Impact of Deferral Option on Investment:

Empirical Evidence from Residential Customers of District Heating Company

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Abstract

This paper examines option to defer an investment in thermal rehabilitation of building. Heat savings generated by energy efficiency investment in two distinctive areas connected to district heating in Prague are studied. Despite substantial difference of heat price over several years no significant difference in heat savings between the two areas is found. It is shown that different volatility of heat prices in different areas and its changes influencing value of deferral option can partly explain the observed flat owner's behavior. Two specific "real" features of the deferral option are further introduced, improvement of the option valuation model is proposed and expected impact on the value of deferral option is discussed.

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Introduction

Classical investment rule based on NPV would suggest that rational flat owners should invest in energy saving measures up to the point when present value of marginal energy saving equals marginal increase in investment cost.

$$\Delta PV = \Delta I \qquad (1)$$

This equation would determine appropriate total investment and achieved savings on "production" curve of savings of each individual building. Achieved savings should be a concave function of marginal investment so that the law of diminishing returns implying that measures with higher yield are implemented earlier would be preserved. Reality is, however, much more complicated because some energy saving measures are mutually exclusive, e.g. it is not possible to install double-glass and triple glass windows at the same time. I will discuss this aspect later.

Since investment into energy saving measures is completely irreversible and future prices of energy are uncertain, flat owner has a valuable option – option to wait and see how the price of heat will develop. This option is given up in the moment of investment, which should decrease maximum marginal investment (other things equal) because present value of energy savings has to cover investment cost and also the value of lost deferral option:

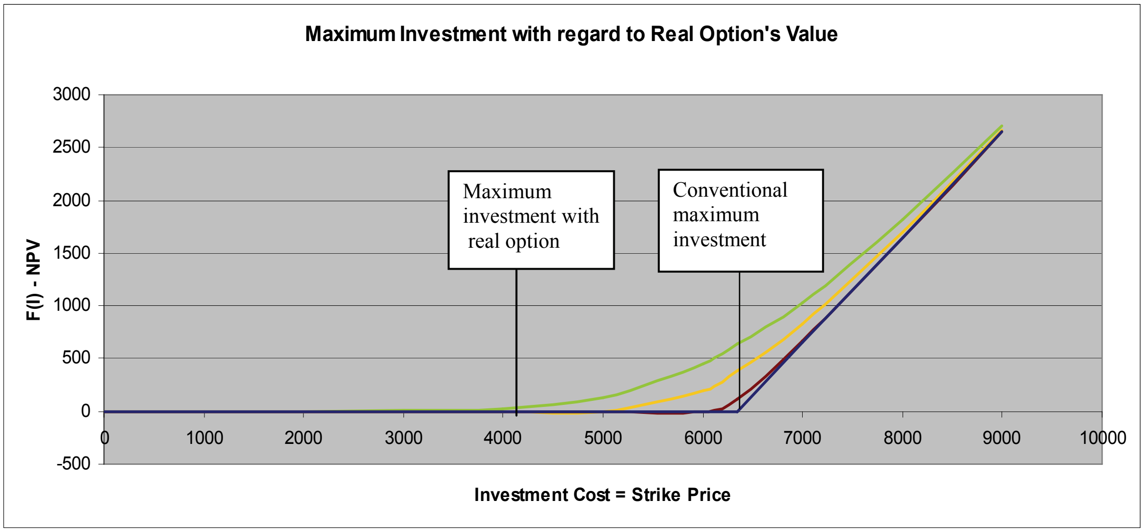
$$\Delta PV = \Delta I + F(\Delta I, \Delta PV) \qquad (2)$$

Value of deferral option can be regarded as function of marginal investment cost which equals its strike price and present value of the energy savings (underlying risky asset). When present value of energy savings is known, equation (2) can be used for determination of maximum marginal investment cost. This approach differs from usual applications of real option analysis where investment as well as current value of underlying risky asset is generally expected to be known in advance. The equation (2) can also be rewritten in the following manner:

$$\Delta NPV = F(\Delta I, \Delta PV) \qquad (3)$$

Figure 2 shows difference between option premium and NPV plotted as function of investment cost (strike price of the option) for different volatilities of the underlying asset. We get familiar set of curves. Maximum investment is, however, found on the horizontal axis where option premium tangentially meets with NPV of the project.

Figure 1



Application of real option theory should thus lead to lower investment and also energy savings than traditional NPV rule would suggest. Furthermore maximum marginal investment should be adversely affected by increasing volatility of the underlying risky asset = present value of energy savings.

The Case of Residential Customers of Prazska teplarenska a.s.

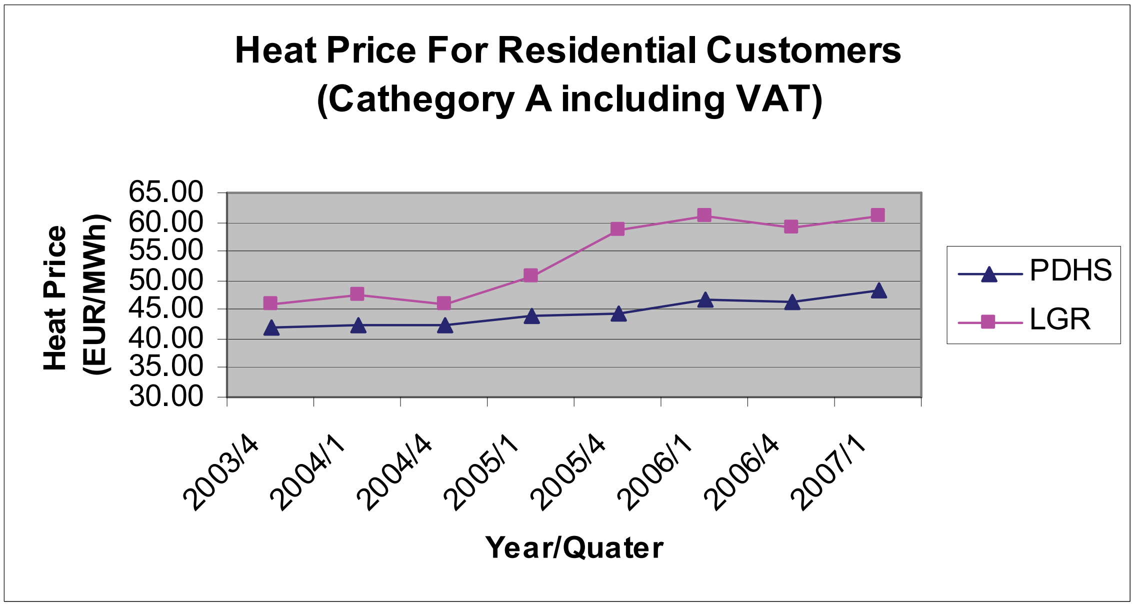
Prazska teplarenska a.s. district heating company supplies with heat for space heating and domestic hot water preparation approximately 275 thousand flats, numerous office buildings and other customers in the city of Prague, the Czech Republic. Heat sales reached 3.5 TWh in 2007. Most of the customers are concrete blocks of flats constructed between 1960 and 1990, infamous for low thermal insulation standards and high specific energy consumption for space heating. Majority of the concerned housing stock in Prague has already been privatized or it was originally built in the framework of housing cooperatives which are being gradually transformed to associations of flat owners.

Since the beginning of the century the city has seen gradually growing renovation effort as subsidies for heating were removed in late nineties and decreasing interest rates and growing willingness of banks to lend to housing cooperatives and flat-owners associations created favorable environment for investment. There are also government programs of limited scope subsidizing partly interest rate provided that substantial part of the loan is used for thermal rehabilitation of the building.

Areas supplied with heat from Prazska teplarenska a.s. can be divided into two parts. In the fist one called the Prague District Heating System (**PDHS**) heat is produced mainly from indigenous brown coal in one process together with production of electricity (combined heat and power production) in the large plants and transported to customers over substantial distances of tens of kilometers. In the second one called the Local Gas Resources (**LGR**) the heat is produced from natural gas, typically in smaller boiler houses situated in the vicinity of customers.

Growing world prices of crude oil since 2005 resulted in rapidly increasing price of natural gas and inevitably lead to substantial increase of heat price in the LGR compared to the PDHS area, where natural gas is used only for peak load production and its influence on total fuel cost is very limited[1].

Figure 2



Since the company was concerned about the impact of increased prices on its customers and its possible influence on heat sales, a comprehensive study was conducted in the beginning of 2009 comparing heat savings in selected areas of LGR and PDHS. The sample areas were carefully selected so that the composition of building stock[2] would be as similar as possible in terms of age and building technology.

Heat consumption for space heating in bricks buildings

Period of constr.	1921-1945	1946-1970	1971-1980	1981-1990	1991-2001	N/A	Total
PDHS	0.0%	15.1%	1.0%	1.8%	1.9%	0.4%	20.2%
LGR	3.5%	16.1%	1.0%	0.0%	1.2%	0.2%	22.1%

Heat consumption for space heating in concrete panels buildings

Period of constr.	1946-1970	1971-1980	1981-1990	1991-2001	N/A	Total
PDHS	19.5%	9.8%	39.4%	10.6%	0.6%	79.8%
LGR	16.9%	8.3%	42.4%	10.2%	0.0%	77.9%

[1] District heating is regulated business in the Czech Republic and for DH companies is therefore very difficult to increase prices for other reasons than increased fuel cost which is generally accepted by the regulator. Exchange rate of 28 CZK/EUR was used.

[2] Composition of building stock was based on information from census conducted in 2001

Estimated average heat consumption per flat for above mentioned periods and building technologies was used for computation of final composition of consumption from sample areas with different composition of building stock. Different parts of the city were included in order to eliminate eventual influence of local variations of household incomes and ownership type as much as possible. Total consumption of heat for space heating in selected sample areas of PDHS and LGR was 263 GWh and 302 GWh respectively, which represents approximately 33 and 38 thousands flats respectively. The total number of buildings covered by the survey in each area can be expected to be close to 1000.

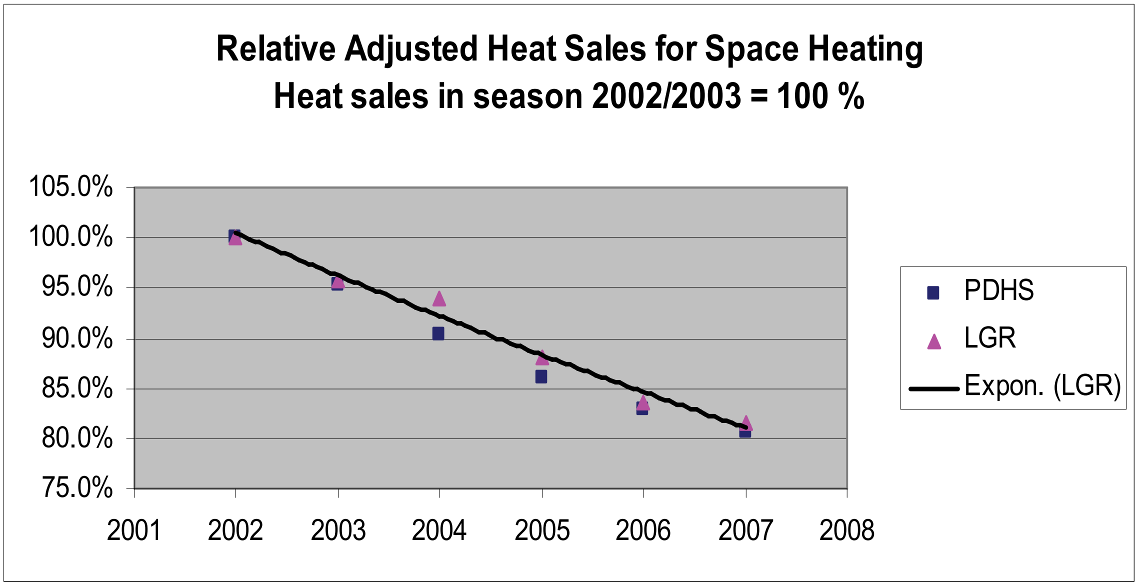
In order to calculate heat savings of existing customers all heat sales to new customers connecting to the district heating in selected areas after 2002 had to be omitted from calculations. Heat sales for domestic water preparation estimated on the basis of demand outside heating season were subtracted from total heat sales in heating season. Thus established heat sales for space heating were then adjusted for different conditions of the heating seasons by means of HDD[3] methodology. The result was surprising as no statistically significant difference between the pace of savings in selected areas in LGR and PDHS was discovered between heating seasons of 2002/2003 and 2007/2008 even though total adjusted space heating sales dropped by 20 %. Following regression coefficients as well as R^2 values were established using OLS method and regression function:

$$y = a \exp(bx) \tag{4}$$

Area	Regression coef. a	Regression coef. B	R^2
LGR	1.048	-0.0428	0.9829
PDHS	1.038	-0.0441	0.9872

Figure 3

[3]Heating degree days are calculated as number of heating days with outdoor temperature below 13°C multiplied by difference between estimated indoor and measured outdoor temperature. Estimated indoor temperature was 19.8 °C.

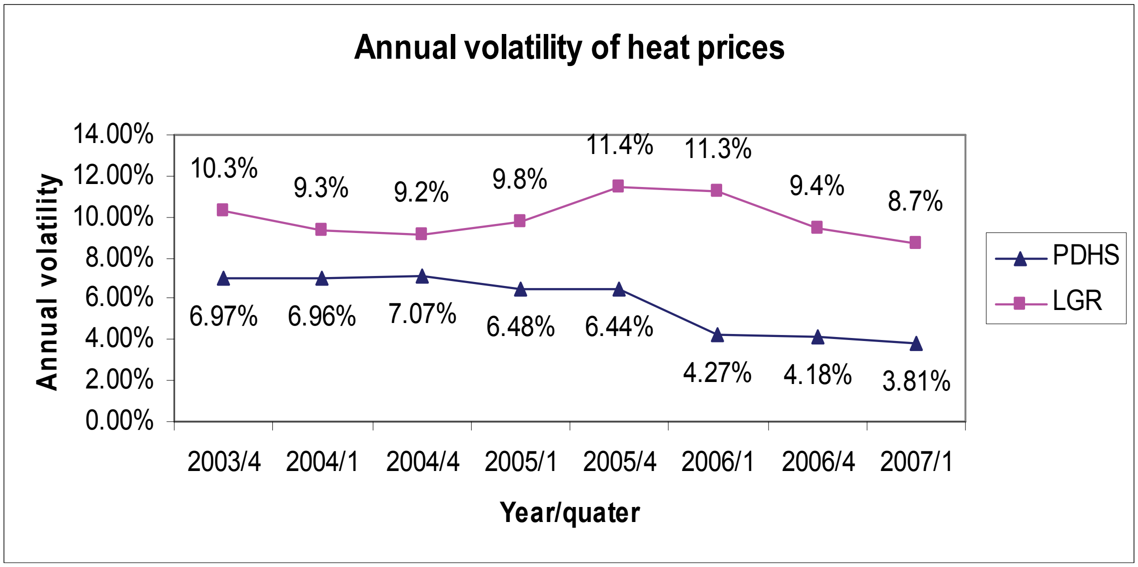


Under the assumption of rationality of home owners this behavior is difficult to explain in the context of traditional DCF thinking. Not only would we have to assume different expectations regarding future growth of price of heat in different areas or different discount rates for future cash flows from saved energy, they would also have to change in the order of tens of percent from one year to another in order to make up for the price difference. Other reasons that could explain our observation would be delay between price signal and action of home owners longer than 2 years or a very flat "production curve" meaning that increase in maximum justifiable investment would bring about very little additional savings. Also an assumption that there is some value that can be attributed to improved dwelling conditions so that energy savings can form only part of the benefits for home owners does not entirely solve the problem because there is no reason why this value should be different for average home owners in different areas. Interest rate subsidies from government or changing expectations about future in investment cost could also theoretically distort the outcome but again their influence should be symmetrical for both areas in question.

When we, however, look at the annual volatility of prices of heat measured as standard deviation of prices for 4 consecutive years ending by quarter for which the volatility is stated[4], we see quite different picture. Not only is there big difference between volatility in the different areas, it was also developing differently over time. While volatility of heat prices in LGR was fluctuating between 8.7 and 11.4 %, volatility of price for PDHS area was decreasing from 7.0 to 3.8 %. This result suggests that real options, namely changing value of option to defer investment could explain at least part of obtained results.

[4] Only prices for fouth and first quater are included since most of the heat consumption takes place in these two quaters. Also district heating companies ussual do not change prices during second and third quater.

Figure 4



The Model and Results

The deferral option is modeled as American call option on the underlying asset which is expected present value of heat savings brought about by marginal investment in thermal rehabilitation of building. The heat prices are expected to follow geometric Brownian motion:

$$dP = \alpha P dt + \sigma P dz \qquad (5)$$

Because there is no maintenance cost to energy efficiency measures, its present value can also be expected to follow geometric Brownian motion[5]. Binomial lattice of the following form was applied as a representation of the stochastic process:

$$u = e^{\sigma},$$
$$d = 1/u,$$
$$p = (1+r-d)/(u-d) \qquad (6)$$

In order to implement American feature of the option decision nodes where option could be prematurely exercised were established at the beginning of each period. When option is not exercised, its holder must postpone the project at least one year. In that case value of the underlying asset decreases in the following manner:

$$\Delta V = V(\delta/(1+\delta)) \qquad (7)$$

where δ is dividend factor established as

[5] Present value of marginal measure could be obtained by dividing heat price with annuity for expected useful life of the measures.

$$\delta=(1+\alpha)/(1+\mu)-1 \quad (8)$$

Variable α denotes expected growth rate of heat prices and μ represents risk adjusted discount rate. ΔV can be regarded as relative dividend payout rate of the underlying asset. Decision on exercising the option is made cum dividend. Unlike financial options, exercise price which equals marginal investment is not set in advance. It is expected to grow at general inflation rate. Maximum current marginal investment satisfying equation (2) can then be found numerically.

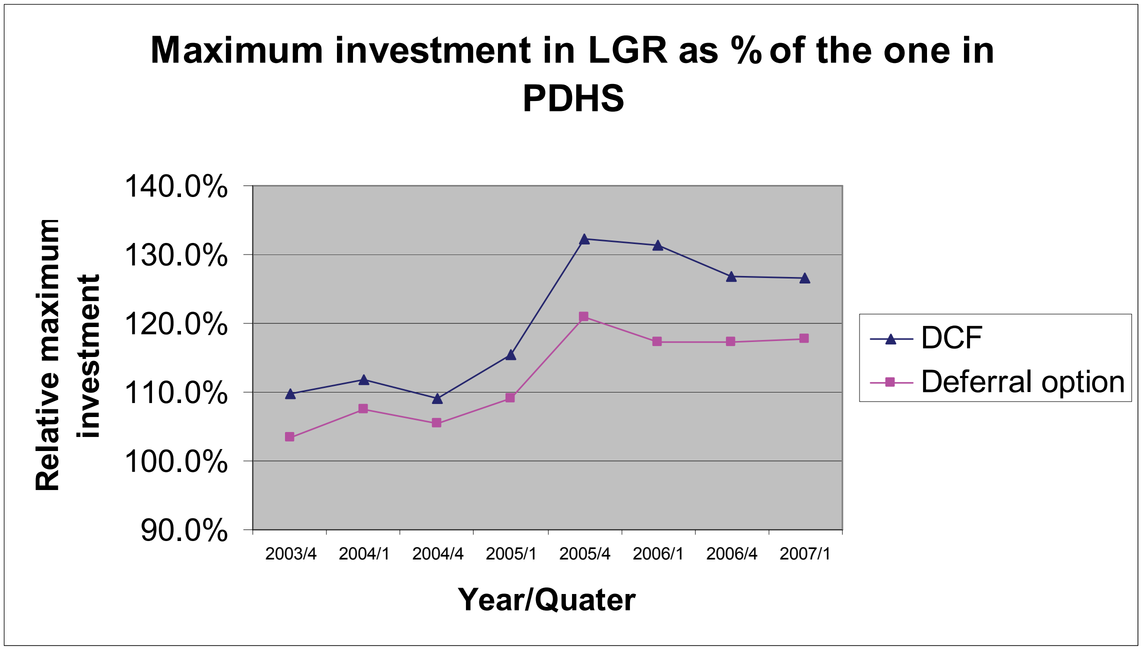
Input variables to the model were following:

Dividend factor δ	3.0 %
Nominal risk free rate r	3.0 %
Expected annual increase in investment cost	2.0 %
Expiration period of the option	4 years
Expected life time of the energy saving investment	30 years
Number of time steps per period	10

The same dividend factor was used for both areas so that the results would not be influenced by its arbitrary choice. In reality one could imagine that the discount rate in LGR could be higher in order to take into account higher risk (volatility of heat prices). On the other hand higher expected growth of heat price in this area could offset much of this increase. Overall long term inflation expectations throughout the period between 2004 and 2007 should have been stable with 10 years fixed average local currency mortgage rate fluctuating between 4.8 and 5.2 %. Expiration period of the option was arbitrarily set to 4 years in order to match the period for which volatility of the heat prices was observed. In reality the ability of flat owners to postpone investment could be longer.

Current heat price and its volatility were thus the only changing inputs into calculation. The results in terms of maximum investment in LGR depicted as per cent of maximum investment in PDHS can be found in figure 5. Results obtained with DCF method and same input parameters are plotted for comparison. Figure 5 shows that higher value of deferral option for flat owners in LGR area compared to those in PDHS eliminates only part of the difference in maximum marginal investment cost flat owners should be willing to pay. Maximum difference in maximum marginal investment cost was decreased to 21 %, most of the time it was below 18 %. The difference between the two areas in terms of observable energy savings should be further decreased by concave production function of savings. When taking into account also other factors such as accuracy level of heat savings measurement, statistical error and time delay I come to a conclusion that any difference in the marginal investment cost below 10 % would be very difficult to spot in heat savings data. Different values of deferral option can thus be regarded as capable of explaining at least part of the flat owner's behavior. The heat sales in 2008-2009 heating season will be important for further verification of this conclusion.

Figure 5



Concluding remarks

I was able to show that a value of the deferral option could have important impact on actual investment and heat savings and explain at least partly the observed behavior of the flat owners connected to district heating system in Prague. Reality of choices the flat owners face is, however, much more complicated than the simplified model introduced earlier in this article. The model tacitly assumed precommitment to a certain energy efficiency standard given by the marginal investment cost. A flat owner possessed an option to defer investment into certain thermal insulation standard but change of this standard in reaction to new information during waiting period was not taken into account.

The option to change energy efficiency standard by changing marginal investment cost should have some value because the decision is mostly irreversible. It is economically quite feasible to increase thickness of insulation from let's say 100 to 120 mm at the time when investment is conceived. However, once the 100 mm insulation has already been installed on a façade of the building, upgrade to 120 mm is totally uneconomical and there is very little chance that it could become economically viable to add those 20 mm of insulation any time soon. Similar example could be made with window replacement. Flat owner thus "locks" himself up in certain energy efficiency standard when he decides to go on and invest. In other words he is giving up an option to change energy efficiency standard in the future. Value of this option should further decrease maximum marginal investment the flat owner would be willing to make.

There was also an assumption embedded in the model that marginal investment cost increases with "inflation" regardless of price of heat. In other words zero correlation between specific price of energy efficiency measure and heat price was assumed. This assumption is hardly realistic because e.g. prices of insulation materials can be expected to be directly influenced by energy prices. Also capacity of firms active in the thermal rehabilitation of buildings in certain area is limited and higher demand provoked by higher prices of heat should result in higher price of works. This feature would not be difficult to address in the model. Unfortunately sufficient input data were not available. Assumption of correlation between investment cost (strike price of option) and value of the underlying asset would be equivalent to decreasing volatility of the underlying asset. This decrease would not be the same in the both areas in question. It would be more important in the PDHS with lower overall price volatility. Value of deferral option would thus be decreased more for flat owners in the area of PDHS than for those in LGR.

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