Individual Discount Rates During the Great Depression:

Evidence from Firewood Prices in Portland, Oregon.

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December, 2017

Preliminary Draft: Do Not Quote.

Abstract

The present study estimates individual discount rates on a monthly basis from 1922 to 1935. To do so, the analysis gathers price quotes for firewood data and estimates rates of time preference from the premium paid for dry, seasoned fuel, relative to green wood. Computing discount rates over 168 months facilitates a first-of-its-kind assessment of time series variation in individual discount rates. The paper examines the influence that wages, inflation, returns of stocks, yields on bonds, as well as cost-of-living indices have on individual discount rates. An assessment of how the macroeconomic shocks before, during, and after the Great Depression affected consumers' discount rates is conducted. Over the entire sample the discount rate is estimated to be 12 percent. Discount rates 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 consumers' discount rates 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 individual discount rates. This synthesis is facilitated by new primary data on the relative prices of seasoned and green firewood. These are two goods that are perfect substitutes in all respects except that dry fuel is ready for current consumption, whereas green wood must cure for about one year before use. The data are used to estimate individual discount rates on a monthly basis from 1922 to 1935. The novel approach to gleaning discount rates 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. Second, the sensitivity of individual discount rates 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 is tested. Third, in a multiple regression framework, the paper tests associations between individual discount rates and (i) indicators of financial conditions such as bond yields, returns on equity, and inflation; as well as (ii) 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 nesting 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 which facilitates identification of consumers' individual discount rates. 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, and the dataset therefore includes the following fuel attributes: type (species) of wood, quantity for sale, and whether the wood is dry or green. It is the latter attribute that permits identification of consumers' time preferences.

The construction of this dataset uniquely positions the present paper to cleanly identify consumers' individual discount rates. In a hedonic pricing framework, the price quotes reveal the premium which consumers' were willing to pay for seasoned firewood relative to raw (or green) fuel. Consider that green firewood and seasoned firewood are perfect substitutes but for the time required to age green fuel. For most wood types, 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. As such, the WTP premium for dry fuel, when expressed in percentage terms, is an estimate of consumers' private rate of discount[1].

[1] The claim that the dry fuel premium offers a clean estimate of consumers' individual discount rate 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 also 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 the households relevant to 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, 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 consumers' time preferences.

Assembling a large database of firewood prices over a time period spanning 14 years capacitates tests of how individual discount rates vary over time. Intertemporal stability in time preferences comprises a gap in the otherwise well-trodden ground of studies on 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; a recent paper examining intertemporal stability in time preference explored just three years of data (Krupa and Stephens, 2013). Conducted herein are tests for trends across years, tests of seasonality, and even month-of-year differences in discount rates. To the author's knowledge this is the first paper in which estimates of discount rates from field data are derived from a uniform context (from purchases of essentially the same product) over such a long, continuous time period.

Data spanning 168 months from 1922 to 1935 uniquely enable tests of how individual discount rates vary according to both discrete macroeconomic shocks (of which this time period is chock full) and continuously measured variables that may plausibly influence time preferences. In terms of events, the paper tests whether discount rates 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 discount rates 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 monthly yields on U.S Treasury Bonds. In addition, the analysis uses monthly wage data gathered from classified ads in the *Portland Oregonian* to assess how responsive

individual discount rates are to income fluctuations. The paper also tests whether discount rates are affected by changes in cost-of-living indices for Portland, Oregon (BLS, 1941).

The regressions described above are positioned 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. This, of course, could be interpreted as a temporary increase in patience. The present analysis is the first to estimate consumers' degree of impatience before, during, and after the events that characterized the Depression. These data enable a test of Romer's (1990) uncertainty hypothesis: by regressing the discount rates 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. Therefore, the standard deviations are incorporated to proxy for uncertainty in future economic conditions.

1.1 What is being measured?

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 consumers' rate of time preference from the firewood price data. The

paper adopts a circumspect stance between these two extremes; while the pure rate of time preference is surely embedded in consumers' WTP for dry fuel, other factors are likely at play. This motivates the inclusion of other covariates pertinent to individual time preference and consumption decisions in the models that estimate individual discount rates. The literature (FLO, 2002) provides a useful framework for consideration of confounding factors. Recall that there are two sets of empirical exercises: one that estimates the individual discount rates from WTP premia for dry fuel, and another that seeks to explain the fitted discount rates as a function of relevant covariates. Because confounders play a critical role in the former, the hedonic models include three categories of covariates: inflation and the price level, opportunity costs of capital, and, broadly, uncertainty in future economic conditions[2].

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

[2] In is important to note that other factors likely to affect individual discount rates cannot be observed or controlled for; among these are the shape of individual utility functions and expectations about income growth and resulting changes in preferences.

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 (investments in equities and fixed income securities) may also play an important role in shaping household demand for green versus dry fuel. As such, the models include yields on U.S. government bonds and returns to equities (the Dow Jones Industrials), in addition to the CPI[3]. 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 discount rates converge to the rate of interest, as they would if consumers were simply arbitraging inter-temporally.

Another important potential confound to the extraction of consumers' individual discount rates from the field is the issue of 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 assume that (or subjects are informed 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.

[3] Importantly, this context is one in which access to capital markets is limited as are opportunities for intertemporal arbitrage; it is unlikely that the average consumer in Portland, Oregon in the 1920's and 1930's was actively engaged in financial markets such that arbitraging price spreads across time was widespread. If consumers were ignoring or neglecting opportunities in capital markets, this bolsters the argument that we are observing choices based on time preference (FLO, 2002).

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 monetary savings is uncertain at the time of purchase of green fuel because the future price of seasoned fuel is unknown. Uncertainty does play a role.

In terms of the second source of uncertainty, the hedonic models control (imperfectly) for consumers' expectations regarding future economic conditions by including a battery of lagged covariates that plausibly shape expectations. These include: wages, inflation, returns to investments in equities and fixed income investments, and costs-of-living.

There are also important determinants of individual discount rates which one cannot observe and therefore cannot properly control for. One such factor noted by FLO (2002) is local curvature in the utility function. This analysis is implicitly making the assumption that consumers' utility function is linear in the magnitudes of the goods under consideration. This seems relatively innocuous in the current context since the empirical exercise is estimating discount rates based on choices over individual cords of fuel wood with average prices of about $6. That is, the context is not focusing on large reallocations of resources over time such that curvature in the utility function would play a large role in explaining relative prices. To the extent that curvature of the utility function is significant even for the small monetary value of goods in question in the present paper, then the estimated discount rates are biased upwards (FLO, 2002).

1.2 Related Literature.

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. And, second, 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 (2010) 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).

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 is able to extract consumer's individual discount rates 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.

1.3 Preview of Results.

Over all months and wood types, the estimated discount rate is 12 percent. Strong seasonal variation in time preferences is detected. Discount rates range from 8 percent during the autumn months to about 16 percent in the summer. The individual discount rates are sensitive to macroeconomic shocks that occurred between 1922 and 1935. During the recession that occurred from 1923 to 1924, discount rates rose by a factor of four. Following the stock market crash of October, 1929, discount rates *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 discount rates.

The remainder of the paper is structured as follows. Section 2 presents a parsimonious theoretical model used to demonstrate how the relative prices of green and seasoned fuel correspond to consumers' discount rates. Section 3 focuses on the data and empirical methodology. Section 4 presents the empirical results and section 5 concludes.

2. Theoretical Model: Intertemporal Choice of Raw and Seasoned Fuel.

Assume that a consumer has preferences defined by a utility function $U(q_t, q_{t+1}, g_t, c_t, c_{t+1})$ where q_t represents the quantity (in energy units, British thermal units (btu's), for example) of seasoned fuel consumed in time period (t), and g_t is the quantity of raw (green, or unseasoned) fuel *purchased* in period (t). The terms (c_t and c_{t+1}) reflect consumption of other goods. For a fixed physical quantity (gallon, mcf, cord) of green and seasoned fuel, the former contains less available energy units: $g_t < q_t$. The seasoning process enhances accessible energy content and the value of fuel. We assume that the consumer earns income (or in this setting has an endowment of wealth) in period (t), given by I_t. Prices for seasoned and raw fuel, expressed in ($/btu) are: $p_t, p_{t+1}, p_{g,t.}$ Then, focusing on just energy fuels, the present value budget constraint is given by:

$$\frac{p_{t+1}q_{t+1}}{1+i} \leq I_t - p_t q_t - p_{g,t} g_t \qquad (1)$$

where (i) is the extant rate of interest.

Then, the consumer's objective is to maximize $U(q_t, q_{t+1}, g_t, c_t, c_{t+1})$ subject to (1). Note that both (q_{t+1}, g_t) are consumed in period (t+1) despite (g_t) being purchased in period (t). Hence, $U(q_t, q_{t+1}, g_t, c_t, c_{t+1}) = u(q_t) + u(c_t) + \delta(u(q_{t+1}) + u(g_t) + u(c_{t+1}))$, where δ

represents the consumer's discount factor: $\left(\frac{1}{1+\rho}\right)$, and ρ = their pure rate of time preference.

The Lagrangian expression is shown in (2), where λ is a Lagrange multiplier.

$$L = u(q_t) + \delta(u(q_{t+1}) + u(g_t)) + \lambda\left(I_t - \frac{p_{t+1}q_{t+1}}{1+i} - p_t q_t - p_{g,t}g_t\right) \quad (2)$$

The first-order conditions for $q_t, g_t, and\ q_{t+1}$ are shown in (3a) - (3c), where $\frac{\partial U}{\partial q_t} = u'_{q_t}$.

$$\frac{\partial L}{\partial q_t} = u'_{q_t} - \lambda p_t = 0 \quad (3a)$$

$$\frac{\partial L}{\partial g_t} = \delta u'_{g_t} - \lambda p_{g,t} = 0 \quad (3b)$$

$$\frac{\partial L}{\partial q_{t+1}} = \delta u'_{q_{t+1}} - \lambda\left(\frac{p_{t+1}}{(1+i)}\right) = 0 \quad (3c)$$

Dividing (3a) by (3b), (3a) by (3c), and (3b) by (3c) yields the following Euler equations:

$$u'_{q_t} \Big/ \delta u'_{g_t} = p_t \Big/ p_{g,t} \quad (4)$$

$$u'_{q_t} \Big/ \delta u'_{q_{t+1}} = p_t \Big/ \left(\frac{p_{t+1}}{(1+i)}\right) \quad (5)$$

$$\delta u'_{g_t} \Big/ \delta u'_{q_{t+1}} = p_{g,t} \Big/ \left(\frac{p_{t+1}}{(1+i)}\right) \quad (6)$$

It is assumed that: $u'_{q_t} = u'_{g_t} = u'_{q_{t+1}}$; the marginal utility derived from energy units in raw or seasoned fuel is equal. This may seem restrictive but is entirely plausible; while the btu's per physical unit of fuel differ depending on whether the fuel is raw or seasoned, the

satisfaction derived from a btu should not, provided the technology used to convert btu's in the fuel to usable heat or power does not change.

Expression (4) is a standard result that suggests the consumer maximizes utility by equating their marginal rate of substitution (MRS) between seasoned and raw fuel purchased in period (t) to the relative prices – the absolute value of the slope of their budget constraint. However, rearranging (4) yields an insight that is pertinent to the empirical estimation pursued later in the paper; provided $u'_{q_t}/u'_{g_t} = 1$, then: $\rho = p_t/p_{g,t} - 1$. This simple expression indicates that the consumer's pure rate of time preference is revealed by the relative prices of seasoned fuel and raw fuel in period (t). This characterization of the consumer's pure rate of time preference stems from the unique empirical setting that features pricing data for perfect substitutes separated only by the time period in which the goods are available for consumption. That is, seasoned fuel embodies btus available for sale *and* consumption immediately, whereas raw fuel contains btus for sale immediately but which cannot be consumed until a future period.

Expression (5) states that the consumer maximizes their intertemporal welfare by equating their MRS of (q_t) for (q_{t+1}) to the absolute value of the slope of the budget line: $p_t(1+i)/p_{t+1}$. This is a well-known result in the context of intertemporal choice.

Rearranging (5) produces: $\rho = p_t(1+i)/p_{t+1} - 1$, an equally familiar result that simply states that the consumer equates their pure rate of time preference to the ratio of real prices across time periods.

Expression (6) suggests that the MRS between raw fuel in period (t) and seasoned fuel in period (t+1) is equated to the ratio of the present value of the seasoned fuel price in period (t+1) to the raw fuel price. Hence: $p_{g,t}(1+i) = p_{t+1}$, alternatively: $(1+i) = {}^{p_{t+1}}/_{p_{g,t}}$. In equilibrium, the price path of raw to seasoned fuel, from period (t) to (t+1) rises at the rate of interest.

3. **Data and Methods.**

The 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 A11. 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 type 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 and the ads listed key attributes ultimately included in the regression analysis.

Table 1displays 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 advertisements in the sample. By far, the largest share of advertisements were for "slab wood" which is a certain cut of softwood, likely Douglas Fir that is often left over from lumber mills. Figure A3 in the appendix shows slabs. The average price per cord

was about $4.8. 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 47% of price quotes do not specify the fuel's seasoning status. Another 7 percent of ads 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 $5.7. About one-quarter of ads 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 advertisements did not designate the type of wood. Despite not reporting type, about half 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; typically block wood is distinguished from slab wood by the dimensions of the cut and 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 ads were for dry fuel, 11 percent were for partially-seasoned wood, and 3 percent were selling raw fuel. Fuel specified as "fir" comprises another 6 percent of ads. While there are several species of fir, these ads 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 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

ads 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 bridges 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 being green is the least common of the categories of seasoning status.

Figure 1 displays the share of advertisements by seasoned status, by month of year. The left-panel of figure 1 focuses on dry fuel and price quotes without seasoning information. In the winter and late autumn months, ads for seasoned fuel comprise between 30 and 40 percent of all ads. This share drops markedly to under 20 percent in the summer. Suppliers of fuel, through their marketing strategies, could be revealing lower demand for dry fuel during the summer. This is intuitive; if the fuel is being used for heat (as opposed to cooking), fuel purchased in the summer won't be used for some time. Figure 1 also shows that the share of ads which do not indicate the seasoning status of the fuel peaks during the

summer months at nearly 80 percent of all ads. As with the reduced share of ads for dry wood, this monthly pattern may reveal that suppliers expect higher demand for dry fuel when the need for fuel is immediate.

The right-panel of figure 1 shows that monthly shares of ads for green and partially-seasoned fuel. The share of advertisements for green fuel is steady throughout the year at under 5 percent. In contrast, ads for partially-seasoned fuel are highest in the winter months. These ads are least frequent during the summer. Hence, the pattern for partially-seasoned wood mimics that of fully seasoned wood. Presumably this reveals that suppliers are catering to consumers preferences for seasoned wood during the times of the year when fuel is needed for immediate consumption.

Figures A1 and A2 in the appendix show the real prices over the 14 years of the sample. Figure A1 consists of two panels. The top panel displays the price series for all wood, the bottom panel focuses on block and slab wood. All prices are expressed in real terms. Beginning with the top panel, the solid line tracks prices for dry wood. The dash reflects prices for fuel in ads that do not specify whether the fuel is green or seasoned. For most of the 14 year time period, dry wood is more expensive than unspecified wood. There are periods early in the sample during which dry wood is less expensive. Both time series fall from 1922 to the late 1920's before rising in the early 1930's. Following the increase in 1931, both price series fell again in 1933 and 1934. The bottom panel reveals a more consistent positive difference in prices for dry fuel and ads for which no data on seasoning is provided. The fact that the dry fuel series for block and slab wood is consistently higher suggests that some of the price reversals in the top panel of figure A1 is due to the fact that

all wood types are included in the top panel. The persistent premium for dry fuel is suggestive evidence of consumers' additional willingness–to-pay (relative to fuel that is ambiguously seasoned) for seasoned fuel that can be consumed immediately.

Figure A2 compares the price series for dry and raw fuel. All wood types are included in the top panel and block and slab is included in the bottom panel. One pattern that is evident in the top panel of figure A2 is that the prices for green fuel are highly volatile early in the sample. As such, there are numerous instances in which prices for green fuel exceed those for dry fuel; some of these price reversals may be due to comparisons of different wood types. The bottom panel of figure A2 offers a cleaner comparison by focusing on just block and slab. The positive price premium for dry fuel is evident in nearly every month for which there are price quotes for both dry and raw fuel.

Figure 2 provides an alternative view of the relative prices of dry, raw, and partially-seasoned fuels. The figure reveals a positive differential between dry and green fuel of nearly 20 percent in the winter months (season 1) and spring months (season 2). The premium falls appreciably in the summer and autumn to around 10 percent. Both green and dry fuel prices display strong seasonality with the highest prices in the winter and spring. In contrast, the price of unspecified fuel is steady throughout the year.

Table 2 reports summary price statistics for the different grades of fuel for block, slab, old-growth, and all other wood types, conditional on there being a fuel type specified in the price quote. Evidence of the premium consumers are willing to pay for seasoned fuel is provided by these summaries. For example, 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 block wood is considerably smaller in percentage terms. The average price of dry block wood is just 5 percent higher than for green block wood and this difference is not statistically significant at conventional levels. However, the premium for dry block wood *relative to partially-seasoned* block wood is nearly 20 percent ($p < 0.01$). And, the dry premium compared to wood that is not denoted as dry or raw is about 6 percent ($p < 0.01$).

Table 2 provides suggestive evidence that consumers are willing-to-pay a significant 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 ($p < 0.01$), conditional on there being no wood type information in the advertisement. Similarly, the price of dry wood is 21 percent higher than partially-seasoned fuel ($p < 0.01$). The price of dry wood is 7 percent greater than the price of wood for which there is no seasoning information ($p < 0.01$).

Finally, the price of dry old growth wood is statistically indistinguishable from the price of green wood, and 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. While just presenting price summaries, table 2 provides redolent evidence of consumers' willingness-to-pay for dry fuel that provides immediate gratification, relative to green fuel that must be seasoned before use. Thus, these average prices uncover, reveal, or otherwise hint at consumer's time preferences.

3.a. Other Data.

The empirical analysis also employs the monthly Consumer Price Index (CPI), (McCusker, 1992) and the monthly Warren and Pearson's Fuel and Light Index (Warren and Pearson, 1933). 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).

3.1 Estimation of Discount Rates.

The primary regression is essentially a hedonic price model that describes fuel prices as a function of attributes of the fuel, macroeconomic confounding factors, flexible time trends, as well as monthly, seasonal, and wood type (species) fixed effects. The dataset is an unbalanced panel in the sense that there are multiple advertisements (and price quotes) for different wood types, by month-of-sample. Figure A4 in the appendix reports the total

number of ads across the 14 years. Recall that the data collection methodology encompassed all ads in the *Portland Oregonian* on a given day for each month. The figure indicates that the number of ads grew from about 50 per day in 1922 up to over 200 per day during the Great Depression. After 1932, the number of ads then fell back to between 50 and 100 per day.

The specification of the hedonic models is shown in (7). The models include: fuel attributes, the consumer price indices (CPI), and the monthly change in the CPI; cost-of-living indices for rent, food, and clothing, for Portland, Oregon (BLS, 1941); monthly yields for U.S. Treasury bonds; monthly changes to the Dow Jones Industrials Index. The baseline specification also controls for the quantity of fuel for sale in each ad, and the total ad counts, by wood type, by month.

$$ln(P_{i,t}) = \beta_0 + \sum_{i=1}^{N} \beta_i T_i + \beta_q Q_{i,t} + \beta_c C_{i,t} + \sum_{s=1}^{4} \alpha_s \varphi_{i,t}^{s} + f(t) + \mu_t F_t + \varepsilon_{i,t} \qquad (7)$$

where:
$P_{i,t}$ = quoted price of fuel type (i) at time (t).
T_i = type of fuelwood
$\varphi_{i,t}^{s}$= four indicator variables depicting if the fuel is being sold as raw (green), dry, partially-dry, or has no season data.
f(t) = flexible function of year, season, month of year, and month of sample during which ad is posted.
F_t = controls for: monthly consumer price index (all goods), Dow Jones, U.S. Treasuries, Cost-of-living indices.
$Q_{i,t}$ = quantity of fuel for sale in ad.
$C_{i,t}$ = quantity of ads posted, by type (i).
$\varepsilon_{i,t}$ = stochastic error term.

The parameter estimates of interest are the $\{\alpha_s\}$ terms. To facilitate interpretation of the parameter estimate for dry fuel as an individual discount rate, 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 individual discount rate.

3.1.a. Discount Rates That Reflect Seasoning Periods Other Than One Year.

The interpretation of the coefficient corresponding to the dry fuel indicator as an individual discount rate 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 $\mathcal{M}_{m+t} = \begin{cases} 37 - \kappa_1(days) & if: days < \omega_{1,m} \\ \kappa_2(days) & if: \omega_{1,m} < days < \omega_{2,m} \\ \kappa_3(days) & if: days > \omega_{2,m} \end{cases}$ (8)

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 ($\kappa_d \; for \; d = 1,2,3$) 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 $\left(p_{g,m}^{d}\right)$ 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:

$$t^{*} = max_{t}\left(ln\left({p_{m+t}}/{p_{g,m+1}^{d}}\right) - 1\right) \tag{9}$$

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:

$$\hat{\rho} = \left(1 + \{\widehat{\alpha_{dry,m}}\}\right)^{{12}/{t^{*}}} - 1 \tag{10}$$

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 $\{\widehat{\alpha_{dry,m}}\}$.

3.2 Estimation of Time Variant Discount Rates.

In addition to the estimation of (7) across the entire sample period, a series of regressions fit (7) to subsamples of the data to test whether and how the parameter estimates of interest vary across time. This is executed in three ways; annual discount rates are

computed for each of the 14 years of data in the sample, by month (across years), and for each of the 168 months of the sample.

Because testing for time series heterogeneity in individual discount rates is not something widely executed in the literature, there is demonstrable value in the exercise. Further, probing whether there is time series variation in discount rates is motivated by the fact that the sample period, 1922 – 1935, spans one of the largest macroeconomic shocks in the history of the United States; working with over 160 monthly discount rates provides an unprecedented opportunity to test how individual discount rates respond to a range of events that occurred during the 1920's and 1930's. These events include: 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 preferences 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 discount rates 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 discount rates respond to continuously measured factors that might reasonably be considered determinants of consumers' time preferences. Again, the unique time series nature of the data affords a new opportunity to test how macroeconomic covariates affect the individual discount rates. Model (11) frames

these tests, by regressing the estimated discount rates, by month-of-sample, on a collections of covariates including: wages in Portland, Oregon, the CPI, U.S. Treasury yields (*Bond*), the Dow Jones Industrials Index (*Dow*), and cost-of-living indices (*COLI*).

$$\hat{\alpha}_{dry,t} = \beta_0 + \theta_0 M_t + g(t) + \theta_0 CPI_t + \theta_1 Bond_t + \theta_2 Dow_t + \theta_3 COLI_t + \theta_4 Price_t + \epsilon_{i,t} \quad (11)$$

All covariates are included in concurrent and lagged values up to six-months. Both the means and the standard deviations (over six previous months) are included. The model also controls for month of year (*M*), and a flexible functional form on the time trend (*g(t)*). The motivation for inclusion of these variables is straightforward. The CPI is included to test how expectations about inflation affects the discount rates; bond yield and stock prices capture returns on alternative uses of cash; the cost-of-living indices are intended to reflect alternative sources of expenditures by households.

4. Empirical Results.

Table 3 presents the estimated discount rates 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 block. 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 0.12. The coefficient is highly significant ($p < 0.01$). This result suggests that consumers' individual discount rate is 12 percent. When the estimation sample is restricted to price quotes that report some type of fuel, the coefficient on dry fuel falls to 0.10 ($p < 0.01$).

The coefficient for dry fuel, restricting the sample to prices for slab wood, is 0.159, suggesting prices are about 16 percent higher for dry wood than for raw wood. The coefficient is highly significant ($p < 0.01$). When the sample is restricted only to ads for block wood, table 3 reports that consumers are not willing to pay a premium for dry fuel. Combining price quotes for block and slab, the estimated coefficient for dry fuel is 0.138, suggesting that consumers' are willing to pay 14 percent more for dry fuel. The coefficient is significant at the 1 percent level.

How do 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 individual discount rates reported in table 3 fall within the very wide range for field studies covered by FLO (2002). However, the range of rates in table 3 are strikingly similar to those estimated in the health-choice papers in FLO (2002).

The range of discount rates 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.

Table 3 also reports the coefficients for partially-seasoned fuel and for prices attributed to fuel without any information on whether it's seasoned or green. For all wood types and for slab, prices for partially-seasoned fuel are not distinguishable from green fuel. For block fuel, for all wood types (with a type reported), and for block and slab fuel, partially-seasoned fuel sells at a discount with respect to green fuel. This could stem from consumers' uncertainty over actually how seasoned the fuel is. Inclusive of all wood types, prices for fuel without seasoning information are between 3 and 4 percent higher than for green fuel. For all of the other categories in table 3, ads with no information on seasoning status of the fuel quote prices that are indistinguishable from green fuel.

4.1 Sensitivity of Discount Rate Estimates to Macroeconomic Controls.

Table 4 reports the discount rates for slab wood with various specifications of the confounding factors discussed in section 1. Column corresponds to the default specification reported in table 3. The estimated discount rate is about 16 percent. The take-home message from table 4 is that the estimated discount rates are not sensitive to how the confounding factors enter the model. Column (2) shows the results from a model that includes the confounding factors in levels, rather than month-over-month changes. The discount rate remains essentially unchanged at 16.1 percent as opposed to 15.9 percent in the default model. Similarly, when 6-month lags are included to proxy for consumers' expectations, the estimated discount rate is 15.8 percent. Finally, when means and

standard deviations are taken over the 6-month lagged confounders, the discount rate falls to 15.4 percent.

4.2 Seasonal and Monthly Variation in Discount Rates.

Table 5 reports the seasonal results for all wood types. The estimated discount rates are all significant at ($p < 0.01$). Recall from table 3 that, across all months, the estimated discount rate was 12 percent. Seasonally, the largest point estimate manifests in price quotes during the summer months. One might intuit that impatience as measured by dry fuel premia would be highest in winter when demand heating demand is both higher and inelastic. Why would the summer dry fuel premium exceed that of winter? Consider that households' demand for fuel wood stems from two uses: heating the home and cooking. While demand for heat is clearly concentrated in the winter months, demand for cooking, one might conjecture, is rather steady all year long. However, in the 1920's and 1930's food preservation (canning) was still a widely used approach to smoothing out the bounty of the end-of-summer harvest for use during the other seasons of the year. Many households did not yet have access to refrigeration or freezer technology. Thus, when the harvest came in, households had to rush to preserve food before it spoiled. Home preserving typically requires boiling water to sterilize containers, and long periods of boiling the foodstuffs to ensure proper preservation. Consumers would be most impatient immediately after harvest, during the late summer months; hence, there would be significant, inelastic demand for dry fuel.

The discount rates estimated from price quotes during the spring and winter months are about 13 and 14 percent. The discount rate gleaned from price quotes during the autumn

months is considerably lower: 7.5 percent. During this time of year, households purchase fuel primarily for the coming winter and spring heating season. The lower discount rate reveals a greater degree of patience: a willingness to procure green fuel and allow it to season.

The left panel of figure 3 displays the month-of-year parameter estimates for dry fuel, inclusive of all wood types. The premium for dry fuel in January is about 15 percent. It rises to nearly 20 percent in February before fall through June to a statistical zero. The discount rate jumps in July and August to 20 percent and 15 percent, respectively. In September, the discount rate is again a statistical zero. The discount rate is then estimated to be under 10 percent through December. Consumers appear to be least willing to delay gratification during the prime heating season and in late summer. These results support those reported in table 5.

The right panel of figure 3 displays the month-of-sample discount rates estimated from price quotes for slab wood. As table 3 indicated, the discount rate extracted from prices of this more homogenous fuel type tend to be higher than that obtained from the regressions that include all wood. The monthly pattern differs somewhat as well. The monthly discount rates are about 20 percent from January through April. The discount rate then falls in May, but never below 10 percent, before rising through the summer months to a peak of over 20 percent in September. The estimated discount rate is at its lowest during the late autumn months of October and November (about 10 percent) before rising again during the month of December.

Some broad patterns in the monthly discount rates obtained from the slab price quotes are similar to those gleaned from prices for all wood. First, the discount rates are lowest in the autumn months. Second, the discount rates peak during the summer months seemingly because of the use of fuel for food preservation during the harvest. Third, rates rise from December through the winter months. However, from March through June, the monthly discount rate series diverge. That obtained from slab prices reveal that consumers are increasingly willing to pay a premium for dry fuel through the last months of the heating season. The all-wood series suggests impatience peaks in February.

Figure A10 in the appendix plots the discount rates that assume annual seasoning times with those that assume consumers optimize their seasoning times by maximizing savings with respect to dry fuel prices. The differences are small (generally less than 10 percentage points) for all wood types. The spread between the discount rates for slab are larger and more systematic. After June, the discount rates estimated assuming that people wait one year before use tend to be higher. Prior to April, there is greater time series variance in the discount rates estimated by assuming consumers optimize seasoning times.

What does one glean from the monthly decompositions? Intra-annual variation in the discount rates likely reflects factors that are idiosyncratic to energy fuels. The rhythms of monthly and seasonal demand emanating from consumption patterns in the household, variation in temperature, and fluctuations in harvests all affect degrees of consumers' impatience in this context. These results make clear that time preference varies throughout the year. However, these patterns may not apply to other settings (consumption of other goods across time).

4.3 Annual Variation in Discount Rates.

Figure 4 shows the estimated discount rates, 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 and plotted. The left panel of figure 4 focuses on the results inclusive of price data for all wood types. Estimated discount rates 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 apparent impatience between 1929 and 1930; rates of time preference fell by 20 percentage points in one year.

The right hand side of figure 4 focuses on discount rates 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 discount rate dropped to under 10 percent in 1930, 1931, and 1932. The discount rate never exceeded10 percent in the last years of the sample. The right-hand panel of figure 4 highlights a structural change in rates of time preference before and after the Great Crash of October, 1929. The papers explores the potential causes of these changes in section 4.4.

4.4 Responsiveness of discount rates to macroeconomic shocks.

Figure 5 plots the month-of-sample discount rates 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 discount rates spiked to almost 60 percent. In the course of the second recession, the estimated discount rates gyrate from below zero to over 20 percent. Then, following the crash both the level and the month-to-month variation in the discount rates fall; during no month following 1929 do the estimated discount rates exceed 20 percent.

Table 6 employs the month-of-sample discount rates 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 discount rates 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 rates of time preference *during the recessionary months.* Specifically, the average discount rate is estimated at 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 discount rate during the 1923-1924 downturn were four-times greater than discount rates estimated in months *not during this recession.* The difference in discount rates is highly significant ($p < 0.000$). The same comparison for the second recession

reveals no statistically significant difference in discount rates. Both of the recessions explored here are considered to have been mild recessions (Zarnowitz, 1992).

Table 6 also displays the t-test of average discount rates for months during the Great Depression. Two aspects of this test are noteworthy. First, the estimated discount rates are *lower* during the Great Depression months than for other months. This contrasts with the months during both recessions in which the discount rates were *higher* than for non-recessionary months. Second, the difference in discount rates 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 discount rates estimated using pricing data from before the crash average 11.8 percent. For the months after the crash, consumers' impatience falls; the discount rate is estimated to be 5.1 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. This position has been argued by many economists dating back to Fisher (1930).

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 as a result of the decline in household wealth. This fact, in and of itself, does not explain the 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, are able to 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, fell 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. 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 of connect the t-tests in table 6 to the prior literature. In order to more rigorously test how individual discount rates 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 discount rates as a function of: hourly wages, returns on investment in stocks and bonds, inflation, rates charged on commercial paper, 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 discount rate used in table 6. All models control flexibly 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 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 discount rate. In contrast, the six-month lagged standard deviation in wages is positively associated with the discount rate ($p < 0.01$); a one-unit increase in the standard deviation is associated with a 0.71 percent increase in the discount rate. Table 7 shows that in all four models, the standard deviation

[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.

of wages positively affects the discount rate. 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 discount rates. 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 discount rates. 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 discount rates ($p < 0.01$).

Also estimated are the joint effects of wages (both means and standard deviations) both through the wage controls and the interactions with inflation. The combined effect of average wages is positive though not significant ($p < 0.10$), 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, equivalently, 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 consumers to sit on their cash: to increase 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 rates of time preference ($p < 0.10$).

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 negative ($p < 0.01$). 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. This result suggests that greater 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 time preference 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 rates of time preference ($p < 0.10$).

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 rates of discount ($p < 0.01$). Likewise, the standard deviation of inflation is positively associated with discount rates.

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 discount rates. 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 rates of time preference fall, and patience builds, during times of heightened uncertainty. This phenomenon appears to be unique to the post-crash time period in the present study. That is, consumer 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).

5. 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 individual discount rates, by month, over 168 months from January, 1922 through December, 1935. The long time series of estimated discount rates provides a first-of-its-kind examination of how individual 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.

To extract discount rates the paper estimates the premium paid for dry, seasoned firewood relative to green wood on a contemporaneous basis. 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' individual discount rates; 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 discount rate is about 12 percent. Significant seasonal variation in the discount rates is detected. 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 discount rates. Hence, uncertainty about future income suppresses impatience. 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). 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 discount rates: the estimated rates are four-times higher during that recession than in other months. Similarly, the discount rates 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 discount rates 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 discount rates 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 time 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.

	Block	Slab	Old Growth	Other[B]
Dry	6.397	5.692	5.779	5.754
	(1.418)[A]	(1.058)	(1.195)	(1.276)
Partially-Dry	5.355	4.620	6.132	4.782
	(1.192)	(0.899)	(0.801)	(1.056)
Green	6.151	4.687	5.347	5.282
	(1.073)	(0.906)	(0.139)	(1.434)
No Season	6.050	4.751	5.926	5.369
Information	(1.141)	(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: Regression Analysis Results: Pricing Seasoned Status.

	All Wood Types	Other[A]	Slab	Block	Slab & Block
Seasoned	0.121***	0.100***	0.159***	0.00163	0.138***
	(0.0124)	(0.0110)	(0.0106)	(0.0260)	(0.00996)
Partially Seasoned	-0.0194	-0.0419***	-0.0112	-0.109***	-0.0282***
	(0.0127)	(0.0113)	(0.0109)	(0.0266)	(0.0102)
No Season Data	0.0356***	0.00382	0.00345	-0.0351	-0.00320
	(0.0121)	(0.0107)	(0.0104)	(0.0220)	(0.00968)
adj. R^2	0.447	0.463	0.445	0.358	0.479
N	14363	13246	6541	1048	7589

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: Discount Rates and Confounding Factors.

	(1)	(2)	(3)	(4)
Seasoned	0.159***	0.161***	0.158***	0.154***
	(0.0106)	(0.0110)	(0.0113)	(0.0108)
Default[1]	X			
Levels[2]		X		
6-Month Lags[3]			X	
Mean over 6-Month Lags[4]				X
SD over 6-Month Lags[5]				X
adj. R^2	0.494	0.480	0.460	0.471
N	6,541	6,561	6,110	6,507

Standard errors in parentheses
Note: * p<0.10, ** p<0.05, *** p<0.01
1 = Model includes: all goods CPI, inflation lagged over previous 12 months, food, clothing, and rent cost-of-living indices for Portland, Oregon, month-over-month changes in yield on U.S. Treasuries, Dow Jones Industrials.
2 = Model includes levels of: all goods CPI, yield on U.S. Treasuries, Dow Jones Industrials, all-good cost-of-living index for Portland, Oregon, wages for Portland, Oregon.
3 = Model includes 1 to 6 month lags in each of the covariate listed above.
4 = Model includes the arithmetic mean of the 1 to 6 month lags in each of the covariates listed above.
5 = Model includes the standard deviation of the 1 to 6 month lags in each of the covariates listed above.

Table 5: Regression Analysis Results: Seasonal Discount Rates.

	All Seasons	Winter	Spring	Summer	Autumn
Seasoned	0.121***	0.139***	0.133***	0.165***	0.0749***
	(0.0124)	(0.0256)	(0.0183)	(0.0320)	(0.0241)
Partially	-0.0194	-0.0172	-0.0155	0.0630*	-0.0421*
Seasoned	(0.0127)	(0.0258)	(0.0192)	(0.0371)	(0.0247)
No Season	0.0356***	0.0470*	0.0254	0.113***	0.00652
Data	(0.0121)	(0.0256)	(0.0177)	(0.0300)	(0.0236)
adj. R^2	0.447	0.452	0.488	0.568	0.513
N	14,363	4,596	4,061	2,350	3,356

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 discount rate to macroeconomic conditions.

Event	Discount Rate During Event[1]	Discount Rate 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 0.072 implies discount rate of 7.2%.
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.

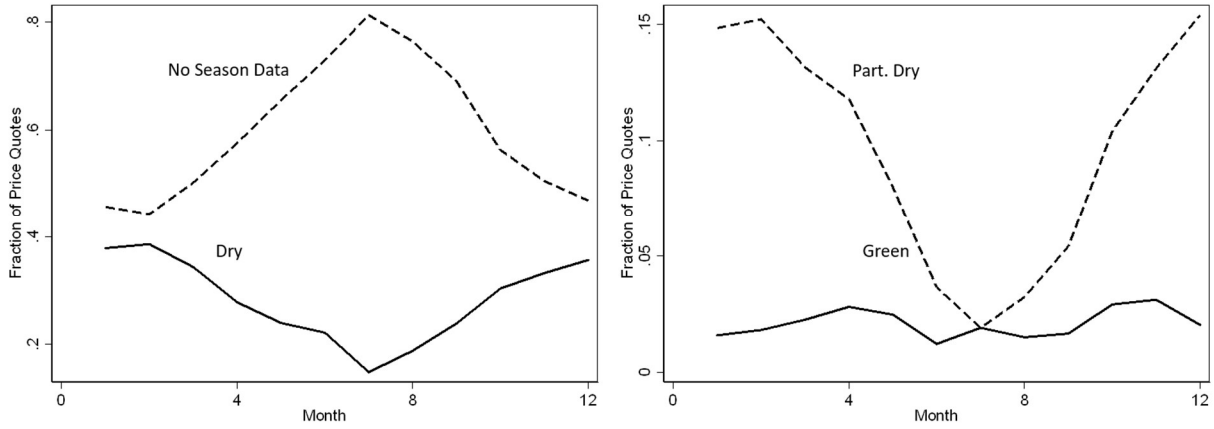
Table 7: Determinants of the discount rate.

	(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"

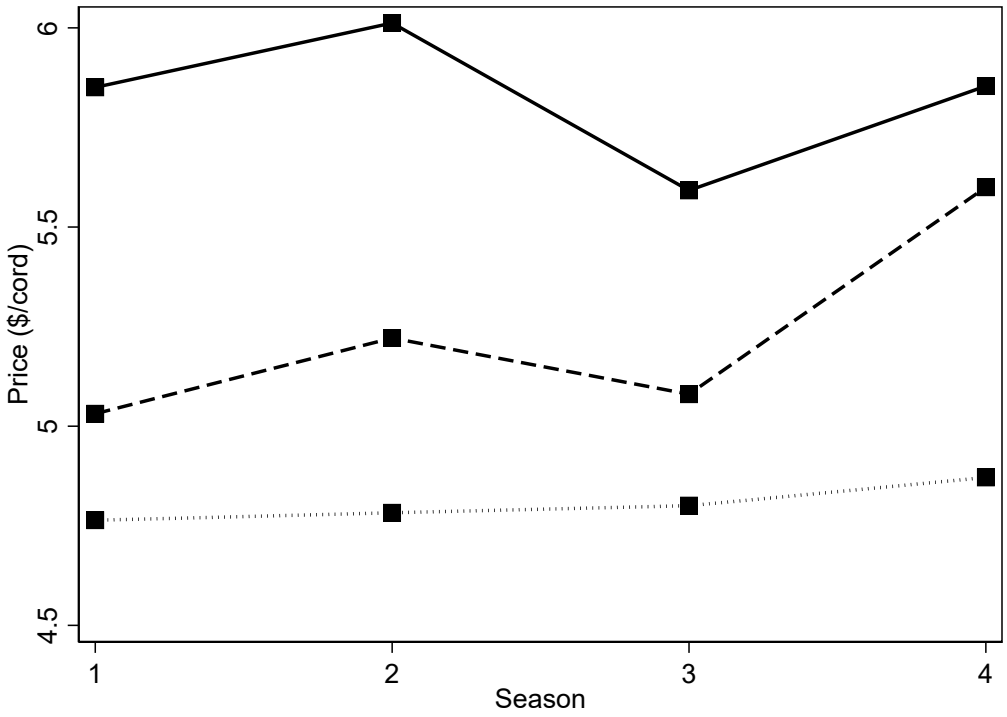
Figures.

Figure 1. Shares of Price Quotes by Seasoned Status of Fuel, by Month.



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

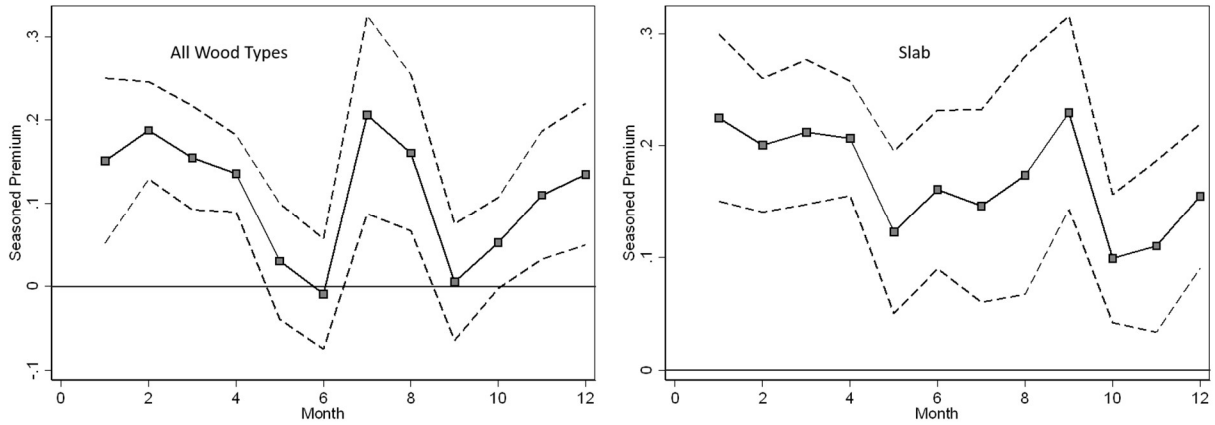
Figure 2: Seasonal Prices by Fuel Season Status.



Season 1 = Winter, 2 = Spring, 3 = Summer, 4 = Autumn

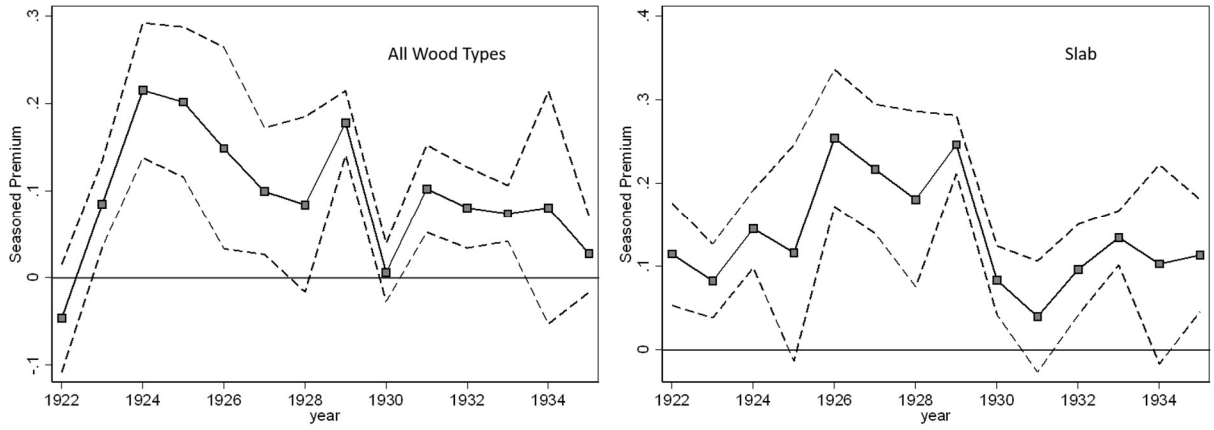
Solid = Dry, Dash = Green, Dot = Partial.

Figure 3: Monthly Premium for Dry Wood.



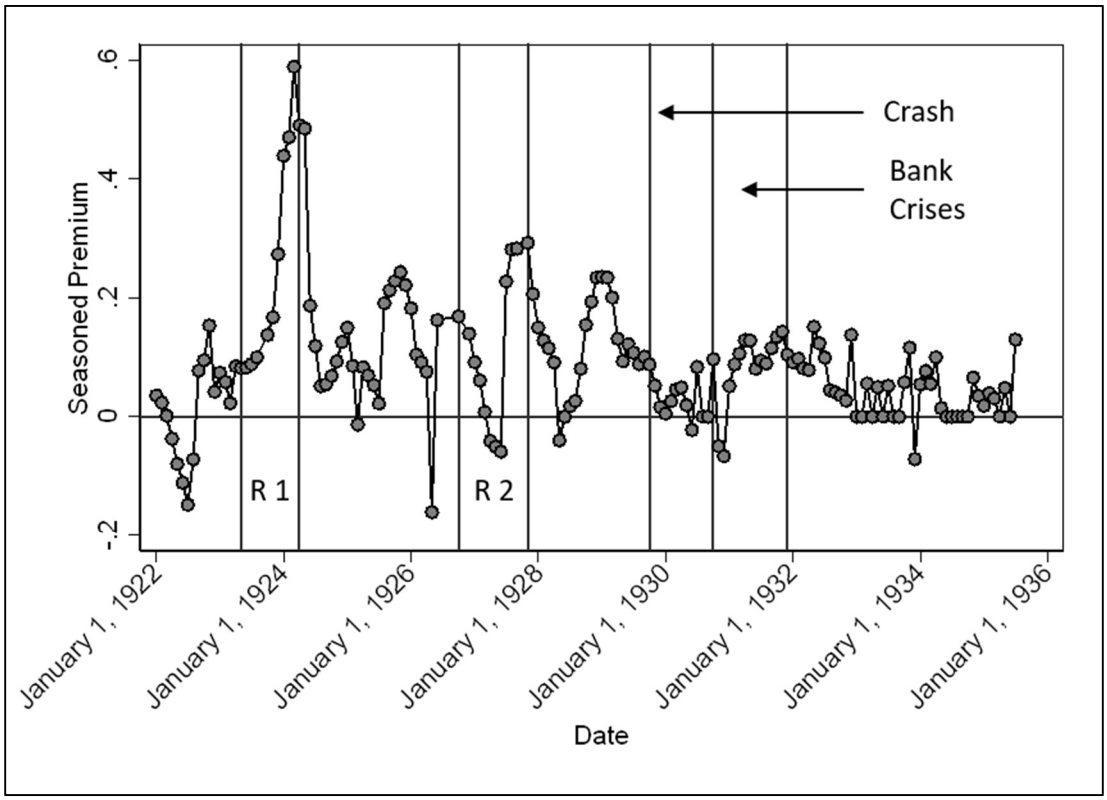
Dashed lines are 95% confidence intervals.

Figure 4: Annual Premium for Dry Wood.



Dashed lines are 95% confidence intervals.

Figure 5: Month of Sample Discount Rate Estimates.



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.

Table A1 reports the results from regression models that are fit to the pricing data for slab wood from each season of the year. The table reveals that the premium for dry fuel revealed in ads placed in winter and spring are significantly larger than in prices quoted during the summer and autumn. It is interesting to compare the results in table A1 to those in table 5. Recall that the dry fuel premium for all wood types was greatest during the summer. Restricting the sample to price quotes for slab wood tells a somewhat different story about intra-annual fuel demand. Consumers' WTP for dry fuel is highest (relative to green wood) in winter (when demand for heating fuels is robust) and spring (when dry fuel stores purchased prior to the heating season are at their lowest ebb). This indicates that slab fuel was predominantly used for heating. In contrast, when the seasonal WTP for dry fuel is computed inclusive of prices for all wood types, the pricing data reveals a preference for dry fuel at times of peak use for both heating and cooking.

Figure A5 displays the results of a test related to the Euler equation in (6) in the main text. Specifically, rearranging (6) indicates that $P_{g,t}(1+i) = P_{t+1}$; if consumers are maximizing their intertemporal welfare, green fuel prices appreciating at the extant rate of interest should equate to seasoned fuel prices one year hence. Figure A5 seeks to test this hypothesis regarding consumer behavior (and prices) by computing $ln\left(\frac{p_{t+1}}{p_{g,t}}\right)$ and plotting that along with a measure of interest rates (the yield on the 10-year U.S. Treasury bond).

The top panel of figure A5 is inclusive of all wood types, while the bottom focuses on slab wood. Figure A5 shows that interest rates fell from 4.5 percent to 2.5 percent between 1922 and 1935. In contrast, the imputed rate of appreciation for green fuel, on average,

increased over this 14 year period. Prior to 1929, returns gyrated between positive and negative 50 percent. After 1929, green fuel exhibited positive returns. The average rate of appreciation over the entire sample period was 13 percent. The results for slab wood also indicate rising rates of appreciation with considerable fluctuations and fewer periods of negative returns. The average annual rate of appreciation for slab fuel was over 20 percent.

Figure A5 suggests that the behavior of consumers and suppliers did not result in green fuel appreciating at the rate of interest. Rather, returns to investment in unseasoned fuel vastly outstripped the risk-free rate. One candidate explanation for this systematic divergence is that there is considerable risk when green fuel purchases are treated as an investment. Consider that there are (at least) two reasons to buy green fuel: as a hedge against rapidly rising prices for dry fuel, and as a speculative investment. Consumers using green fuel as a hedge, on average, benefited by procuring fuel early; whether realized or not, the rate of appreciation of this fuel was considerable (though with significant variation), especially compared to the risk-free rate. However, the wild swings in rates of appreciation (even for homogenous slab wood) may have deterred broadly based speculative investment which would have arbitraged away the spread between average rates of return on investment in green fuel and risk-free assets.

Figure A6 shows the ratio of imputed prices assuming that green fuel had appreciated at the rate of interest to observed dry fuel prices. The average ratio is 0.94 over the entire 14 year period. From this we can infer that dry fuel prices would have been about 10 percent lower had green fuel appreciated at the rate of interest. Before 1930, the ratio averages 1.03 and after 1930 it is 0.83.

The bottom panel of figure A6 includes only prices for slab wood. The average ratio is 0.84 over the entire 14 year period; Dry fuel prices would have been about 15 percent lower had green slab fuel appreciated at the rate of interest. Before 1930, the ratio averages 0.92 and after 1930 it is 0.76. These differences suggest that green fuel *actually* appreciated more rapidly (relative to the rate of interest) after 1929.

Figure A7 revisits the Euler equation in (5) in the main text of the paper. Rearranging (5) produces: $\rho = {p_t(1+i)}/{p_{t+1}} - 1$: the consumer equates their pure rate of time preference to the ratio of real prices across time periods. In the main text of the paper, the focus is on estimating discount rates by using the premium of dry to green fuel observed in the same time periods. Figure A7 takes an alternative tack by estimating the discount rate using the ratio of prices shown in (5). The top panel of figure A7 employs all price quotes for dry fuel, and the bottom panel limits the sample to only those for slab wood. Over all of the monthly discount rates shown in the top panel of figure A7, the discount rate produced using (5) averages about 4 percent, whereas that estimated using the relative prices of dry to green fuel averages about 9 percent. The two series are weakly, positively correlated with one another.

Despite these differences, the two estimates do share properties in common. Both sets of discount rates fall after the stock market crash of 1929. The discount rates produced using (5) fall from about 9 percent to a statistical zero after the crash. And, the rates estimated using the relative prices of dry to green fuel falls from 13 percent to 5 percent. During the 1923 to 1924 recession, discount rates produced using (5) are estimated to be 18 percent.

In other months, they are just 2 percent. (Recall from table 6 that the discount rates reported in the main text are also significantly higher during this recessionary period.)

In the bottom panel, the divergence between the two sets of discount rates is greater. Over all of the monthly discount rates shown in the bottom panel of figure A7, the discount rate produced using (5) averages about 4 percent, whereas that estimated using the relative prices of dry to green fuel averages about 13 percent. The two series are weakly, positively correlated with one another: the Pearson's correlation coefficient fit to these two series is just 0.086.

Like the "all wood" discount rates shown in the top panel of figure A7, the two series of estimates for slab wood also have some structural similarities. Both sets of discount rates fall after the stock market crash of 1929. The discount rates produced using (5) fall from about 8 percent to a statistical zero after the crash. And, the rates estimated using the relative prices of dry to green fuel fall from 17 percent to 9 percent. During the 1923 to 1924 recession, discount rates produced using (5) are estimated to be 15 percent. In other months, they are just 3 percent. The discount rates for slab estimated using the relative prices of dry to green fuel fell from 16 percent to 13 percent during this recessionary period.

The results presented in figure A5 through A7, ultimately, relate to a potential confound in the estimation of time preferences through observed, market behavior. As FLO (2002) note, consumer choices 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 forces (time preference and intertemporal arbitrage) in a field setting

in which all we observe are prices and quantities (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).

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.

Comparing yields on the 10-year bonds with the imputed discount rates also enables a test of convergence of the sort hypothesized by FLO (2002): between estimated rates of time preference and market interest rates. Table A2 presents the result of this comparison.

What table A2 shows is that the differences between estimated discount rates 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. The yield on 10-year bonds is probably the best estimate of the extant market rate of interest. However, it is unclear whether the diminishment of the spread is *convergence* of the imputed discount rates to zero or due to the reduction in time preference from the events that occurred during the Great Depression. This topic is left to future research.

Figure A8 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 current dry fuel price is about 20 percent higher than the moisture adjusted green fuel price one month after purchase. 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, the maximum savings occurs about 15 months later. For acquisitions of green fuel in September, the yield maximizing seasoning time is about 10 months. And, for December, waiting almost two years maximizes savings earned by purchasing green fuel. Figure A9 reproduces the results in figure A8 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, the

yield-maximizing waiting time tends to be over 12 months. For green fuel purchased in June, the largest savings occurs at three months and 15 months later. And, for green fuel acquired in September, waiting until nine months after purchase maximizes savings relative to dry fuel.

Figure A10 estimates the adjusted monthly discount rates (conceptually depicted in (10)) employing the yield maximizing seasoning time as defined in (9). The left-panel does so for all wood types. This graph shows that the monthly discount rates are not dramatically affected by the seasoning adjustment. Differences of about 5 percentage points manifest for discount rates gleaned from prices in February, November, and December.

The right-hand panel of figure A10 focuses on slab wood. The seasoning adjustment to discount rates appreciably affects the estimated discount rates in January, February, and March. Assuming consumers wait for the savings-maximizing time before use increases the variance in the discount rate across these months. After June, discount rates estimated assuming consumers maximize savings tend to be lower than the discount rates fitted by assuming consumers season wood for one year (with the exception of September). The differences between the two approaches (assuming consumers wait one year versus the optimal time as depicted in figure A9) yields a spread of between 5 and 10 percentage points in the discount rate.

Table A1: Regression Analysis Results: Pricing Seasoned Status of Slab Wood Fuel by Time of Year.

	Winter	Spring	Summer	Autumn
Seasoned	0.186***	0.188***	0.162***	0.109***
	(0.0181)	(0.0183)	(0.0245)	(0.0250)
Part. Seas.	0.0201	0.00429	0.000928	-0.0645**
	(0.0184)	(0.0188)	(0.0306)	(0.0258)
No_Season	0.0348*	0.0138	0.0161	-0.0405
	(0.0184)	(0.0177)	(0.0206)	(0.0253)
Constant	13247.4***	-5806.9	-4611.5	20719.4**
	(3729.3)	(3677.0)	(6214.2)	(9535.6)
adj. R^2	0.483	0.514	0.385	0.436
N	2,208	1,964	863	1,506

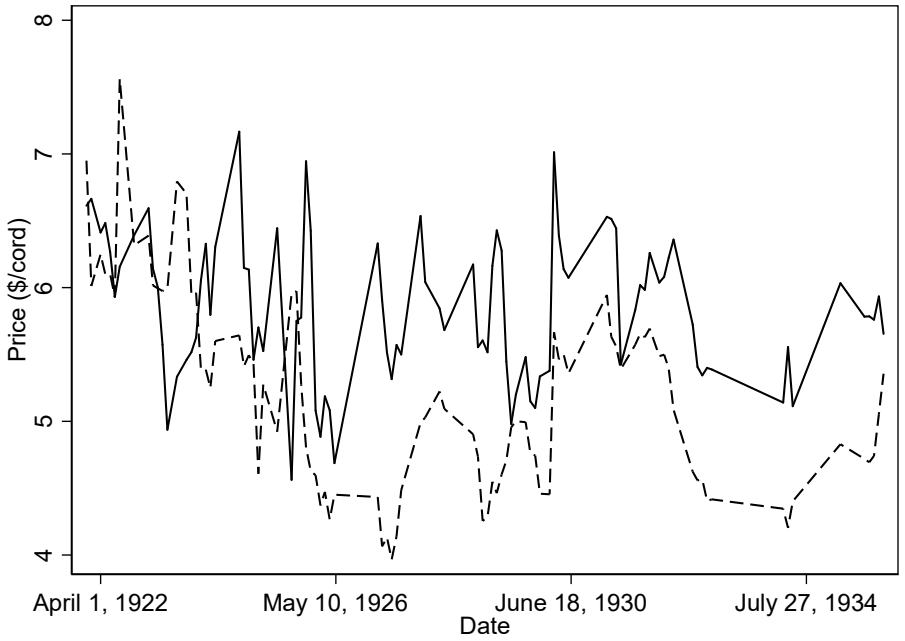
Standard errors in parentheses
Note: * p<0.10, ** p<0.05, *** p<0.01
Green fuel is the excluded case.
Dependent variable is natural log of price.

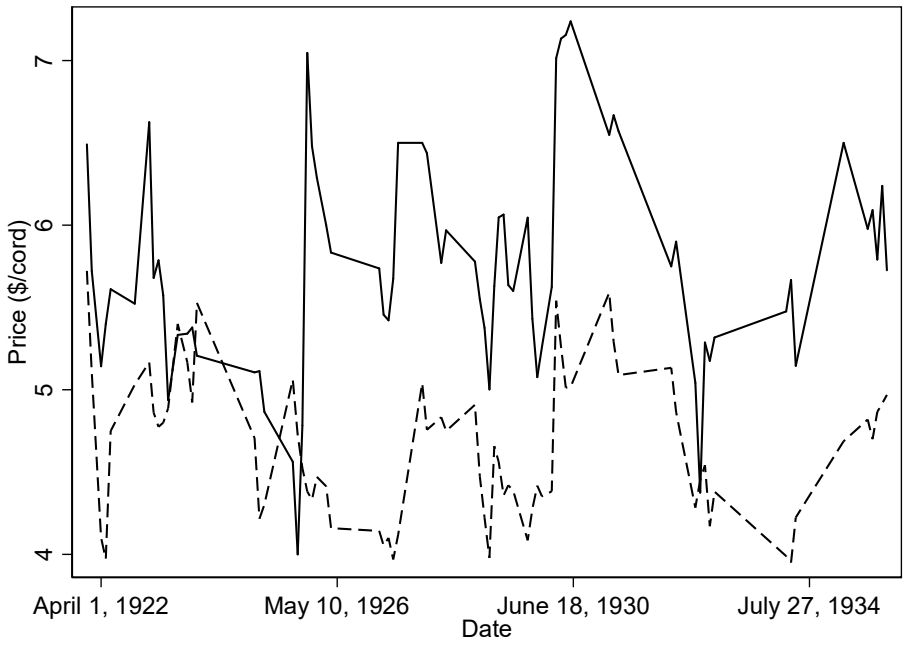
Table A2: Comparison of Discount Rates to Yields on Alternative Investments.

	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 discount rates and returns (yields) on alternative investments to zero.

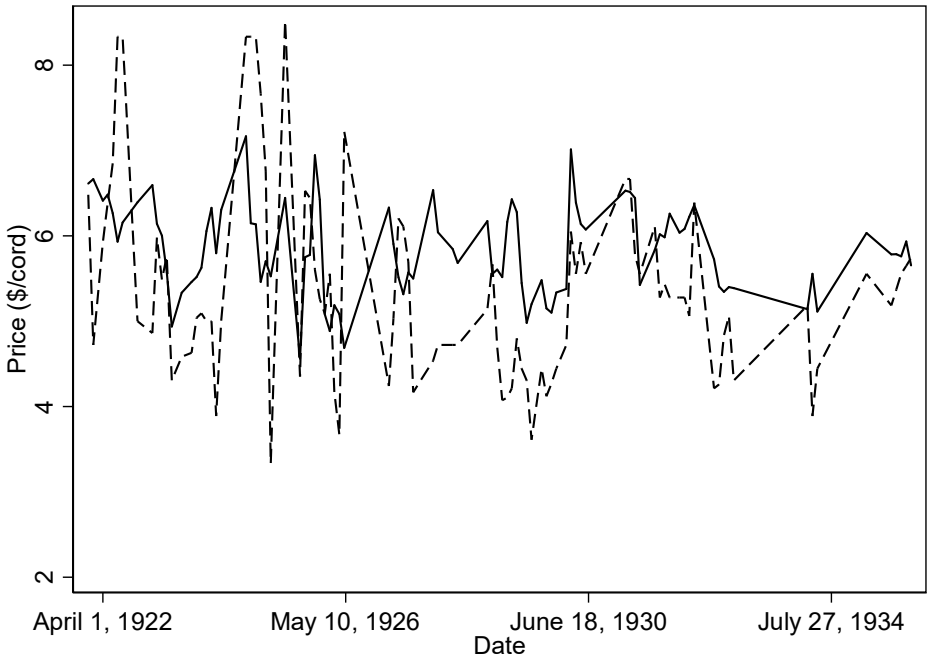
Figure A1: Fuel Prices: Dry Fuel and No Season Data (All wood top, block and slab bottom).

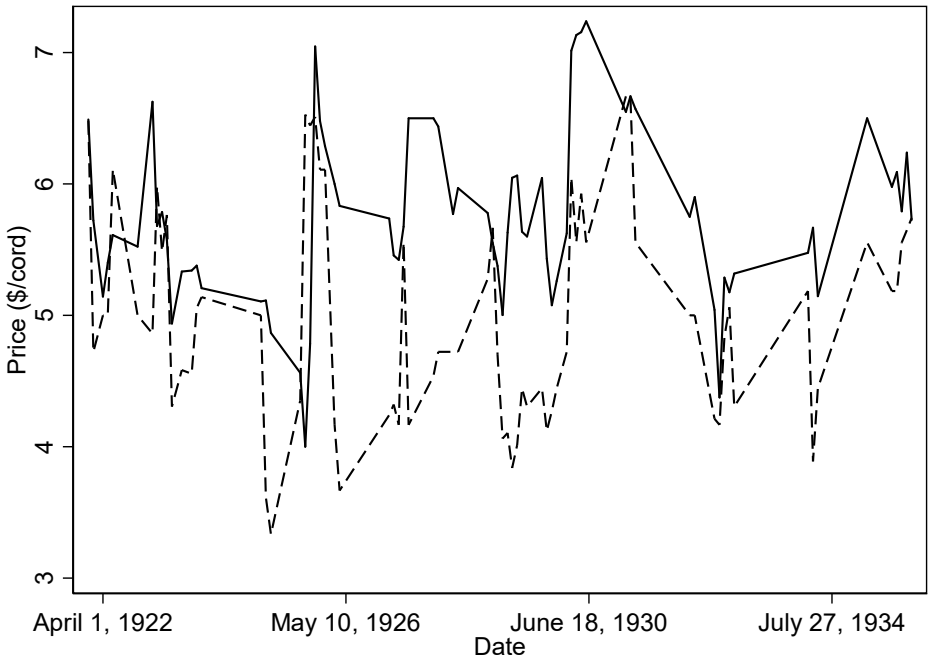




Solid: Dry fuel, dash: no season data.

Figure A2: Dry Fuel and Green Fuel Prices (All wood top, Block and Slab bottom).





Solid: Dry fuel, dash: green fuel.

Figure A3: Slab wood.



Figure A4: Ad Counts.

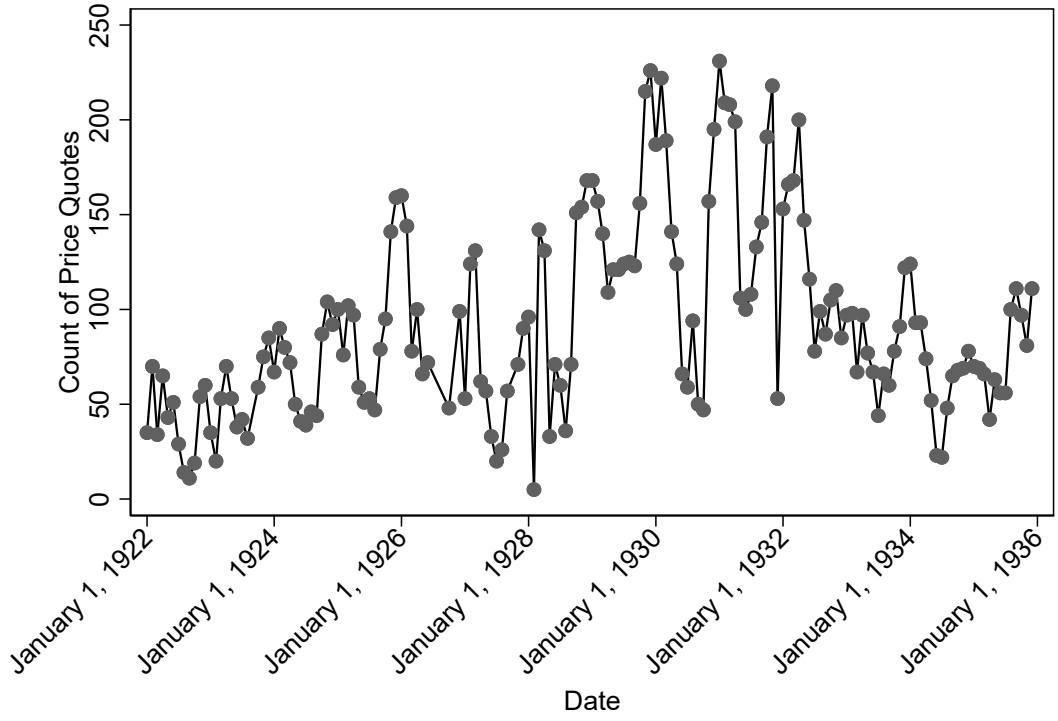
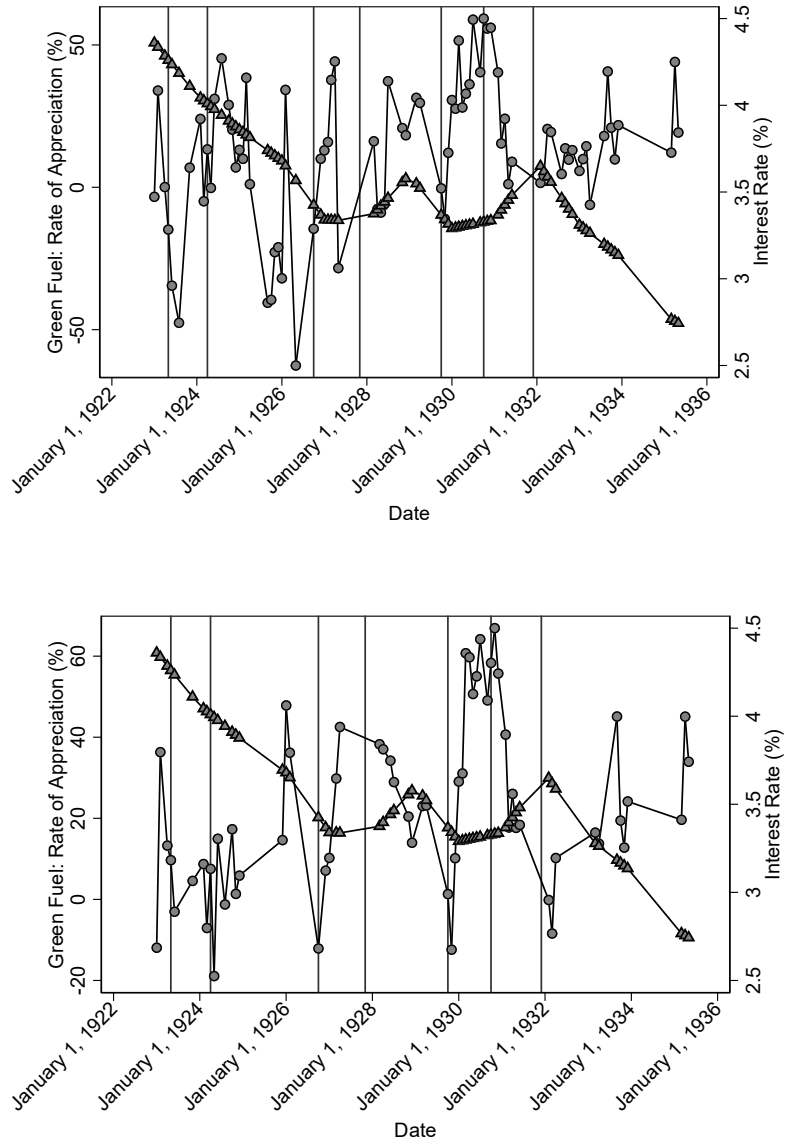
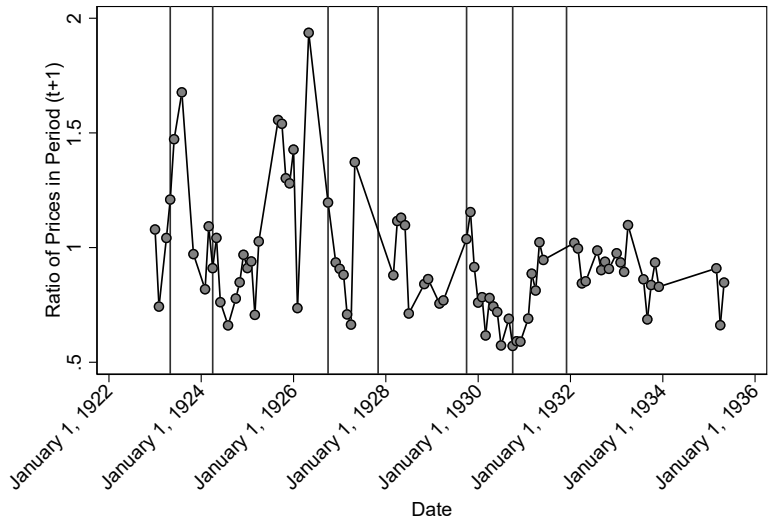


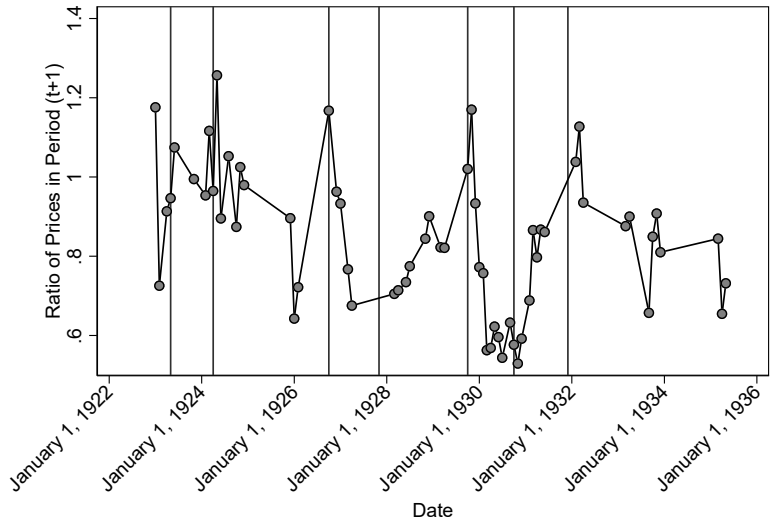
Figure A5: Rate of Appreciation of Green Fuel and Interest Rates.



Top panel: All wood types. Bottom panel: Slab wood. Circles represent the percent 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 triangles represent interest rates as represented by the yields on 10-year U.S. Treasuries. 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.

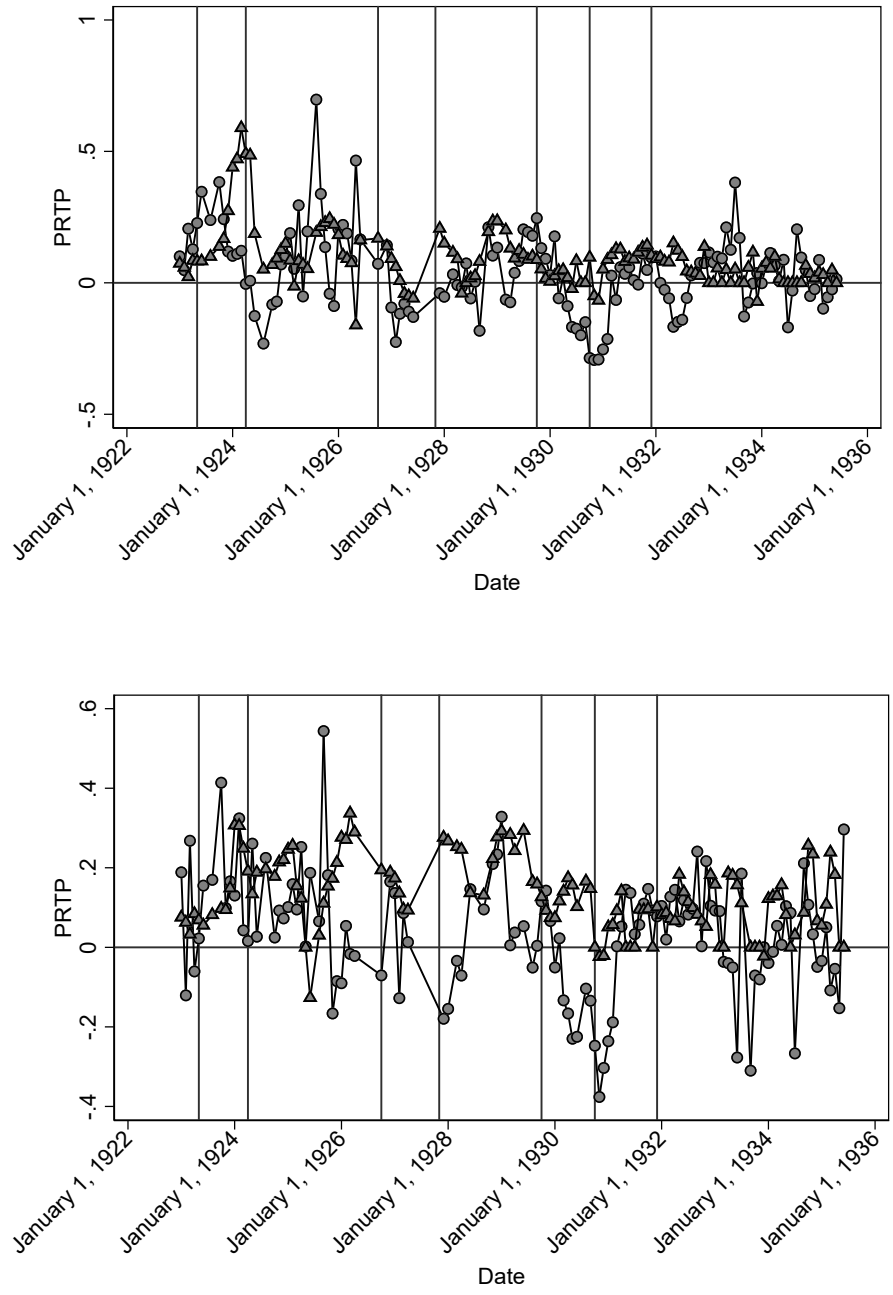
Figure A6: Ratio of Prices of Fuel One Year After Purchase of Green Fuel.





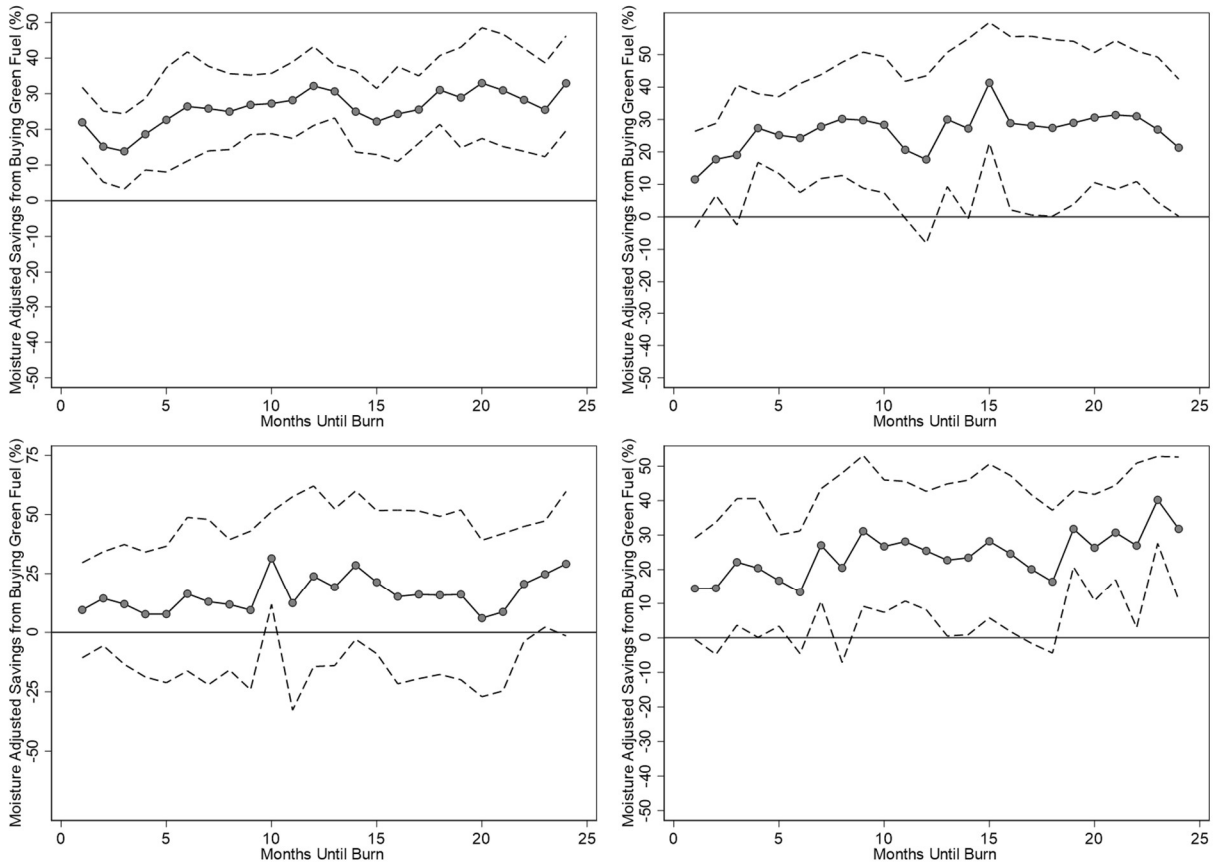
Top panel: All wood types. Bottom panel: Slab wood. Ratio of prices one year after purchase of green fuel: appreciation at the rate of interest over the observed appreciation rate.

Figure A7: Comparison of Imputed Pure Rates of Time Preference.



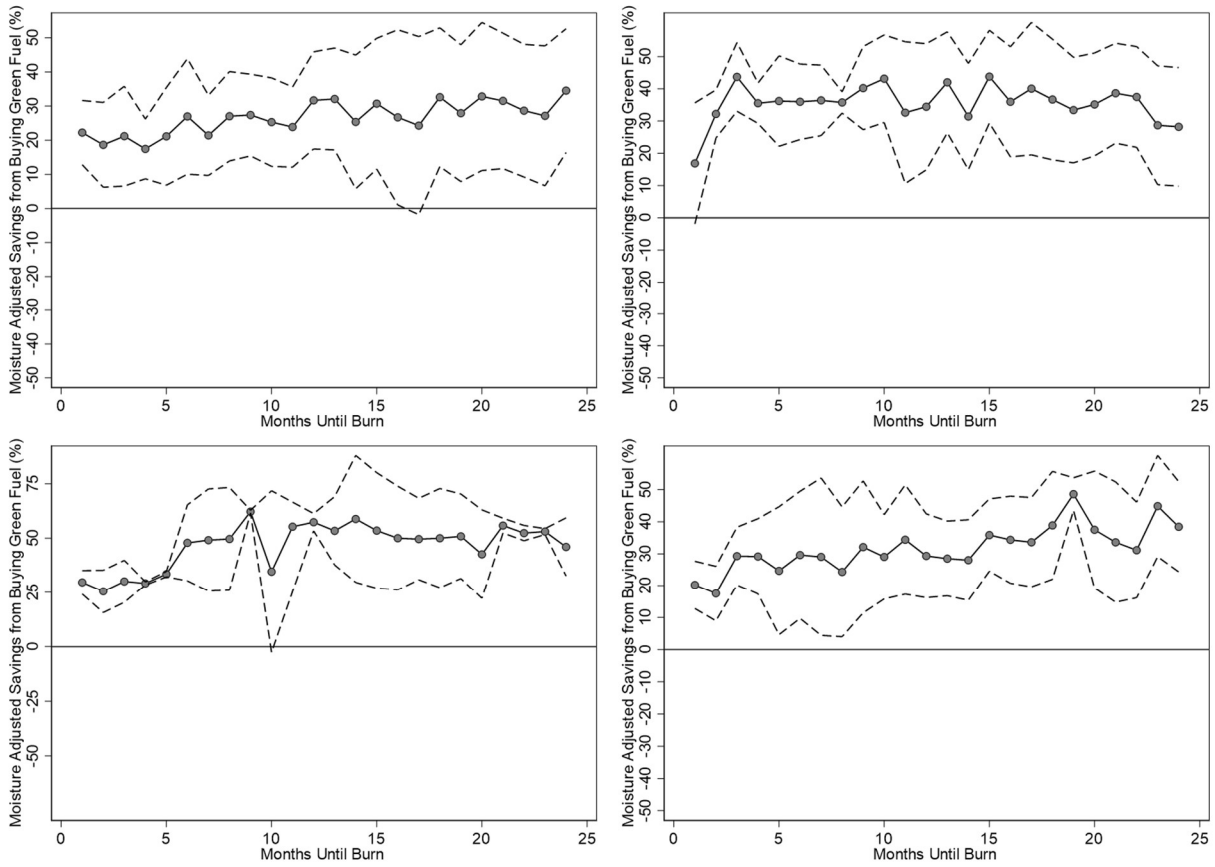
Top panel: All wood types, Bottom panel: Slab wood. Circles represent the estimate of consumers' pure rate of time preference as estimated using the Euler equation in (5). This is the ratio of dry fuel prices in period (t) times (1+i) to dry fuel prices in period (t+1). Triangles represent the estimate of consumers' pure rate of time preference as the premium of dry fuel prices to green fuel prices in period (t).

Figure A8: Firewood Yield Curves: Rate of Return on Green Fuel Relative to Dry Fuel at Different Lengths of Time Since Purchase for All Wood Types.



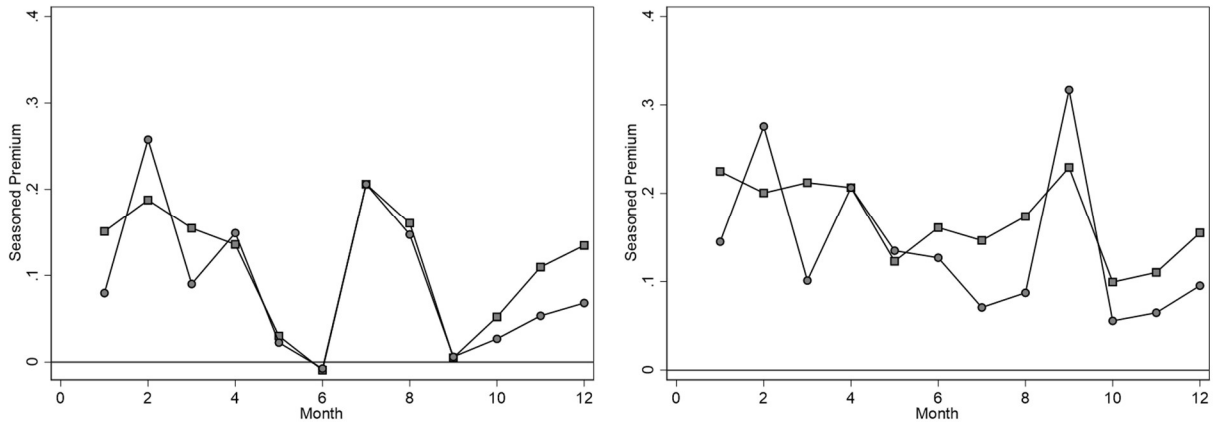
Each panel depicts the natural log of dry price to moisture adjusted green fuel price from 30 days to 365 days after purchase: $ln\left(p_{m+t}/p^{d}_{g,m+1}\right) - 1$. The top left panel considers the case in which green fuel is purchased in March. Figure A9 considers all types of wood.

Figure A9: 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: $ln\left(p_{m+t}/p^{d}_{g,m+1}\right) - 1$. The top left panel considers the case in which green fuel is purchased in March. Figure A9 considers the case of slab wood.

Figure A10: 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.



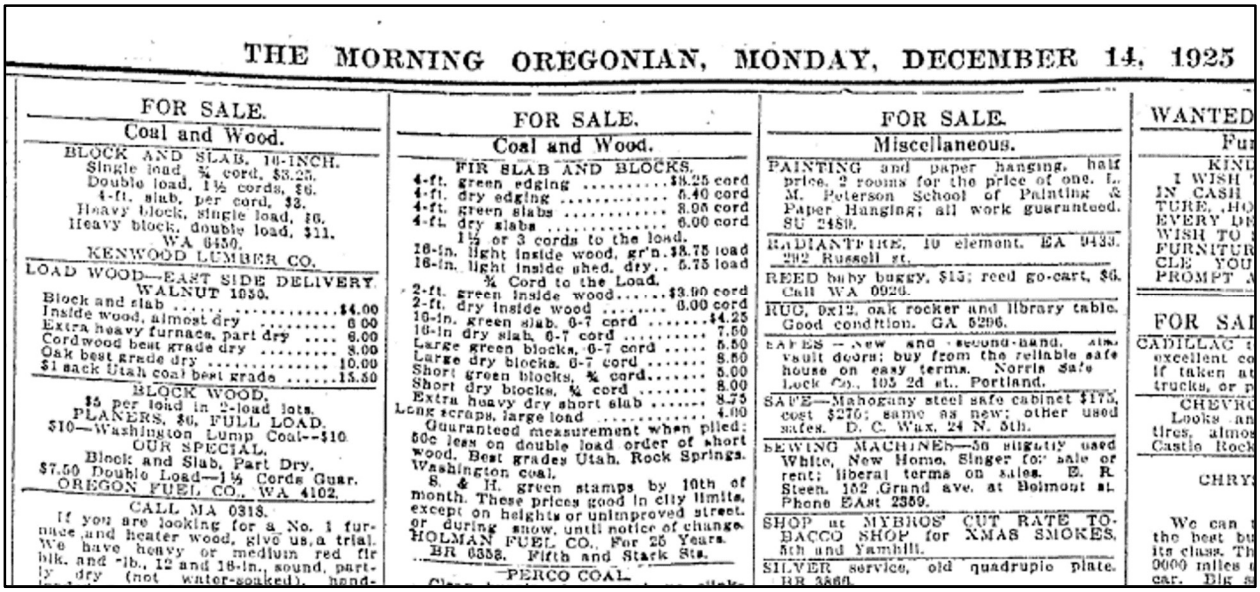
Squares: time of use is one year from green purchase.

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

Left panel: all wood.

Right panel: slab wood.

Figure A11: 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, $8.25.
Double load, 1½ cords, $6.
4-ft. slab, per cord, $3.
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 16-in., 12 and 18-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 ..... 6.40 cord
4-ft. green slabs ..... 8.00 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.. 6.75 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 6558. 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 2389.

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

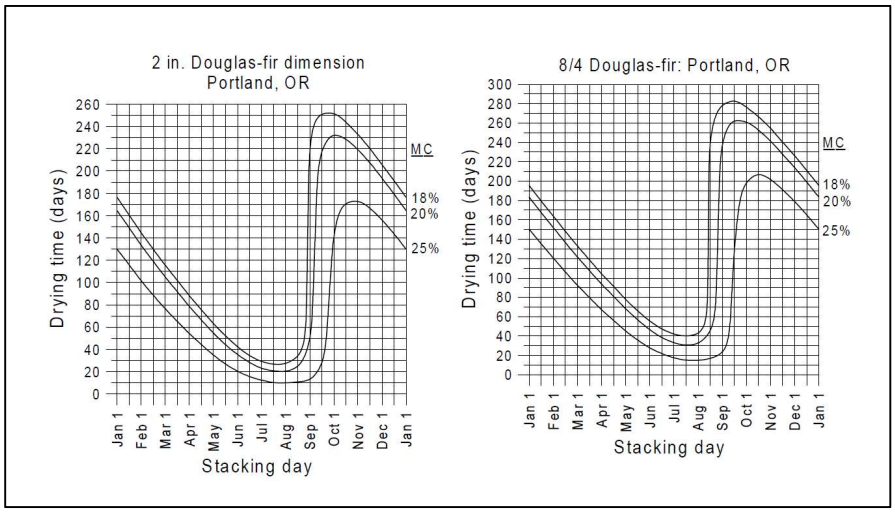
SILVER service, old quadruple plate. BR 3860.

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

Figure A12: Drying Time for Douglas Fir in Oregon.



Source: Simpson and Hart, 2000.