

On the divergence between fuel and service prices: The importance of technological change and diffusion in an American frontier economy



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Abstract

This paper assembles heating fuel prices for the U.S. state of Vermont, from the colonial era to the present, in order to test whether energy fuel prices and energy service prices have diverged over this time period. Prior authors have reported evidence of a significant difference between long run energy fuel prices and energy service prices. However, this is the first analysis to pose this question beginning in the context of colonial America. In accord with earlier work focused in the U.K. the paper reports a significant divergence in fuel and service prices. In this setting real heating fuel prices increased over the 220 year time period by a factor of between 15 and 20. In contrast, heating service prices increased by a factor of two. Expressed in labor units, heating service prices have fallen in Vermont by 25%, while fuel prices were essentially flat. Finally, over this two century time period in Vermont and the U.K., the rate of change in service prices expressed in labor units is remarkably similar: -1.1% and -0.9% , per annum, respectively.

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1. Introduction

In their most basic form, price indices are weighted-averages used to summarize price changes and to convert nominal to real values. Such indices assume that, for a given good, the consumption weights are comparable across time; i.e. the same good of the same quality is being consumed. However, consumption is more appropriately defined in terms of services. This distinction is crucial for energy fuels. These are inputs used in the production of services upon which welfare ultimately depends. As technology that transforms inputs to services matures, fuel prices and service prices may change to different

degrees and in different directions. In such contexts, conventional price indices are likely biased. This in turn influences the measurement of national aggregates such as Gross Domestic Product (GDP) and national income. Because measures such as GDP influence macroeconomic policy and financial markets (both of which affect consumer decision-making) the consequences of this issue are broad.

Since the earliest epochs of history, humans have employed fuels to make heat that is necessary for survival. The means by which humans create heat have changed considerably through time and the efficiency of technology that converts raw fuel to heat has greatly

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improved from open hearth to fireplaces and stoves and then central furnaces. This type of technological upheaval leads to the separation between service prices and fuel prices noted above. The specific focus of the paper is on space heating — the means by which fuels are used to warm residential dwellings. Production of heat is central to societal energy use, quality of life, and by extension, welfare, in many parts of the world. Further, heating technology permitted expansion of human settlements much farther from the equator. This resettlement had ramifications for population growth and global development.

Within this context, this paper gathers heating fuel prices for the U.S. state of Vermont, from the colonial era to the present, in order to test whether energy fuel prices and energy *service* prices have diverged over this time period. Economists have made the case that the divergence between energy fuel prices and service prices is a subject worthy of study (Nordhaus, 1997; Fouquet, 2008, 2011; Fouquet and Pearson, 2003, 2006). However, this is the first analysis to explore the divergence between fuel and service prices beginning in the context of a frontier economy in colonial America and running through the present.

The state of Vermont provides an interesting empirical context for three reasons: location, local fuel endowments, and its pattern of development. Given its remote location, in the early colonial period Vermont affords an opportunity to explore divergences between fuel and service prices in what was effectively a frontier economy. Second, the state was endowed with one abundant natural fuel resource: biomass. Because biomass was plentiful and Vermont was isolated, firewood was persistently cheaper than coal. Despite this orientation of relative prices, consumers in Vermont transitioned away from firewood in the middle 20th century. This suggests a response to factors aside from market prices. Finally, the study tracks fuel prices beginning in the colonial era and follows them through the growth and modernization of Vermont's economy. This context facilitates a connection between the literature on energy transitions in developing countries and early American energy history (Rubio and Folchi, 2012).

The paper assembles a time series data set covering fuel prices, consumption shares, efficiency ratings, and income in Vermont from 1790 to 2010. With these data the analysis asks three questions. First, and most fundamental to the paper: how have real heating fuel and service prices changed between 1790 and 2010 in Vermont? This question is explored in terms of both monetary and labor units. Second, in order to compare the case of an economy that progresses from the frontier to a

modern state, to a developed one, the paper asks: how do changes in heating service prices reported herein compare to those in the U.K. from 1790 to 2010? Finally, since the rate of adoption of new technology may impact any divergence between fuel and service prices, the paper asks: what effect does using observed consumption patterns versus assuming all consumption occurs at the technological frontier have on the time path of service prices? This is an important exercise because some prior authors (Nordhaus, 1997) have assumed consumption occurs at the technological frontier, while others (Fouquet, 2011) have used observed consumption shares.

The analysis finds significant differences in the growth rates of fuel and service prices in Vermont. Real consumption-weighted average fuel prices increased by about 1.4%, annually. In contrast, real heating service prices grew by about 0.2% per year. Thus, accounting for efficiency improvements in heating technology reduces the real growth in prices by nearly a factor of seven. Over 220 years, fuel prices increased by a factor of between 15 and 20, while service prices doubled. When the series are expressed in terms of labor equivalents, service prices fell by 1% annually, or 25% cumulatively, from 1790 to 2010. Fuel prices in labor units show no discernable trend.

In contrast to the 0.2% rate of growth in Vermont, real heating service prices in the U.K. fell by 0.7% annually, between 1790 and 2010. Similar to the 1% decline in Vermont, the labor price of heat fell by 0.9% in the U.K. However, between 1790 and 1850, the labor price of heating services in the U.K. fell more rapidly than in Vermont. Thereafter, the rates of reduction in heating service prices in Vermont and the U.K. were quite similar. One likely reason for the difference in price trends up until 1850 stems from Vermont's geographic isolation; Vermont was using strictly biomass as coal had not yet penetrated Vermont markets. Thus, advances in heating technology (and concomitant efficiency gains) that were available in the U.K. and other U.S. colonies had not reached the Vermont frontier economy. The delayed diffusion of fuels and technology to Vermont had clear effects on the labor price of heat. As the U.K. had already transitioned to coal by 1800, the U.K. labor price of heat fell rapidly from 1800 to 1850. In contrast, the labor price of heat in Vermont was effectively constant over this time period. Vermont consumers were still using biomass burned in primitive technology. Once coal and associated technology penetrated the Vermont market, the change in labor price of heat matched that in the U.K. Finally, whether the observed consumption shares in Vermont are used or one assumes that only the

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