOP for XMAS SMOKES, 5th and Yamhill.

SILVER service, old quadruple plate. BR 3860.

Source: ***Portland, Oregonian*** **December 14th, 1925.**

Figure A2: Month of Sample Counts of Price Quotes.

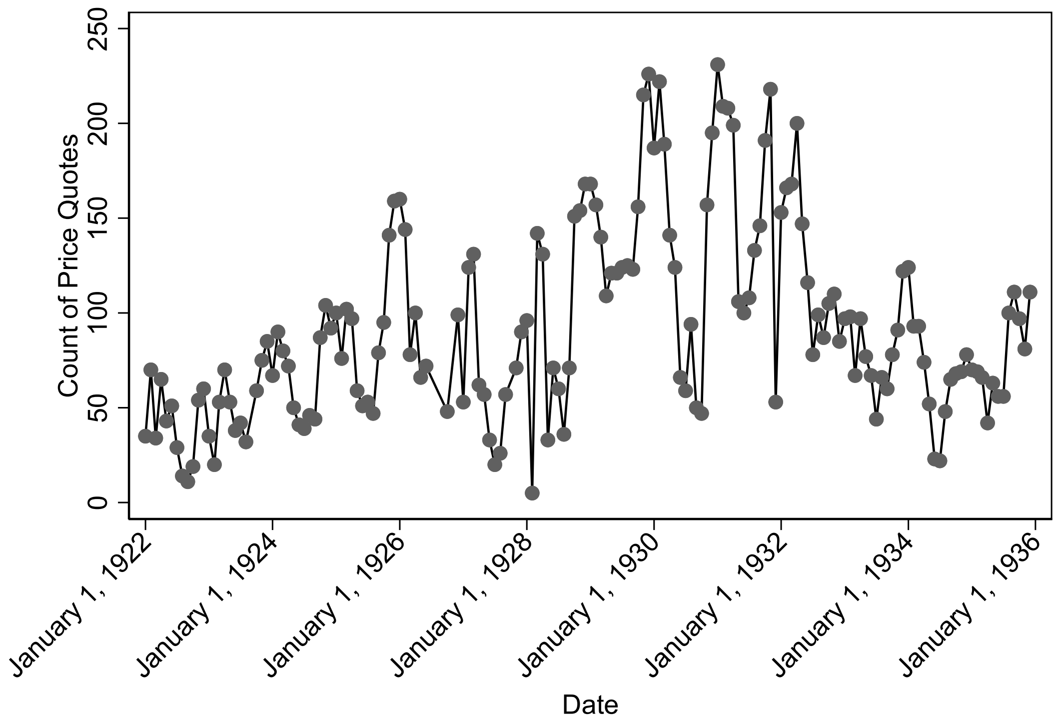
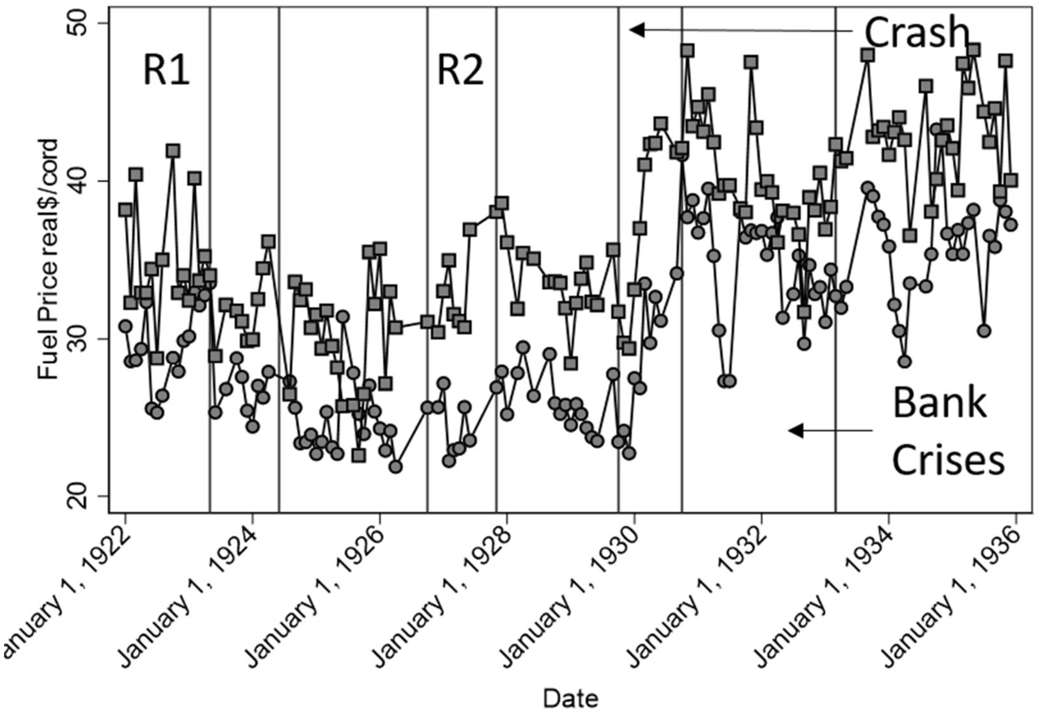


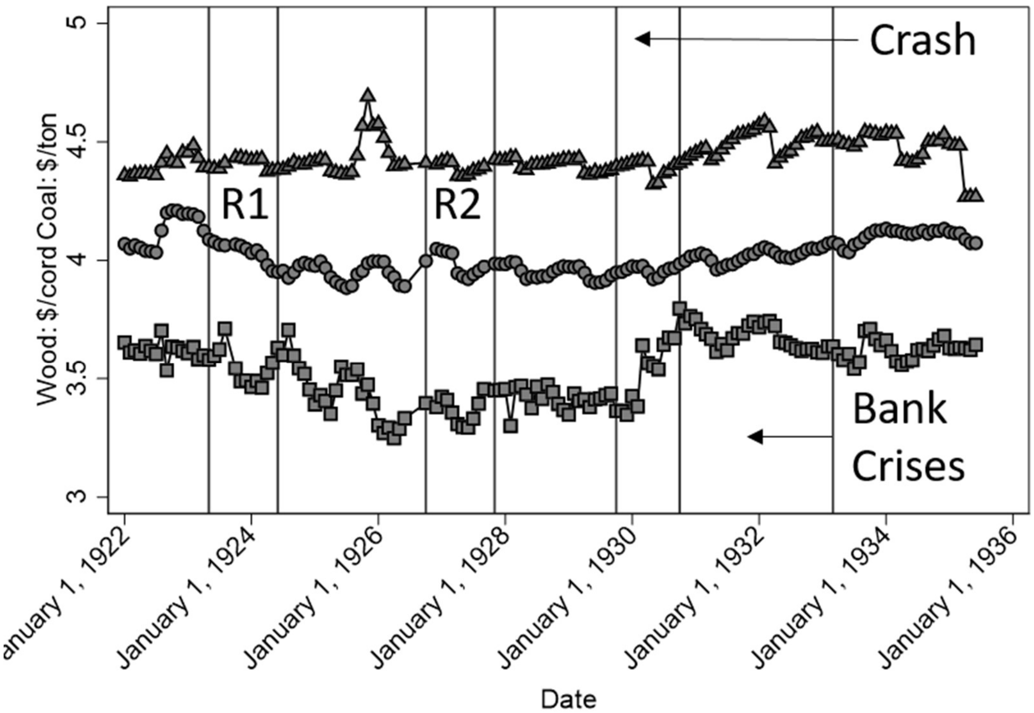
Figure A3: Slab wood.

Figure A4: Real Dry and Green or Partially-Dry Firewood Prices.



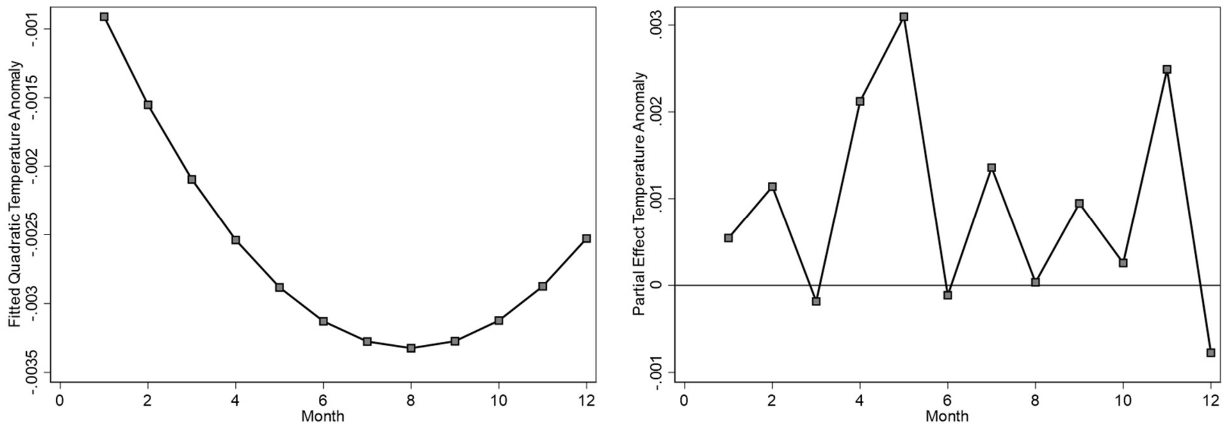
Prices expressed in ($1982). The left-hand most pair of vertical lines indicate the recession from 1923 – 1924. The next pair of vertical lines indicate the recession from 1926 to 1927. The third vertical line from the right marks the date of the stock market Crash of October, 1929. The next pair of vertical line span the banking crises.

Figure A5: Coal and Firewood Prices.



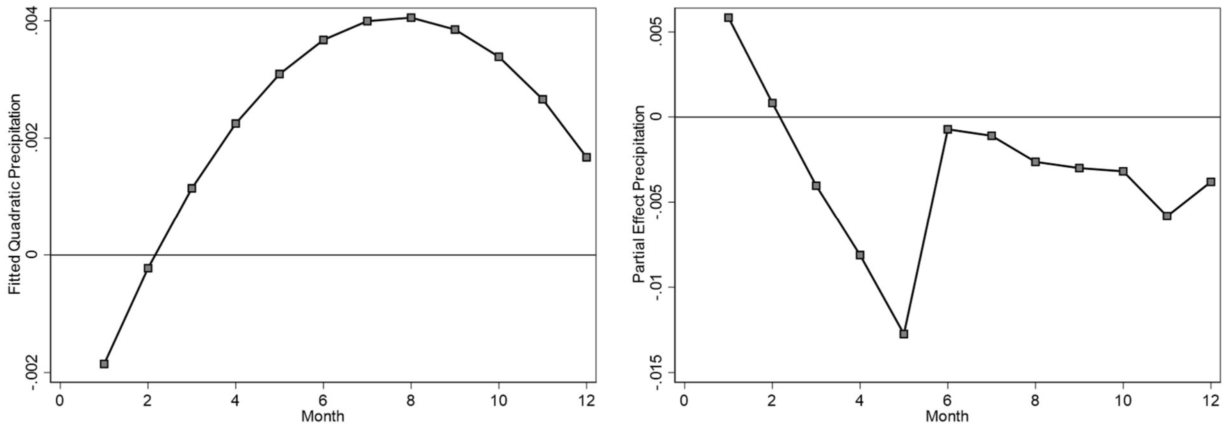
Prices expressed in real 1984$. Triangles = anthracite coal in U.S. short tons; Circles = bituminous coal in U.S. short tons; Squares = firewood in cords.

Figure A6: Partial Effects of Temperature Anomaly by Month-of-Year.



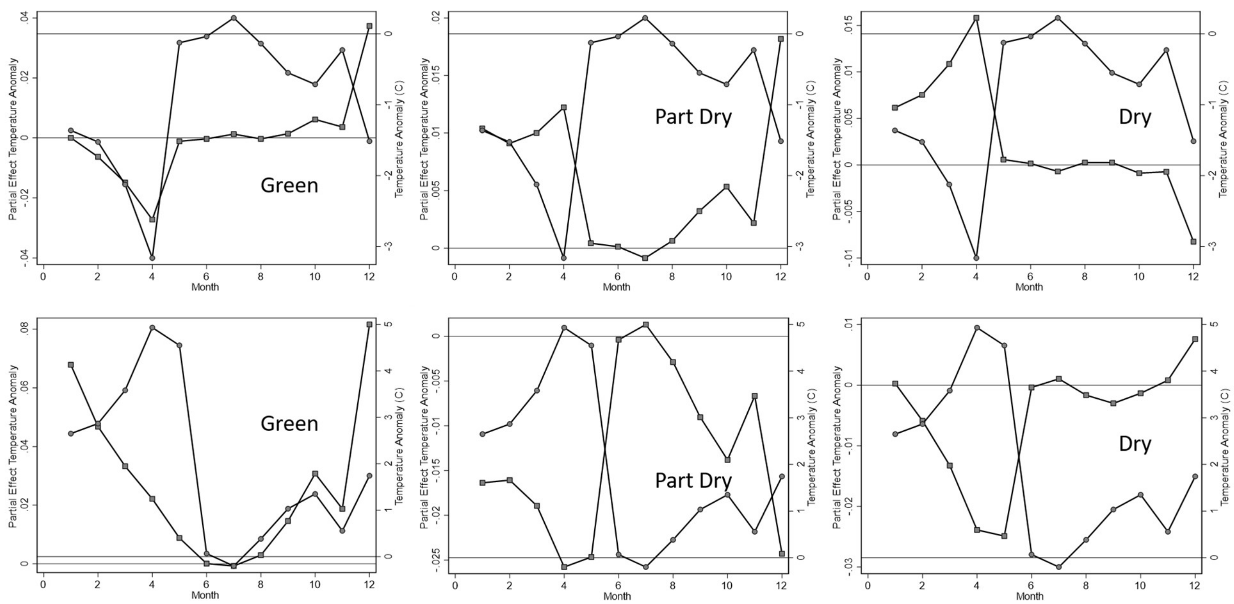
Left panel: partial effect of cumulative temperature anomaly x month on fuel price; Right panel: partial effect of cumulative temperature anomaly x month on fuel price evaluated at mean temperature anomaly by month-of-year.

Figure A7: Partial Effects of Precipitation by Month-of-Year.



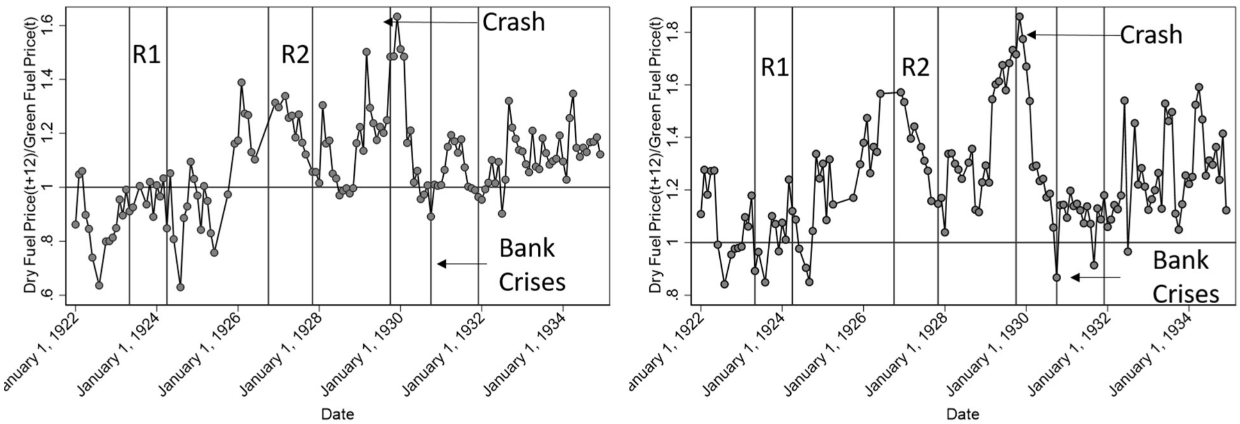
Left panel: partial effect of cumulative precipitation anomaly x month on fuel price; Right panel: partial effect of cumulative precipitation anomaly x month on fuel price evaluated at mean precipitation by month-of-year.

Figure A8: Partial Effects of Temperature Anomaly on Fuel Prices and Temperature Anomaly Plots Before the Great Crash (top) and After the Great Crash (bottom).



Squares: fuel prices, circles: temperature anomaly. Top Panel: Before Great Crash; Bottom Panel: After Great Crash.

Figure A9: Rate of Appreciation of Green Fuel.



Left panel: All wood types. Right panel: Slab wood. Graphs depict the annual increase in the real price of a cord of green fuel as determined by the real price of a dry cord, one year after the purchase of the green cord. The left-hand most pair of vertical lines indicate the recession from 1923 – 1924. The next pair of vertical lines indicate the recession from 1926 to 1927. The third vertical line from the right marks the date of the stock market Crash of October, 1929. The next pair of vertical line span the banking crises.