Discount Rates During the Great Depression Era:

Evidence from Firewood Prices in Portland, Oregon.

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Abstract

The present study gathers prices for firewood and estimates rates of time preference from the premium paid for dry fuel, relative to green wood, on a monthly basis from 1922 to 1935. This facilitates a first-of-its-kind assessment of time series variation in rates of time preference. The paper examines the influence that wages, inflation, returns on stocks, yields on bonds, as well as cost-of-living indices have on estimates of time preference. The analysis conducts an assessment of how the macroeconomic shocks before, during, and after the Great Depression affected time preference. Over the entire sample, the estimated premium for dry fuel is 12 percent. This premium increased by a factor of four during the recession of 1923 to 1924, and fell by a factor of two following the stock market crash of October, 1929. Key factors in determining the premium for dry fuel are: variation in wages, inflation, stock market returns, and bond yields. The results herein provide empirical support for the uncertainty hypothesis as an explanation for the precipitous fall in consumption expenditures following the crash.

Keywords: Discount rate, time preference, Great Depression, uncertainty hypothesis, firewood.

JEL Codes: N12, N32, N52, D15.

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 field estimates of time preferences. 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. An estimate of the price differential between 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 using over 14,000 price quotes that span 168 months' worth of market activity; premiums for dry fuel are estimated 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 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 of, 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. The data are gathered from one day during the middle of each month over the 168 months from 1922 to 1935. All price quotes on the sampled day 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.

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[1] The claim that the dry fuel premium offers a clean 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.

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 for market participants in the present analysis. 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 were likely to weigh such decisions heavily. That households likely devoted considerable thought to their fuel wood purchases increases the present study's ability to recover consumers' 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 would have reflected years of accumulated knowledge. Specifically, 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 also 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 two sets of empirical exercises. First, a series of hedonic pricing models estimate the marginal implicit price of dry fuel relative to green

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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.

1.1 Hedonic Estimation of Time Preferences.

The hedonic models describe prices of firewood as a function of a number of attributes. 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 really 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 rates 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 are quite likely at play. This motivates the inclusion of other covariates in the hedonic models that are potentially pertinent to individual time preference and consumption decisions. The hedonic models include three categories of covariates intended to capture variation from likely confounding factors[2]: inflation and the price level, opportunity costs of investments in green fuel, and, broadly, uncertainty in future economic conditions.

As FLO (2002) note, consumers' expectations about inflation may be an important determinant of intertemporal choice, because individual forecasts of prices in future periods will affect one's WTP for products today. As noted above, the period 1922 through

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[2] The literature (FLO, 2002) provides a useful framework for consideration of confounding factors when attempting to elicit time preferences in empirical settings.

1935 encompasses periods of both significant inflation, prior to the stock market crash of 1929, and periods of deflation, following the crash in the early 1930's. The models include the levels and monthly changes in the all-goods CPI to control for inflation. In addition, cost-of-living indices for Portland, Oregon (published by the BLS, 1941) are included. These controls provide a more targeted or specific gauge of the price level in the markets observed in this study.

Alternative uses of cash may also play an important role in shaping household demand for green versus dry fuel. That is, the decision to purchase green fuel essentially locks up cash that could otherwise be invested to earn some rate of return. As such, the models include yields on 10-year U.S. government bonds and returns to equities (the Dow Jones Industrials).

Another important potential confound to the extraction of consumers' time preferences from field data is uncertainty. This manifests in two ways: uncertainty over future rewards, and uncertainty in future economic or financial conditions. In terms of the former, experimental studies typically ensure that future rewards manifest deterministically. An issue in most field studies is that expected rewards may not occur. More pointedly, consumers whose behavior is observed in field studies may doubt whether payoffs will manifest. The present paper partially sidesteps this issue. The payoffs from holding raw fuel depend on natural processes – the seasoning of fuel wood. Provided the fuel is stored properly (and recall the representative household in Portland at this time relied heavily on wood for fuel and had done so for decades) this process is guaranteed to occur. It is certain that green fuel will mature to dry fuel. However, the precise monetary savings is uncertain

at the time of purchase of green fuel because the future price of seasoned fuel is unknown[3].

Additionally, uncertainty over future economic conditions is imperfectly captured in the

hedonic models by including month-to-month changes in: wages, inflation, returns to

investments in equities and fixed income investments, and costs-of-living.

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. 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, the Banking Crises of 1931 and 1932, and the Great Depression which

"officially" spans August, 1929 to March, 1933. In terms of continuous variables, the paper

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. Prior authors note that an

important test is whether current rates of interest (in capital markets) influence revealed

discount rates (FLO, 2002; Krupa and Stephens, 2013). The essence of such a test is

whether revealed rates of time preference converge to the rate of interest, as they would if

consumers were simply arbitraging inter-temporally. In addition, the analysis controls for

monthly wages using data gathered from classified ads in the *Portland Oregonian*. The

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[3] Figure A4 in the appendix plots empirical returns on investment in green fuel computed
as the rate of appreciation in prices from the green fuel price in period (t) to the dry fuel
price observed one year hence.

paper also tests whether changes in cost-of-living indices for Portland, Oregon (BLS, 1941) affect the estimated time preferences.

The regressions described above position the paper to inform the literature on the causes and exacerbating forces of the Great Depression. Prior authors qualitatively argued and empirically estimated 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. The present analysis is the first to estimate rates of time preference before, during, and after the events that characterized the Depression based on consumption choices over a household staple. These data enable a test of Romer's (1990) uncertainty hypothesis by regressing the estimated dry fuel premiums on 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.

1.3 Related Literature.

Assembling a large database of firewood prices over a period spanning 14 years capacitates tests of how rates of time preference vary over time. Intertemporal stability in time preferences comprises a gap in the otherwise well-trodden ground of studies on discount rates and time preference, (Frederick, Loewenstein, and O'Donoghue, (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. To the author's knowledge this is the first paper in which estimates of time preferences from field data are derived from a uniform context (from purchases of essentially the same product) over such a long, continuous time period.

More broadly, FLO (2002) provides the benchmark reference for laboratory and field studies on empirical discount rates. A key takeaway from FLO (2002) is that there have been many more lab-based studies than field studies. Another conclusion from FLO (2002) is the range of estimated discount rates produced by the empirical studies is very, very broad. Within this space, and especially relevant to the current work, are papers focusing on how discount rates vary (within the same experimental population) across time and according to varying financial conditions.

Importantly, the few 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 term of the lease.

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. In contrast to Hausman's seminal work (1979), the present paper aims to extract consumer's time preferences directly from price differentials in fuel. And, since the price quotes are observed contemporaneously, estimates of consumers' rates of time preference are not confounded by technological change in this setting.

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.

Over all months and wood types, the estimated premium for dry fuel is 12 percent. The estimated rates of time preference are sensitive to macroeconomic shocks that occurred

between 1922 and 1935. During the recession that occurred from 1923 to 1924, rates of time preference rose by a factor of four. Following the stock market crash of October, 1929, rates of time preference *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 estimated rates of time preference.

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 prices for fuelwood in Portland, Oregon, USA. The data were gathered from the *Portland Oregonian* online archives over the period 1922 through 1935. An example of classified ads that contain price quotes is found in figure A1. The data consist of over 14,000 price quotations that were gathered manually from classified advertisements. 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. All advertisements from each sampled day are included in the estimation dataset – provided the images on the archives were legible.

Table 1 displays the summary statistics for the price data. While there are many other 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. These types of fuel account for 97 percent of all price quotes in the sample. By far, the largest share of price quotes were for

"slab wood" which is a certain cut of softwood, likely Douglas Fir that is left over from lumber mills. Figure A2 in the appendix shows a picture of slab wood. The average price per cord was about $5. Nearly 30 percent of the advertisements 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% of price quotes do not specify the fuel's seasoning status. Another 8 percent of price quotes are for old-growth fuel. Old-growth trees are more dense than second-growth. Hence, such fuel is likely to contain more usable energy per unit volume than fuel derived from second-growth trees. The price of fuel denoted as old-growth averaged about $5.9. About 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, approximately 4 percent were for partially-seasoned wood, and 3 percent were for raw fuel. Ads for block wood contribute another 7 percent of observations. Block is another cut of softwood. Block wood is distinguished from slab wood by the dimensions of the cut: it is also a residual from saw mills, with less edging and bark than slab. This wood type is 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" comprises another 6 percent of ads. While there are several species of fir, these price quotes are likely dominated by Douglas Fir, because of the widespread distribution of this species in the Pacific Northwest, its importance in the timber industry, and its higher energy content relative to other fir

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species. 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 how fuel was often derived from other uses of wood. For example, ads for "mill" and "planer" fuel indicate demand for 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 wood-working. Ads for "wreckage" often specify that the fuel came from piers or docks that were demolished. 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: just over $8 per cord. For all types with the exception of wreckage wood, the majority of advertisements do not specify whether the fuel is raw or seasoned. Those ads that do report seasoning status most commonly report dry fuel. Fuel advertised as green is the least common of the categories of seasoning status.

Figure 1 presents the ratios of 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 are 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. There is considerable variation in the price ratio. The maximum price differential occurred in 1929, prior to the stock market crash. 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 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 a smaller range in the relative prices, and fewer cases in which green fuel prices exceeded those of dry fuel. It also appears from the figure that the relative prices rise through the 1920's before falling during the early 1930's.

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 evidence of the premium consumers are willing to pay for seasoned fuel. Across all wood types, dry fuel averages about $5.9 per cord, whereas green fuel averages just $5.3. This suggests a dry fuel premium relative to green fuel of about 10 percent. Dry fuel is also more expensive than either partially-dry fuel or that without seasoned status denoted in the advertisement. The average price for dry slab is $5.7 per cord, which is about 22 percent higher than the average price for green slab wood. Dry fuel also is about 23 percent more expensive than partially-seasoned fuel. The price for dry slab is 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 the price of wood without seasoning information posted in the advertisement. Similarly, the price of raw slab fuel is not statistically different from the price of partially-seasoned slab wood.

The premium for dry old-growth wood is considerably smaller in percentage terms. The average price of dry old-growth wood is just 8 percent higher than for green old-growth wood. The price of dry old growth wood is 3 percent smaller than fuel without reported

seasoning status (p < 0.05). Counterintuitively, dry old growth fuel is 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 are 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 is about 7 percent higher than green wood (p < 0.01), 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. However, as section 2.1 describes, controlling for temporal fixed effects and other confounders will help to identify time preferences.

The empirical analysis also employs the monthly Consumer Price Index (CPI), (McCusker, 1992). Daily values for the Dow Jones Industrial Index is provided by Measuring Worth (https://www.measuringworth.com/). Monthly yields on U.S. government bonds is provided by the U.S. Federal Reserve (Federal Reserve, 1943). Cost-of-living indices 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).

2.1 Estimation of Discount Rates.

The primary regression used to elicit time preference is essentially a hedonic price model that describes fuel prices as a function of attributes of the fuel, hourly wages, macroeconomic confounding factors, year, month of year, seasonal, and wood type fixed effects. Also included in the models is a quadratic time trend. The dataset is an unbalanced panel in the sense that there are multiple price quotes for different wood types, by month-of-sample. Figure A3 in the appendix reports the total number of price quotes across the 14 years. Recall that the data collection methodology encompassed all price quotes in all advertisements in the *Portland Oregonian* on a given day for each month. 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.

The specification of the hedonic models begins parsimoniously and sequentially adds additional controls. In (1), the model includes only a time trend, $f(t)$, year (γ_t) and fuel type (T_i) fixed effects, and controls for seasoned status of the fuel ($\varphi_{i,t}^S$).

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

Model (2) includes seasonal fixed effects, denoted S_j.

$$ln(P_{i,t}) = \beta_0 + \sum_{i=1}^{N} \beta_i T_i + \sum_{s=1}^{4} \alpha_s \varphi_{i,t}^S + f(t) + \gamma_t + \sum_{j=1}^{4} \theta_j S_j + \varepsilon_{i,t} \tag{2}$$

Model (3) includes the consumer price indices (CPI), and monthly yields for U.S. Treasury bonds, the Dow Jones Industrials Index, and hourly wages for Portland, Oregon. These

covariates are subsumed into $(\mu_t F_t)$, in (3). Also included is the quantity of fuel for sale in each ad $(Q_{i,t})$.

$$ln\big(P_{i,t}\big) = \beta_0 + \beta_q Q_{i,t} + \sum_{i=1}^{N} \beta_i T_i + \sum_{s=1}^{4} \alpha_s \varphi_{i,t}^s + f(t) + \gamma_t + \sum_{j=1}^{4} \theta_j S_j + \mu_t F_t + \varepsilon_{i,t} \quad (3)$$

Finally, (4) expresses the CPI, bond yields and the Dow in monthly changes, as well as including cost-of-living indices for rent, food, and clothing, for Portland, Oregon (BLS, 1941). These controls are represented below in the index G_t.

$$ln\big(P_{i,t}\big) = \beta_0 + \beta_q Q_{i,t} + \sum_{i=1}^{N} \beta_i T_i + \sum_{s=1}^{4} \alpha_s \varphi_{i,t}^s + f(t) + \gamma_t + \sum_{j=1}^{4} \theta_j S_j + \omega_t G_t + \varepsilon_{i,t} \quad (4)$$

The parameter estimates of interest are the $\{\alpha_s\}$ terms. To facilitate interpretation of the parameter estimate for dry fuel as a discount *rate*, or *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 percentage premium for dry fuel. It is the empirical estimate of the rate of time preference or discount rate.

2.2 Estimation of Temporal Stability in Time Preferences.

In addition to the estimation of the hedonic models across the entire sample period, a series of regressions fit (4) to subsamples of the data to test whether and how the parameter estimates of interest vary across time. This is executed in two ways; dry fuel premiums are computed for each of the 14 years of data in the sample and for each of the 168 months of the sample.

Few empirical contexts in the literature facilitate testing for time series heterogeneity in rates of time preference. 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 and 1932, the recessions in 1923 – 1924 and 1926 – 1927, and the entire period comprising the Great Depression.

Testing for time series variation in time preference begins simply, by conducting t-tests of the fitted discount rates in "treatment" and "control" periods. For example, the full sample (168 months' worth) of estimated discount rates 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 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 events listed above.

Of course, also of interest is how the estimated rates of time preference respond to continuously measured factors that might reasonably be considered to influence intertemporal choice. Again, the unique time series nature of the data affords a new opportunity to test how macroeconomic covariates affect time preferences. Model (5) frames these tests, by regressing the estimated dry fuel premiums, by month-of-sample, on a collections 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*), and cost-of-living indices (*COLI*).

$$\hat{\alpha}_{dry,t} = \beta_0 + \theta_0 M_t + g(t) + W_t + \theta_0 CPI_t + \theta_1 Bond_t + \theta_2 Dow_t + \theta_3 COLI_t + \epsilon_t$$

$$(5)$$

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.

3. Empirical Results.

Table 3 presents the estimated dry fuel premiums using pricing data for four categories and types of wood: all wood types, all types of wood fuel *conditional on some type being reported,* slab, and old-growth. Green, or raw, fuel is the excluded case. The parameter estimate for dry fuel, inclusive of all wood types, across all 14 years of data is 0.126. The coefficient is highly significant (p < 0.01). This result suggests that consumers' are willing-to-pay about 12 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. 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. Fuel without any information about seasoning sells at a small (4 percent) premium over green fuel.

The second column of table 2 restricts the estimation sample to advertisements that report some type of fuel. With this subsample, the coefficient on dry fuel falls to 0.108 (p < 0.01). Partially-seasoned fuel sells at a modest discount with respect to green fuel.

The coefficient for dry fuel, restricting the sample to prices for slab wood, is 0.167, suggesting prices are about 17 percent higher for dry wood than for raw wood. The coefficient is highly significant (p < 0.01). In addition, the prices for both partially-seasoned fuel and those ads without any seasoning information are not distinguishable from prices for green fuel.

A key difference in restricting the sample to just slab wood prices is the homogeneity of the fuel being priced. That is, the results in the first two columns of table 3 include very different fuel types (such as oak and wreckage). Although the models include wood type fixed effects, unobserved, time-variant confounding factors for these different fuel types may affect the estimated dry fuel premiums.

When the sample is restricted only to ads for old-growth fuel, table 3 reports that consumers are willing-to-pay a 12 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.

If we are to interpret the dry fuel premiums as indicative of consumers' discount rates, it is logical to ask how these estimates compare to estimates in the literature. FLO (2002) provide a summary of empirically estimated discount rates. Focusing on field studies, FLO report a range of between 0 and 300 percent for estimated discounted rates in contexts in which the tradeoffs involve monetary rewards. Hausman's seminal paper (1979) estimated discount rates between 5 and 89 percent. Gateley (1980) found a range between 45 and 300 percent. The work of Warner and Pleeter (2001) suggested discount rates of between

0 and 71 percent. Several field studies included in the summary presented in FLO focus on discount rates revealed by choices involving health and longevity. Moore and Viscusi (1988, 1990a, 1990b) report a much narrower range of between 1 and 14 percent. Similarly, Viscusi and Moore (1989) find a discount rate of 11 percent for health-related choices. Clearly, the estimates of dry fuel premiums reported in table 3, which are suggestive of consumers' discount rates, fall within the very wide range for field studies covered by FLO (2002). Although, as stated above, unobservable attributes of the fuel limit one's ability to interpret the coefficients on dry fuel as individual discount rates, the degree to which consumers' appear willing-to-pay for goods available for immediate consumption relative to goods that are seasoned for one year, is strikingly similar to those estimated in the health-choice papers in FLO (2002).

The dry fuel premiums reported in table 3 are also quite similar to those in Lawrence (1991) who extracts rates of time preference from the Panel Study of Income Dynamics. Krupka and Stephens (2013) estimate discount rates ranging from 40 to 90 percent, well above the range of rate reported herein.

3.1 Sensitivity of Estimated Dry Fuel Premiums to Model Specification.

Table 4 reports the dry fuel premiums for all wood types with various specifications of the hedonic model. Column (4) corresponds to the default specification reported in table 3. Beginning with column (1), this specification includes only year fixed effects and a quadratic time trend, along with the controls for seasoned status of the fuel. Using this specification, the estimated dry fuel premium is 13.5 percent. Adding season and month-of-year fixed effects yields an estimated dry fuel premium of 13.8 percent. Incorporating the

CPI, wages, controls for alternative investment choices (the Dow Jones Industrials index, and yields of 10-year U.S. Treasury bonds), and cost-of-living indices (COLI) for Portland, Oregon reduces the dry fuel premium to 13.2 percent. Finally, expressing the controls in month-over-month changes drops the dry fuel premium to 12.6 percent, the value reported in table 3.

Table 5 reports the dry fuel premiums for slab wood types across the four specifications of the hedonic model. Like table 4, column (4) in table 5 corresponds to the default specification reported in table 3. In column (1), with only year fixed effects and a quadratic time trend, along with the controls for seasoned status of the fuel, the estimated dry fuel premium is 19.6 percent, three percentage points higher than the premium derived from the default specification. Adding season and month-of-year fixed effects yields an estimated dry fuel premium of 19.2 percent. Incorporating the CPI, wages, the Dow Jones Industrials index, yields of 10-year U.S. Treasury bonds, and the COLI for Portland, Oregon reduces the dry fuel premium to 16.8 percent. And, expressing the controls in month-over-month changes drops the dry fuel premium to 16.7 percent, the value reported in table 3.

Table 5 suggests that the explanatory power of the model is markedly improved upon the inclusion of the CPI, wages, the Dow Jones Industrials index, yields of 10-year U.S. Treasury bonds, and the COLI. Further, the dry fuel premium is sensitive to the change in specification from the model in column (2), to that in column (3).

3.2 Annual Variation in Time Preferences.

Figure 3 shows the estimated dry fuel premiums, by year, for all wood types and for slab wood from 1922 to 1935. In each case, observations are restricted to a particular year, and

the dry fuel premium, relative to raw fuel, along with 95 percent confidence intervals, are computed using the specification in (4) and plotted. The left panel of figure 3 shows the results inclusive of price data for all wood types. Estimated dry fuel premiums rise from a statistical zero in 1922 to over 20 percent in 1924. From 1925 through 1928, the discount rates fall 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, discount rates fall to zero. Then, the estimated rates of time preference 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. 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 willingness-to-pay for fuel available for immediate consumption, relative to fuel that must be seasoned for about one year. 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 right hand side of figure 3 focuses on the dry fuel premium estimated from pricing data 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 1926 and 1929. Then, after 1929, the estimated premium dropped to under 10 percent in 1930, 1931, and 1932. The dry fuel premium never exceeded 10 percent in the last years of the sample. As above, it is important to re-emphasize that the dry fuel premium is not a direct estimate of consumers' rates of time preference. That said the right-hand panel of figure 3

highlights an apparent structural change in consumers' WTP for fuel for immediate

consumption relative to that delayed by one year before and after the Great Crash of

October 1929. The paper explores factors that may help to explain these changes in section

3.3.

One position with respect to intertemporal preferences is that these are fixed over time.

This view leads one to conclude that factors other than time preferences drive the dramatic

increase in the relative price pf dry fuel in the 1920's. Yet, the recent literature is clear;

some evidence suggests temporal stability (Meier and Sprenger, 2015), while other papers

detect time series variation in discount rates (Krupka and Stephens, 2013). Meier and

Sprenger (2015) provide a review of the few studies that have targeted temporal stability

in time preferences. Perhaps most relevant to the present study is Krupka and Stephens

(2013) who find longitudinal variation in discount rates. In particular, they find that

discount rates increase by nearly 30 percentage points from sampled months in 1972 to

late 1973. The fact that a controlled experimental study detected temporal variation in time

preferences lends support to the argument that intertemporal choice parameters at least

played a role in the time series variation in dry fuel premiums during the 1920's and

1930's.

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. 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 almost 60 percent. In the course of the second

recession, the estimated dry fuel premiums gyrate 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 decline; during no month following 1929 do the estimated premiums exceed 20 percent.

Table 6 employs the month-of-sample dry fuel premiums to test whether and how they respond to the severe macroeconomic shocks that occurred during the 1922 to 1935 period. The first row of table 6 reports the average dry fuel premiums estimated during the months of both recessions and those estimated in the non-recession months. (Recessions occurred from May of 1923 to June of 1924 and then again from October of 1926 to November, 1927.) This comparison reveals a stunning increase in apparent rates of time preference *during the recessionary months.* Specifically, the average dry fuel premium is 20 percent during the recessions and just under 7 percent in non-recessionary months. The difference is highly significant (p < 0.000). The second and third rows of table 6 further decompose the results according to the first recession (May, 1923 to June, 1924), and the second recession (October, 1926 to November, 1927). These results clearly indicate that time preference was affected by conditions during the first recession and not the second. The estimated dry fuel premiums during the 1923-1924 downturn were four-times greater than dry fuel premiums estimated in months *not during this recession.* The difference in dry fuel premiums is highly significant (p < 0.000). 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 6 also displays the t-test of average dry fuel premiums for months during the Great Depression. Two aspects of this test are noteworthy. First, the estimated dry fuel premiums are *lower* during the Great Depression 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. Second, the difference in dry fuel premiums is relatively small (just 3.1 percentage points), and only marginally significant ($p < 0.10$) relative to the comparison made for the first recession.

The final test in table 6 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 11.9 percent. For the months after the crash, consumers' impatience falls; the dry fuel premium is estimated to be 5.0 percent during the months after the crash. The difference between these two estimated rates is significantly different from zero at conventional levels ($p < 0.001$).

Both the 1923 to 1924 recession, the stock market crash, and the Great Depression appear to have affected consumers' time preferences. 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 6: 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.

The detected increase in patience after the crash and during the Depression revealed in table 6 is more difficult to parse. Hall and Ferguson (1998) note that, following the crash of October 1929, household consumption expenditures fell because of the decline in household wealth. This fact, in and of itself, would not explain a drop in discount rates. Temin (1976) and Romer (1990) argue that the large decline in consumption was primarily driven by fluctuations in, and ultimately the decline in, stock prices. This literature viewed stock prices as a measure of uncertainty in future economic conditions, especially income. 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. To synthesize these arguments; the driving force behind the unusually large reduction in consumers' expenditures was not so much the roughly 17 percent reduction in personal income (Friedman and Schwartz, 1963), but rather the increased uncertainty about future economic conditions (Hall and Ferguson, 1998; Romer, 1990). And, crucially, heightened uncertainty increased the demand for money respective to other assets that could be acquired and held (Friedman, 1956). 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 hold cash, (to reduce

consumption of *those goods the acquisition of which could be delayed*) one way that this behavior could manifest is through increased patience.

The results from table 6 herein certainly support this position. The estimated rates of time preference, gleaned from prices for a household staple, 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 by over one-half following the crash. 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. Thus, they held more cash than if they had purchased dry fuel. This behavior would reduce demand for dry fuel and the premium paid for it. By delaying consumption of fuel, their measureable patience increased. In contrast, during a short, mild recession consumers revealed less patience, tilting their focus *toward the present*; a more typical response to an adverse income shock.

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 6. 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 channel that is most relevant to the results in table 6. If consumers' expected the price level to continue to fall, they are more likely to hoard cash so that they can consumer 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. This is

consistent with the increased patience observed in table 6.

The arguments above connect the t-tests in table 6 to the prior literature. In order to more

rigorously test how dry fuel premiums were affected by the various economic forces at

work, table 7 presents the results of the regression that seeks to explain the month-of-

sample dry fuel premiums as a function of: hourly wages, returns on investment in stocks

and bonds, inflation, and various measures of the cost-of-living in Portland, Oregon.

Table 7 displays the results from four different models. In each, the dependent variable is

the estimated month-of-sample dry fuel premiums used in table 6. In addition to the

variables listed above, the models control for time trends and for month-of-year fixed

effects, along with an indicator for the stock market crash of October 1929, the two

recessions, and the Great Depression. 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[4] (averaged across occupations, by month-of-

sample) in the regression in addition to the recession, crash, and depression indicators.

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 ($p < 0.01$); a one-unit increase in the standard deviation is associated with a 0.71

percent increase in the dry fuel premium. Table 7 shows that in all four models, the

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[4] 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.

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, 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 7, the indicator variables for the crash of 1929, and the recession in 1926 – 1927 are not significantly associated with the dry fuel premiums. In contrast, the 1923 – 1924 recession indicator is highly significant ($p < 0.01$). The coefficient ranges between 0.14 and 0.19 in models (1) through (4). The depression indicator is not significant in model (1).

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). Model (2) also includes interactions between wages and the measures of inflation. The standard deviation of inflation is significantly ($p < 0.01$), positively associated with the dry fuel premium. The coefficient on the standard deviation in wages remains positive and significant. The magnitude of the coefficient rises by a factor of about three relative to model (1). The interaction term between the standard deviations of wages and inflation is significant and negatively associated with the dry fuel premiums ($p < 0.01$).

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, while that of the standard deviation of wages (both directly and through inflation) is negatively related to rates of time preference ($p < 0.01$). The latter result, that uncertainty in wages induces a reduction in discount rates, or an

increase in patience, broadly comports with Bernanke's (1983) and Romer's (1990) arguments as to the root causes of the reduction in consumption expenditures following the crash. Uncertainty regarding future economic conditions induces an increase in consumers' patience.

The coefficient on the 1923 – 1924 recession remains positive and significant ($p < 0.01$). The depression indicator now shows a marginally significant and negative effect on the dry fuel premiums ($p < 0.10$).

Column (3) includes means and standard deviations (again, over six month lagged values) of returns on the Dow Jones Industrials, U.S. Treasury yields, and rates charged on commercial paper. The standard deviation of returns on the Dow Industrials is significant and negatively related to dry fuel premiums ($p < 0.01$). 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 was a primary cause of reductions in consumer expenditures on durables. In the present context, this metric is also strongly associated with a reduction in consumers' impatience; fluctuations in stock returns induces consumers to become more patient. And it comports with the effect of variability in wages; gyrations in wages or stock returns is a signal about uncertainty in future economic conditions. Both effects appear to reduce discount rates, suggesting consumers become more patient in such times.

The standard deviation in U.S. Treasury yields is positive and significant ($p < 0.01$). 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 impatience, or willingness to consume in the present. 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 discount rate. The positive coefficient also reinforces the positive effect that uncertainty in inflation (as measured by relative changes in the CPI) has on time preferences. Rates charged on commercial paper are not related to dry fuel premiums in model (3).

As in models (1) and (2), the coefficient on the 1923 – 1924 recession remains positive and significant ($p < 0.01$). Akin to model (2), the depression indicator shows a significant and negative effect on the dry fuel premiums ($p < 0.10$).

The effect of wages and inflation, along with their interactions, are robust to the inclusion of the Dow, U.S. Treasury yields, and rates on commercial paper in model (3). In particular, the standard deviation of wages is, taken together with the interaction term on the standard deviation of inflation, significant and negatively related to the dry fuel premiums ($p < 0.01$). Likewise, the standard deviation of inflation is positively associated with the dry fuel premiums.

Column (4) includes three different cost-of-living indices for Portland reported by the Bureau of Labor Statistics (BLS, 1941): for rent, food, and clothing. Variability in the rental cost index is inversely related to discount rates ($p < 0.10$). The mean has no effect. Neither the food index nor the clothing index is associated with rates of time preference. The coefficients for uncertainty in the Dow Jones, U.S. Treasury yields, and wages (through the direct control and the interaction with inflation) are robust to the inclusion of the cost-of-

living indices. The 1923 – 1924 recession indicator remains significant in model (4). The depression indicator is no longer significant. The effect of wages and inflation (both in standard deviations) remains as in previous specifications.

The results in table 7 suggest that uncertainty in economic conditions plays a central role in shaping consumers' time preferences. Variability in wages, inflation, and 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 7 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).

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 rates of time preference respond to wages, inflation,

returns of various investments, and costs-of-living. The particular time period under study also facilitates unique tests of how the macroeconomic shocks during the 1920's and 1930's affected time preference.

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. This yields an estimate of consumers' time preferences; green and seasoned fuel are perfect substitutes but for the fact that a consumer must wait roughly one year to use green fuel.

Controlling for time trends, monthly and seasonal fixed effects, a battery of macroeconomic indicators, and wood type fixed effects, the estimated dry fuel premiums is about 12 percent. The analysis of factors that determine or affect consumers' rates of time preference reveal 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 discount rates. This is also true for inflation (as measured by the CPI), monthly returns on the Dow Industrials, and U.S. Treasury bond yields. More specifically, the paper reports that variation in wages and inflation (the joint effect through an interaction with the standard deviation in inflation and the direct effect of wage uncertainty) negatively affect rates of time preference. The fact that the present analysis finds no consistent evidence that wages (in levels) affects consumers' time preference runs counter to findings in the literature (Lawrance, 1991; Newell and Siikamaki, 2015). However, significant apparent instability in time preferences has been detected in other studies (Krupka and

Stephens, 2013). Rather, the results herein suggest that fluctuations in wage income are critical in determining intertemporal choice. The negative coefficient on standard deviations in stock returns suggests that uncertainty in capital income also diminishes rates of time preference. The negative coefficients on wage and capital income both relate to the uncertainty hypothesis (Romer, 1990) which is a prominent argument as to what explains the dramatic reduction in consumer expenditures that was observed following the stock market crash of 1929.

The paper also is in a unique position to tests how macroeconomic shocks between 1922 and 1935 affected consumers' rates of time preference. The recession that occurred from 1923 to 1924 had a large, positive effect on dry fuel premiums: the estimated rates are four-times higher during that recession than in other months. Similarly, the dry fuel premiums prior to the stock market crash were about two-times larger than those estimated afterwards. Finally, the Great Depression (defined as August 1929 through March of 1933) suppressed dry fuel premiums only modestly.

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 prices driven by time preferences during the 1920's and 1930's affords new opportunities to explore aspects of consumer behavior during that time. Most directly, the paper provides evidence that consumers became significantly more patient – likely hoarding cash – after the crash of 1929. In addition, uncertainty in their economic futures, as measured by variability in both

capital and wage income suppressed impatience. Both effects contribute to the understanding of what led to the precipitous fall in consumption (especially of durables) in the early 1930's. Of course, Portland, Oregon does not the entire country make. However, 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 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 Information	5.467	4.751	5.926	5.369
	(1.521)	(0.917)	(1.112)	(1.462)

A = 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	0.126***	0.108***	0.167***	0.122***
	(0.0127)	(0.0117)	(0.0115)	(0.0269)
Partially	-0.0139	-0.0348***	-0.00349	0.114***
Seasoned	(0.0131)	(0.0121)	(0.0118)	(0.0281)
No Season	0.0412***	0.0127	0.0131	0.152***
Data	(0.0124)	(0.0114)	(0.0113)	(0.0214)
adj. R^2	0.428	0.438	0.418	0.539
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: All Wood Dry Fuel Premium: Sensitivity to Alternative Specifications.

	(1)	**(2)**	**(3)**	**(4)**
Seasoned	0.135***	0.138***	0.132***	0.126***
	(0.0128)	(0.0128)	(0.0129)	(0.0127)
Year Fixed Effects	X	X	X	X
Time Trend				
Season, Month, Fixed Effects		X	X	X
CPI, Dow Jones, Wages, Bond Yields			X	X
COLI			X	X
Month-Month Changes				X
adj. R²	0.350	0.365	0.398	0.428
N	14398	14398	14398	14363

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

Table 5: Slab Wood Dry Fuel Premium: Sensitivity to Alternative Specifications.

	(1)	(2)	(3)	(4)
Seasoned	0.196***	0.192***	0.168***	0.167***
	(0.0137)	(0.0135)	(0.0118)	(0.0115)
Year Fixed Effects	X	X	X	X
Time Trend				
Season, Month, Fixed Effects		X	X	X
CPI, Dow Jones, Wages, Bond Yields			X	X
COLI			X	X
Month-Month Changes				X
adj. R²	0.177	0.197	0.394	0.418
N	6561	6561	6561	6541

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.

Table 6: Sensitivity of the dry fuel premiums to macroeconomic conditions.

Event	Dry Premium During Event[1]	Dry Premium Not During Event	T-Statistic of Difference
Both Recessions	0.200 (0.036)[2]	0.068 (0.007)	-6.050*** [0.000][3]
May, '23 – June, '24 Recession	0.277 (0.053)	0.072 (0.007)	-7.379*** [0.000]
Oct., '26 – Nov., '27 Recession	0.117 (0.039)	0.087 (0.009)	-0.912 [0.182]
Great Depression	0.065 (0.008)	0.098 (0.012)	1.691** [0.057]
Crash of Oct., 1929	0.050[4] (0.006)	0.119 (0.014)	4.069*** [0.000]

1 = Average coefficient on variable denoting dry fuel. Green fuel is the excluded case. Derived from regression model with natural log of price as dependent variable, hence coefficient of 0.200 implies discount rate of 20%.
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 7: Determinants of the dry fuel premium.

	(1)	(2)	(3)	(4)
Wage	0.707**	2.462***	3.049***	2.547***
SD	(0.282)	(0.607)	(0.612)	(0.778)
Wage	0.0955	0.147	0.110	0.127
Mean	(0.0869)	(0.0947)	(0.153)	(0.193)
Recession	0.177***	0.144***	0.180***	0.192***
(1923 – 1924)	(0.0508)	(0.0436)	(0.0413)	(0.0542)
Depression	-0.0287	-0.0539*	-0.0514*	-0.0311
	(0.0266)	(0.0289)	(0.0279)	(0.0311)
Inflation		34.26***	42.59***	35.22**
SD		(9.928)	(10.10)	(14.52)
Inflation		-12.16	-16.21	-12.48
Mean		(8.967)	(10.38)	(17.42)
Wage x Inflation		16.57	23.95	16.14
Mean		(15.68)	(18.02)	(28.45)
Wage x Inflation		-324.7***	-394.2***	-313.9***
SD		(96.25)	(95.58)	(119.6)
Dow Jones			-1.111***	-0.805*
SD			(0.310)	(0.427)
Dow Jones			0.319	0.399
Mean			(0.366)	(0.509)
U.S. Treasury Yield			4.094***	4.052***
SD			(0.978)	(0.999)
U.S. Treasury Yield			-0.857	0.210
Mean			(0.895)	(1.392)
Commercial Paper Rate			-0.0407	-0.166
SD			(0.194)	(0.232)
Commercial Paper Rate			-0.126	-0.111
Mean			(0.318)	(0.433)
COLI Rent				-0.0441*
SD				(0.0241)
COLI Rent				0.00145
Mean				(0.00371)
adj. R-sq	0.397	0.471	0.526	0.539
N	150	150	149	149

Standard errors in parentheses

* p<0.10   ** p<0.05   *** p<0.01"

Figures.

Figure 1. Ratio of Dry Fuel to Green Fuel Prices.
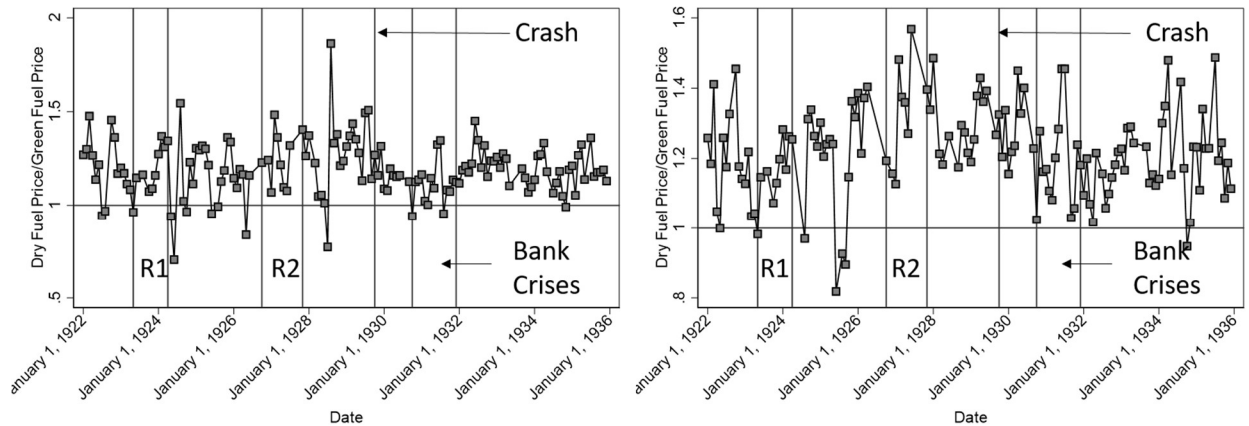
Left panel: all wood types. Right panel: slab wood.

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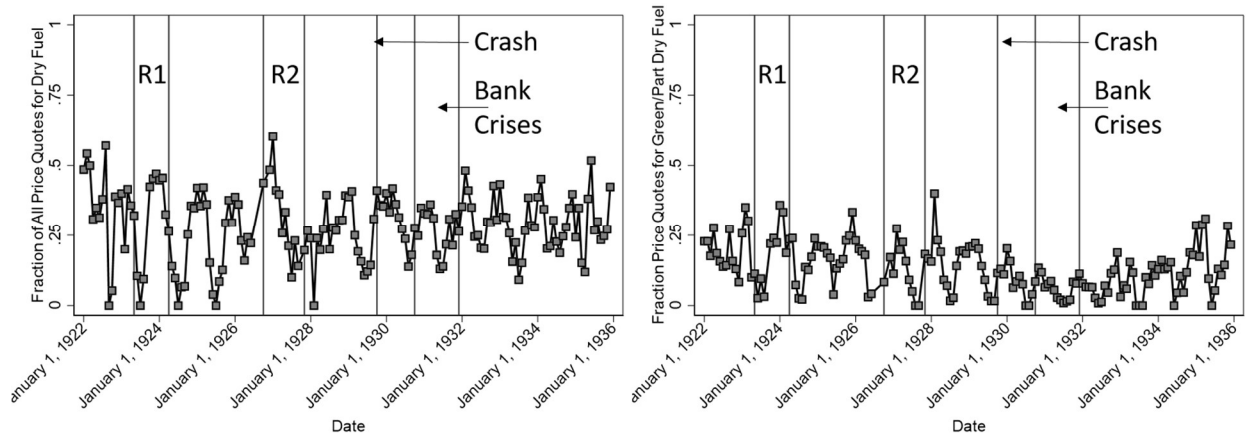
Source: *Portland Oregonian,* Various from 1922 – 1935.

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.
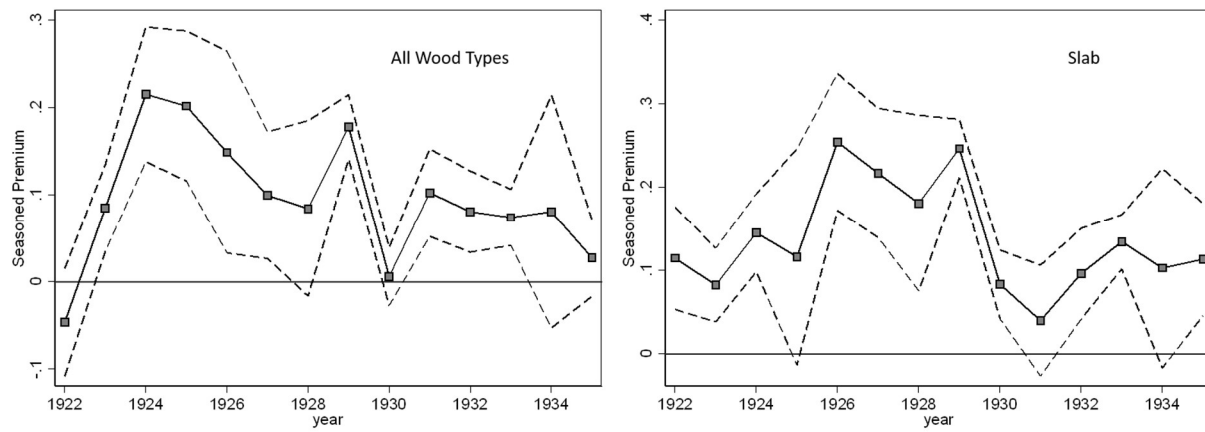
Dashed lines are 95% confidence intervals.

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

Figure 4: Month of Sample Dry Fuel Premium.
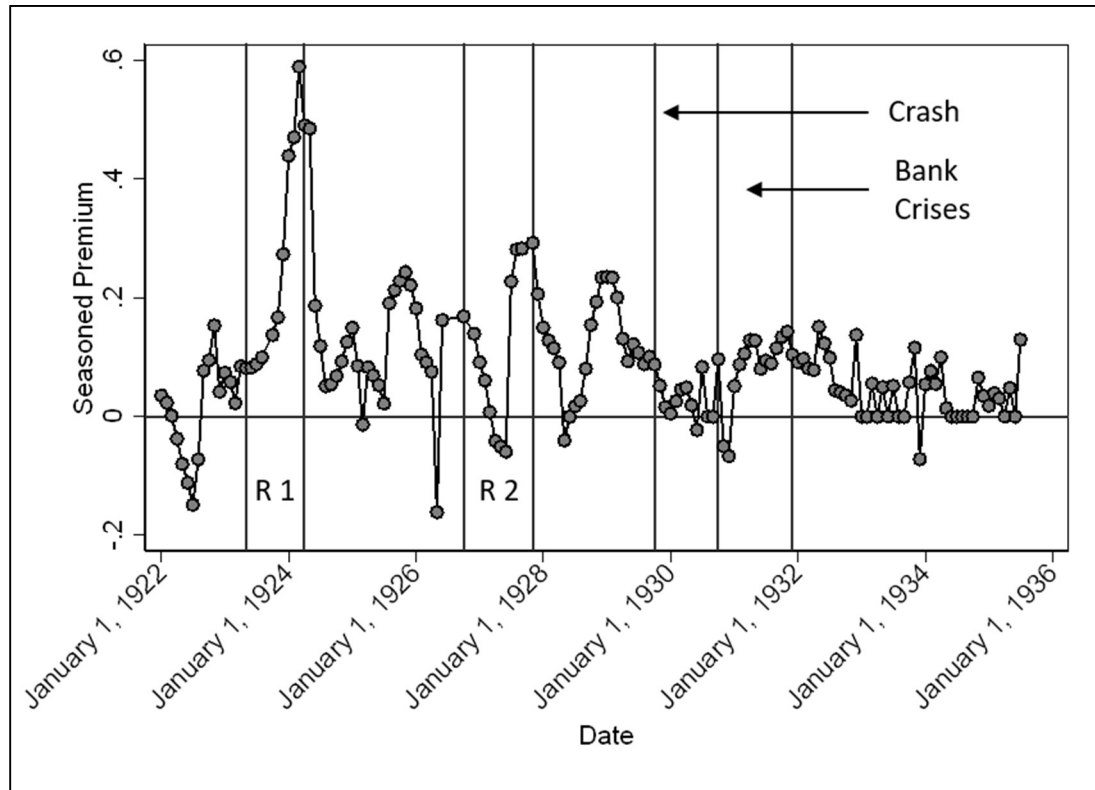
Source: *Portland Oregonian,* Various from 1922 – 1935.

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).

Appendix.

This supplementary appendix covers two topics: the methods and results used to model dry fuel premiums when the assumption that consumers allow green fuel to season for one full year is relaxed, and, a systematic comparison of the apparent rate of return on green fuel investments relative to other common investments.

1. **Dry Fuel Premiums and Rates of Time Preference That Reflect Seasoning Periods Other Than One Year.**

The interpretation of the coefficient corresponding to the dry fuel premium as indicative of discount rates assumes that green fuel is allowed to season for one full year before consumption. However, it is possible that consumers instead optimize their timing of consumption of fuel depending on the savings they earn relative to dry fuel. This depends on two factors: the rate of seasoning and the subsequent (post purchase of green fuel) price fluctuations in dry fuel. To model this, data on drying times of Douglas Fir in Portland, Oregon provided by the United States Department of Agriculture (USDA) are used (Simpson and Hart, 2000). The relevant plots are shown in figure A12 of the appendix.

The calculations involve the following steps. Let $\{\widehat{\alpha_{dry,m}}\}$ represent the fitted coefficient for dry fuel in month of year $m.$ Assume that consumers burn the fuel (purchased in a green state) when doing so maximizes the rate of savings relative to purchasing dry fuel. To determine this "optimal" time of consumption, one first needs to calculate the moisture content of the fuel. These calculations rely on data provided by Simpson and Hart (2000).

Moisture content at time $(m{+}t)$, that is, (t) months after purchase during month-of-year (m)

is given by $\mathcal{M}_{m+t} = \begin{cases} 37 - \kappa_1(days) & if: days < \omega_{1,m} \\ \kappa_2(days) & if: \omega_{1,m} < days < \omega_{2,m} \\ \kappa_3(days) & if: days > \omega_{2,m} \end{cases}$ \hfill (A.1)

Moisture is modeled as a piecewise linear function of the days in storage ($days$). For each

month of purchase (m), the knots of the piecewise function ($\omega_{1,m}$) differ as do the

incremental reductions in moisture with each passing day embodied in the (κ_d for $d =$

1,2,3) parameters. The knots are determined by the moisture thresholds identified in

Simpson and Hart (2000): 25 percent, 20 percent, and 18 percent. Above, 37 corresponds

to the moisture content (percent) of green Douglas Fir. Next, the dry price equivalent

$(p_{g,m}^d)$ is calculated by dividing the green price by one minus the moisture content: $p_{g,m}^d =$

$\left({p_{g,m}}/{(1 - \mathcal{M}_{m+t})} \right)$. To estimate the rate of savings from using (partially-seasoned) green

fuel (t) months after purchase, the natural log of the price relatives is computed:

$ln\left({p_{m+t}}/{p_{g,m+1}^d} \right) - 1$. Then, the time period after purchase is identified which maximizes

savings:

$t^* = max_t \left(ln\left({p_{m+t}}/{p_{g,m+1}^d} \right) - 1 \right)$ \hfill (A.2)

Finally, assuming consumers use the fuel that was purchased raw during month (m) at (t^*),

the $\{\widehat{\alpha_{s,m}}\}$ coefficient for dry fuel is adjusted in the following manner:

$\hat{\rho} = \left(1 + \{\widehat{\alpha_{dry,m}}\}\right)^{{12}/{t^*}} - 1$ \hfill (A.3)

Thus, $\hat{\rho}$ differs from $\{\widehat{\alpha_{dry,m}}\}$ if the optimal waiting period is not one year. For t^* less than 12, $\hat{\rho}$ exceeds $\{\widehat{\alpha_{dry,m}}\}$, and for t^* greater than 12, $\hat{\rho}$ exceeds $\{\widehat{\alpha_{dry,m}}\}$.

Figure A5 depicts the yield (rate of savings) associated with buying green fuel in four months of the year: March, June, September, and December. The savings rate are calculated over a range of seasoning times of from one month to 24 months. These results are for all wood types. The top-left panel indicates that burning green fuel just 30 days after purchase in March yields a *savings* of about 20 percent. That is, the observed dry fuel price one month after purchase is about 20 percent higher than the moisture adjusted green fuel price. After falling in months two and three, the rate of savings increases as the fuel ages. The rate of savings rises until about 12 months after purchase at which time consumers would save nearly 30 percent, relative to dry fuel prices at that time. With some minor differences, the form of these "yield curves" are similar across months. Although the curves are noisily estimated for some months because of few observed price quotes, each has a positive slope with respect to seasoning time. For green fuel purchased in June, shown in the top-right panel of figure A5, the maximum savings occurs about 15 months after purchase. For acquisitions of green fuel in September (bottom-left) the yield maximizing seasoning time is about 10 months. And, for December, waiting almost two years maximizes savings earned by purchasing green fuel. Figure A6 reproduces the results in figure A5 but restricting sales to slab wood. Again, the "yield curves" are positively sloped with respect to seasoning time. For purchases made in March and December (top-left panel and bottom-right panel, respectively), the yield-maximizing waiting time tends to be over 12 months. For green fuel purchased in June (top-right panel), the largest savings occurs at

three months and 15 months after purchase. And, for green fuel acquired in September, waiting until nine months after purchase maximizes savings relative to dry fuel.

Figure A7 presents the estimates of month-of-year dry fuel premiums, employing the yield maximizing seasoning time as defined in (A.2). The left-panel does so for all wood types. This graph shows that the monthly dry premiums, adjusted for the estimated optimal seasoning periods, are not dramatically different from the dry premiums that assume fuel is seasoned for one full year. Differences of about 5 percentage points manifest for premiums gleaned from prices in February, November, and December.

The right-hand panel of figure A7 focuses on slab wood. Assuming consumers wait for the savings-maximizing time before use increases the variance in the dry fuel premiums in January, February, and March. Differences between the series that adjusts the dry fuel premium by optimal seasoning time and that which assumes one year seasoning times are about 5-10 percent. After June, dry fuel premiums estimated assuming consumers maximize savings tend to be lower than those fitted by assuming consumers season wood for one year (with the exception of September).

2. 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 A1 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 A5 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. Prior to the stock market

crash of 1929, the return on investment in green fuel was about 14 percent (sd = 17). After

the crash, the return averaged 33 percent (sd = 20). 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 divergence, not

convergence.

Tables and Figures.

Table A1: Comparison of Dry Fuel Premiums to Yields on Alternative Investments.

	Pre-Crash	Post-Crash	Full Sample
10-Year Bond	7.926***	1.775***	5.301***
	(1.397)	(0.630)	(0.877)
Dow Jones	10.654***	6.107***	8.701***
	(1.505)	(1.436)	(1.070)
Commercial	11.932***	7.893***	10.208***
Paper	(1.492)	(1.735)	(1.139)
S&P	10.629***	6.103***	8.685***
	(1.481)	(1.480)	(1.069)
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.

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

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

Figure A2: Slab wood.

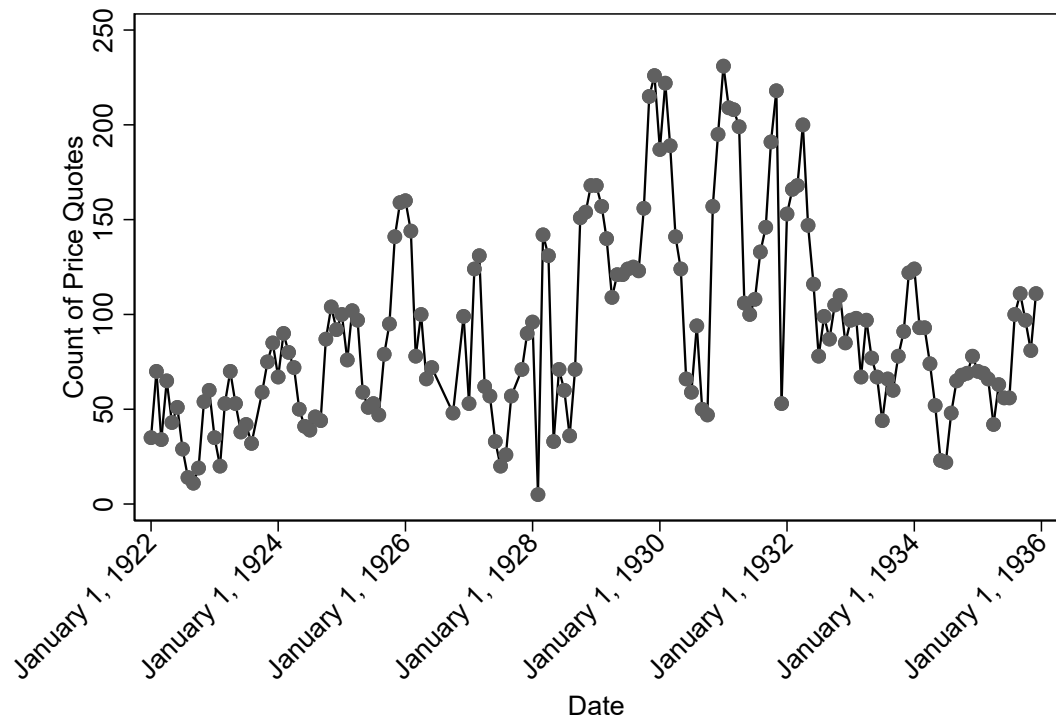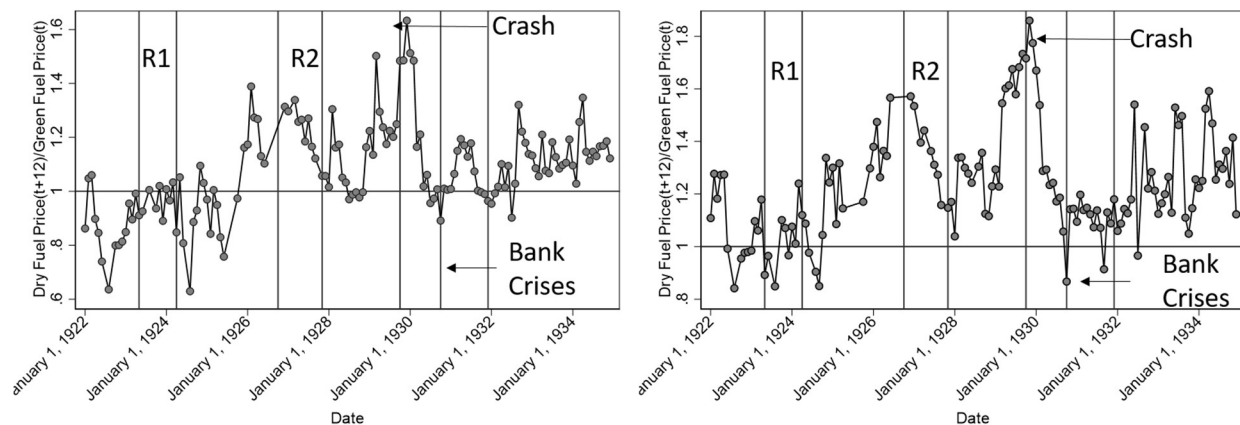**Figure A3: Month of Sample Counts of Price Quotes.**

**Figure A4: 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.

Figure A5: Firewood Yield Curves: Rate of Return on Green Fuel Relative to Dry Fuel at Different Lengths of Time Since Purchase for All Wood Types.
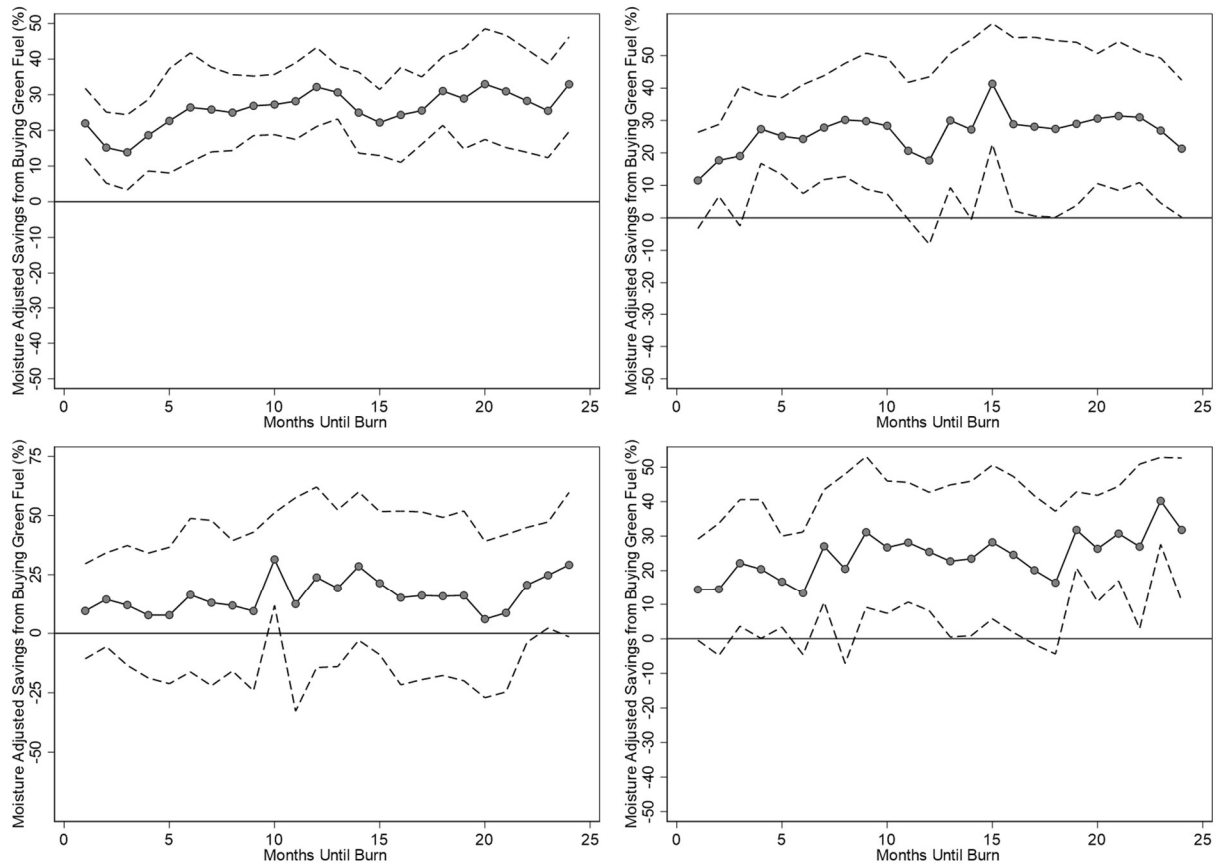


Each panel depicts the natural log of dry price to moisture adjusted green fuel price from 30 days to 365 days after purchase: $ln\left(p_{m+t}\Big/p_{g,m+1}^{d}\right) - 1$. The top left panel considers the case in which green fuel is purchased in March, top-right = June, bottom-left = September, bottom-right = December. Figure A5 considers all types of wood.

Figure A6: Firewood Yield Curves: Rate of Return on Green Fuel Relative to Dry Fuel at Different Lengths of Time Since Purchase for the Case of Slab Wood.
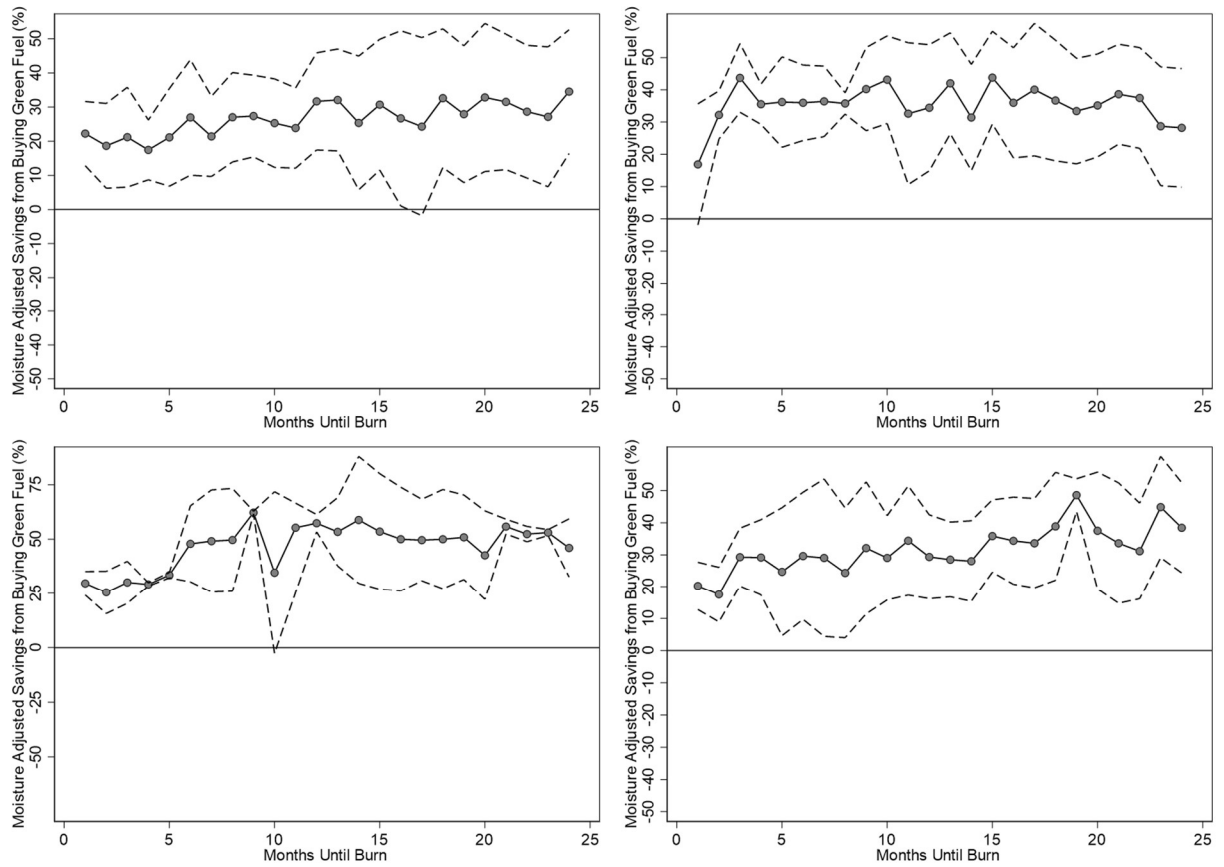
Each panel depicts the natural log of dry price to moisture adjusted green fuel price from 30 days to 365 days after purchase: $ln\left(\dfrac{p_{m+t}}{p_{g,m+1}^d}\right) - 1$. The top left panel considers the case in which green fuel is purchased in March, top-right = June, bottom-left = September, bottom-right = December. Figure A6 considers the case of slab wood.

Figure A7: Comparison of Discount Rates Computed Assuming Fuel Ages for One Year and Assuming Consumers Use Fuel at Time of Maximum Savings Relative to Dry Fuel.
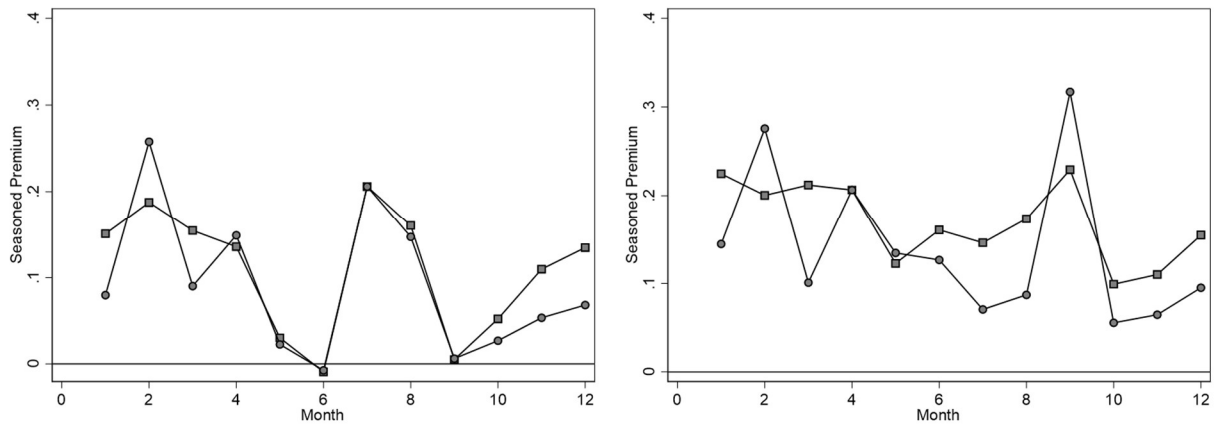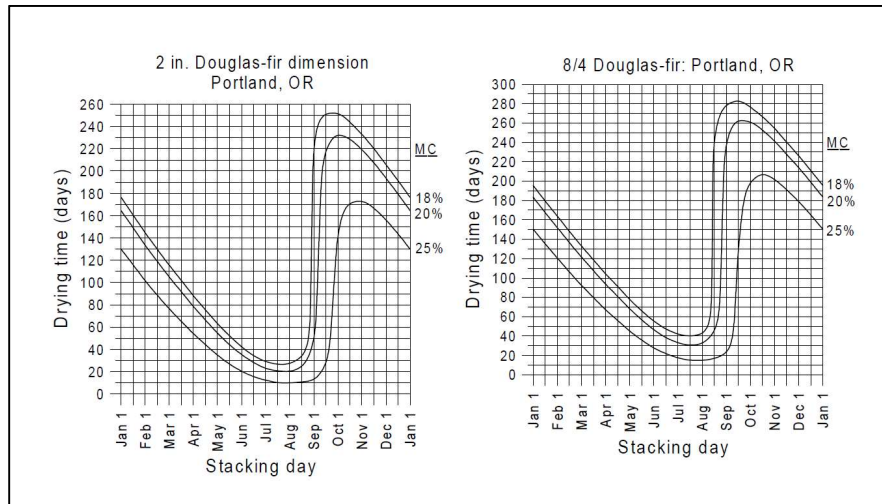

Squares: time of use is one year from green purchase.

Circles: time of use is maximum return from green purchase.

Left panel: all wood.

Right panel: slab wood.

Figure A8: Drying Time for Douglas Fir in Oregon.

Source: Simpson and Hart, 2000.