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Split Incentives and Energy Efficiency in Canadian Multi-Family Dwellings

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Abstract

This paper examines the energy-related behaviour of occupants and owners of multi-family dwellings in Canada, some of whom do not pay directly for electricity or heat, but instead have these costs included in their rent or condo fees. Using data from the 2003 Survey of Household Energy Use, we look at the extent to which split incentives that result from bill-paying arrangements effect a variety of activities including the setting of temperatures at various times of the day and the use of eco-friendly options in basic household tasks. Findings suggest that these split incentives do indeed impact some aspects of occupant behaviour, with households who do not pay directly for their heat opting for increased thermal comfort and being less sensitive to whether or not somebody is at home and the severity of the climate when deciding on temperature settings. Regardless of who pays for utilities, Canadian households who live in multi-family dwellings are generally unresponsive to fuel prices. Our empirical results suggest that the possibility of environmental benefits from policies aimed at improving energy-efficiency in this sector, especially if targeted at reducing the impacts of the behaviour of those who do not pay directly for energy use.

Keywords: energy efficiency; agency effects; household behaviour

1. Introduction

According to the 2006 census, approximately 43% of private dwellings in Canada were multi-family units, a category that encompasses a wide variety of configurations including semi-detached houses, row-houses and apartments. Patterns vary considerably across the country, with the lowest concentrations of multi-family units (under 25%) found in New Brunswick, Prince Edward Island and Saskatchewan and the highest concentrations (over 45%) in British Columbia, Quebec and Nunavut (Statistics Canada, 2006). In spite of their prevalence in Canada, owners and occupants of multi-family dwellings are underrepresented in terms of participation in government-sponsored energy conservation programs. For example, multi-family dwellings other than apartment buildings (which were not eligible under the program) represented only about 10% of EnerGuide for Housing (EGH) participants[i], although they constitute about 15% of the Canadian housing market.

To some extent, the energy-efficiency challenges faced by occupants of multi-family dwellings are the same as those faced by occupants of single-family detached homes. That is, energy-efficiency will be a function of the types of technologies used by the household and their intensities of use. However, barriers to energy-efficiency improvements, beyond those related to eligibility for program participation, can arise due to the fact that many occupants of multi-family units are renters, most of whom do not select the major appliances that are used by the household, and many of whom have the cost of their utilities included in their monthly rental payments. The latter situation also arises for owner-occupants when costs of utilities are included in condominium fees. The corresponding agency and asymmetric information problems involved complicate the sets of incentives faced by the owners and occupants of these dwellings.

In this paper, we investigate energy-efficiency related behaviour of residents and owners of multi-family dwellings in Canada in order to determine whether or not they should be especially targeted for increased participation in energy efficiency programs. To this end, we employ data from the 2003 Survey of Household Energy Use (SHEU 2003). This survey, conducted by Statistics Canada on behalf of Natural Resources Canada, provides data on dwelling characteristics, installed technologies and their intensity of use, energy use, and household decisions and demographics for 4551 Canadian households, 1244 of which resided in semi-detached houses, row houses or low-rise apartment buildings.[ii] Our results provide mixed evidence regarding the extent of the impact of agency issues on energy-related behaviour.   The reported intensity of total energy consumption is significantly higher for households when the heating bill is paid by a landlord; and the same holds for electricity consumption when households do not pay their own electricity bills. Much of the energy use data have been imputed by the surveyors, however, and therefore may not provide an accurate picture of actual behaviour. A clearer picture of can be obtained by examining temperature settings. When a household is not responsible for directly paying for heat, temperatures are set at a higher level during daytime hours, and households are less likely to turn down the thermostat when a dwelling is unoccupied. Surprisingly, those who pay directly for heat are not responsive to fuel prices, while those who do not pay directly sometimes increase temperatures when fuel prices are high. The influence of agency problems on various other aspects of energy-related behavior (building upgrades by owners, engaging in 'eco-friendly' practices by occupants) is less pronounced. Even when landlords pay for the electricity or heat used by tenants, dwelling renovation rates remain quite low in the rental market. Although landlords who pay for heat do plan for more energy-saving renovations in the near future than their counterparts with tenants who pay their own heating bills, the impact is not statistically significant. Eco-friendly behaviour by tenants is affected more by household income than by bill-paying arrangements.

The structure of the paper is as follows. In Section 2 we provide an overview of the major issues associated with energy use in multi-family dwellings, with an emphasis on agency and asymmetric information problems that can arise when occupants are tenants and/or do not directly pay their own utility bills. Section 3 provides a statistical overview of the energy-related characteristics and behaviours pertaining to multi-family dwellings, their owners, and their occupants from the SHEU 2003 survey. This is followed in Section 4 by a more formal econometric analysis of energy-related behaviour related to these dwellings. Section 5 concludes.

2. Energy Efficiency Challenges in Multi-Family Dwellings

As is the case for single-family dwellings, energy efficiency gains achieved by households living in multi-family dwellings will be determined to a large extent by the types of technologies that are in place and the intensity with which these technologies are used. Households with newer, more energy-efficient technologies have the capability to heat / cool their dwelling space and perform basic household tasks with less purchased energy than other households. Although lower income households may be less likely to own newer technologies, they will also be less likely to own as many pieces of energy-using equipment (computers, televisions, dishwashers, etc.). For higher income households, energy bills will constitute a relatively small portion of their budgets, and it is hypothesized that they are likely to be less concerned with energy costs than lower income households in so far as their energy consumption habits are concerned.

At any given point in time, in both single family and multi-family dwellings, many households will not be using the most efficient among currently available technologies. The stock of household appliances is only replaced gradually over time as older models exit from use and are replaced by newer ones. And when choosing a new appliance, 'first-cost' purchase price considerations, which tend to be higher for more energy-efficient models, may dominate future energy savings in the selection process. Even if a highly efficient model is selected, the lower energy costs related to the use of the appliance may lead to a standard 'rebound effect' of an increased intensity of use (Sorrell and Dimitropoulos, 2008). Furthermore, while the use of energy will in theory be affected by current and expected future prices, the extent to which prices affect behaviour may be limited given the fact that energy bills are generally received with a lag of a month or more, and these bills do not reveal which appliance(s) / household activities are contributing most towards the cost of energy consumed by the household (Brown, 2001).[iii]

The choice of technologies and their intensity of use can be complicated in multi-family dwellings by agency problems that arise when either the dwelling is rented or is owned with utilities included in monthly 'condo fees'. Counihan and Nemtzow (1981) were among the first to point out the importance of agency problems in the context of tenant-landlord relationships. They note that in situations where tenants pay their own utilities, and therefore the landlord does not benefit directly from reduced energy use, a landlord's major appliance and heating technology purchase decisions will be influenced primarily by 'first-cost' considerations. Furthermore, they note that legislation, such as that introduced in the US in the late 1970s requiring separate electricity metering in new apartment buildings, can inadvertently skew landlords away from possibly more efficient technologies such as central heating systems (which may be more likely to be properly maintained) and towards the use of, possibly less efficient, individual electric heating.

For tenants who pay their own utilities, given their relative transiency and their limited say in the choice of major appliances and heating/cooling technologies, cost-saving investments in energy efficient technologies will generally be limited to 'portable' technologies (such as electronic equipment and compact fluorescent lighting) that tenants can take with them when they move. Tenants and condominium owners who do not pay directly for their own electricity, on the other hand, are unlikely to ever see a separate energy bill and may therefore have at best a vague idea of the costs associated with their energy consumption habits, providing fewer incentives to invest in energy-efficient products or engage in eco-friendly behaviour.

The potential agency problems associated with occupants of multi-family dwellings can be summarized succinctly into four possible cases, as shown in Table 1 (based on American Council for an Energy-Efficient Economy, 2007). In Case1, with an owner-occupied unit where the occupant both chooses the stock of appliances and pays the energy bills, there are no agency problems. Case 2 involves a common landlord-tenant situation where an owner's decisions regarding the selection of appliances and heating/cooling equipment to be installed may be driven primarily by purchase price (borne by the owner/landlord) and not the operating costs (borne by the occupant/tenant). Since newer more efficient appliances usually come with a higher price tag, it would be expected that a landlord will be likely to (i) wait longer to replace older appliances; and (ii) select less efficient models when new appliances are installed. This efficiency problem may be lessened in areas where vacancy rates are high, since landlords may have an incentive to install newer energy-efficient appliances in order to improve the attractiveness of their rental properties (Meyer-Rencschhausen, 1983; Stoecklein *et al*, 2005; Volker and Johnson, 2008).

Case 3 case occurs in landlord-tenant situations where a landlord (owner) both chooses the technologies and pays the utility bills. As the landlord reaps the benefits of energy cost savings from the installation of energy-efficient equipment, there will be no 'efficiency' problem. There will be, however, a potential 'usage' problem that arises due to the fact that the marginal cost of using appliances and heating / cooling technologies is effectively zero for tenants (occupants) who decide on the intensity of use of energy-using equipment (Munley *et al*, 1990; Levinson and Nieman, 2004). It would be expected that tenants who do not pay for utilities would, *ceteris paribus*, use more of these seemingly ‘free’ energy inputs. Case 4, possibly the least common in practice, occurs in situations where the occupant chooses the technologies but does not pay directly for the energy that is used. This occurs, for example, in owned condominiums when utility costs are included in condo fees. In such a scenario, there could be both ‘efficiency’ and ‘usage’ problems as the purchaser of the technology does not pay for their use and the agent paying the utility bills does not determine the usage patterns.

Table 1: Agency problems in multi-family dwellings

	Occupant selects equipment	*Owner selects equipment*
Occupant pays the bill	**Case 1**: no principal-agent problem	**Case 2**: efficiency problem
Owner pays the bill	**Case 4**: usage and efficiency problem	**Case 3**: usage problem

Source: **American Council for an Energy-Efficient Economy (2007)**

Aside from agency problems, there can also be asymmetric information issues associated with landlord-tenant relationships. When a landlord purchases appliances, potential tenants cannot be sure of their energy efficiency characteristics (Meyer-Renschhausen, 1983; Levinson and Nieman, 2004). Although new major appliances are generally labeled with information regarding their energy-use characteristics, an unscrupulous landlord might remove or alter the labels (Murtishaw and Sathaye, 2007). Levinson and Nieman suggest that this sort of asymmetric information problem, where tenants are unsure about expected utility costs, may provide landlords with an incentive to offer to pay the utilities as a signaling device to indicate that a unit truly is energy-efficient.

These asymmetric information obstacles are in addition to the more general barriers associated with gathering sufficient information to make optimal decisions regarding the selection of energy-efficient technologies. Brown (2001) points out that energy audits can be useful in this regard. Volker and Johnson (2008) note that free energy audits provided by a Midwestern US utility company were often performed repeatedly on the same structure with the same recommendations being made each time. The dwellings where the energy-efficiency retrofits recommended in the (repeated) audits were not implemented tended to be those where the occupants had low incomes and/or were renters.

Counihan and Nemtzow (1981) and Meyer-Rencshhausen (1983) note that landlords, as investors, consider the purchase of energy-efficiency technologies as one of many possible investment strategies. Therefore, especially for corporate landlords, the returns to increasing energy-efficiency in the units that they own will be compared to returns on other types of investments. In jurisdictions with rent-controls, the returns to energy-efficiency investments will tend to be lower given that the associated costs are less likely to be recouped by the landlord. Meyer-Rencschhausen finds that landlords in Germany are more likely to make energy-efficiency investments when the rental units are located close to the landlord's residence. In fact, multi-family dwellings where the landlord occupies one of the units tend to be better equipped. Laquatra (1992) focuses on rural rental dwellings and finds that different types of landlords (*large/professional* vs. *small/family business*) face different types of barriers regarding investments in energy efficiency improvements.

As far as access to government-sponsored initiatives to increase energy efficiency is concerned, this can be more difficult for owners of multi-family dwellings, especially when policies have multiple aims (which may include, for example, providing benefits that accrue primarily to low-income households). As was mentioned above, Canada's EnerGuide for Housing program that was in effect at the time of the SHEU survey used in our analysis did not apply to apartment buildings. Another recent example can be found in the Weatherization Assistance Program for Low-Income Persons in the U.S. To be eligible to participate in this program, owners of multi-family units are required to guarantee that the benefits would accrue primarily to low-income tenants. In cases where utility costs are included in the rent this is somewhat problematic since landlords receive the pecuniary benefits related to the resulting lower energy costs (although there will be health and safety benefits that accrue to tenants). Other restrictions on landlords include guarantees that rents for low-income tenants will not increase as a result of expenditures on weatherization and a prohibition against expenditures that would lead to 'undue or excessive enhancement' of buildings that are weatherized under the program. The procedural burdens associated with applying to this particular energy-efficiency program were reduced after a ruling that deemed that certain buildings that fall under a set of assisted or public housing programs automatically meet one or more of the restrictions related to the accrual of benefits and rent restrictions on the eligibility for participation (US Department of Energy, 2010).

Previous empirical studies on energy use in multi-family provide evidence of a significant 'usage' effect in rental units with landlord-paid utilities. Levinson and Nieman (2004) find that renters in the U.S. who do not pay their own utilities tend to keep their apartments warmer while they are out than those who pay for their own heat. This effect is at least partially mitigated by the landlord's provision of more energy-efficiency technologies in these apartments. Evidence of a usage effect is also provided in Munley *et al* (1990) who, using data from the late 1970s, find that in otherwise identical blocks of centrally heated apartments (equipped with identical appliances) where one half of tenants paid their own electricity bills, those tenants who had their electricity costs included in their rent used on average a little over 30% more electricity than their counterparts. Further evidence of efficiency problems is found by Davis (2009) who, using a subset of observations from the US 2005 Residential Energy Consumption Survey that excludes dwellings with utility–included rental payments, finds that owner-occupied dwellings are more likely than rental dwellings to have at least one Energy Star product in each appliance category. Finally, a set of case studies commissioned by the International Energy Agency estimate the proportion of energy use that is subject to split-incentives or other barriers for a variety of sectors (refrigerators, water and space heaters, commercial office leasing, vending machines) for a number of OECD countries. In many cases it is found that large shares of energy use are subject to split-incentives, but the real effect of these barriers on the level of energy use is difficult to quantify (American Council for an Energy-Efficient Economy, 2007).

3. Characteristics of Multi-family Dwellings: SHEU 2003

Before proceeding to an econometric analysis of energy-related decisions in Canada's multi-family dwelling sector, we present some stylized facts from the SHEU 2003 data set. Note that buildings constructed before 1920 are excluded from the analysis and that although 28% of the households surveyed lived in multi-family dwellings, the sampling frame used for the survey did not include any high-rise (> 4 storey) apartment buildings. Once we omit observations with missing values corresponding to questions regarding the responsibility for the payment of utility bills, we are left with a set of 1057 multi-family dwellings which can be divided into two main types: 534 low-rise apartments (LRAs) and 523 duplex / double / row / terrace type (DDRT) housing units.

Who pays the bills?

Information regarding whose responsibility it is to pay utility bills is contained in Table 2. We see that there are a wide variety of arrangements in place. While it is common practice for a landlord to pay natural gas or oil bills, it is less common for a landlord to pay for electricity (which is more easily metered on an individual household basis). In approximately 95% of cases where oil or natural gas are used to provide heat in a LRA, tenants do not see the bills. These percentages are much lower in DDRT style units where heating and water systems are less likely to be common for the entire building and therefore separate billing for fuel is more easily implemented. This can also be seen in terms of the fact that heat and hot water are more likely to be included in a tenant's rent for those residing in LRAs than in DDRT style housing units. It is not surprising to see that occupants tend to be responsible for the direct payment of utility bills in owner-occupied units. Almost all owner-occupants pay for electricity directly, while owner-occupants in LRA units where natural gas is used are likely to have their natural gas costs included in condo fees. In only one instance did a survey respondent residing in an owner-occupied DDRT style unit not pay all of the associated energy bills.

Table 2: Responsibility for utility bills in multi-family dwellings* (SHEU 2003)

PANEL A: Rental units				
Utility bill	Duplex / Double /Row / Terrace (DDRT)		Low Rise Apartments (LRA)	
	Occupant pays	Landlord pays	Occupant pays	Landlord pays
Electricity	79%	21%	77%	23%
Natural gas	63%	37%	4%	96%
Oil	33%	67%	5%	95%
Purpose				
Space heating	70%	30%	58%	42%
Hot water	75%	25%	68%	32%
PANEL B: Owner-occupied units				
Utility bill	DDRT		LRA	
	Occupant pays	Included in condo fees	Occupant pays	Included in condo fees
Electricity	100%	0%	97%	3%
Natural gas	99%	1%	26%	74%
Oil	100%	0%	100%	0%
Purpose				
Space heating	100%	0%	84%	16%
Hot water	99%	1%	73%	27%

* all percentages are conditional on energy source / service being in use

Basic Characteristics of Dwellings and their Occupants

Summary statistics pertaining to basic household and dwelling characteristics for DDRTs and LRAs appear in Panels A and B of Table 3, respectively.[iv] While apartments tend to be occupied primarily by renters, DDRT-style dwellings in the sample have more owner-occupants than renters. Although not presented in Table 3, regional differences exist, with the highest rate of apartment ownership being found in B.C. and the lowest rate in the Maritimes. Larger families with more children tend to opt for DDRT units. Not surprisingly, owner-occupied dwellings have a higher proportion of occupants whose incomes are relatively high (above $ 60,000) than rental dwellings. Furthermore, dwellings where the occupant pays all of the energy bills also tend to attract higher income households compared to those where landlords pay one or more of the energy bills, as lower income households operating on a stricter budget may prefer to protected against possible adverse swings in energy costs (Levinson and Niemann, 2004).

According to Counihan and Nemtzow (1983), rented buildings tend to be older and less energy efficient. The age structure of multi-family rental housing units in SHEU generally follows a similar pattern. The majority (over 80%) of multi-family dwellings occupied by tenants were constructed between 1950 and 1990, while a large proportion (over 70%) of owner-occupied multi-family dwellings were built after 1970. In Table 3, we see that, with the exception of occupant-pay LRAs, the average year of construction is more recent for owner-occupied dwellings than for renter-occupied dwellings. These observations are likely to have repercussions for the amount of energy consumed by renters relative to owners, since newer buildings are likely to incorporate newer technologies and are expected to be more energy efficient.

Regarding the energy sources used in the dwellings, the information provided in Table 3 indicates that nearly 70% of the 534 LRA occupants use electricity for space heating, and about 20% use natural gas, with the remainder using heating oil or other sources of energy. The patterns are similar across rented and owner-occupied units, with a slightly higher rate of natural gas usage in owned units. In owner-occupied DDRT dwellings, natural gas is the primary source of heating (54% of dwellings), followed by electricity (38%). In rental DDRT dwellings however, the split is reversed (57% electricity, 38% natural gas). The choice of energy source for water and space heating is strongly correlated with the type of heating equipment installed in the building.

The equipment selected for space and water heating, along with the energy source used, often limits the billing options for the utility supplier. In situations where separate metering for each unit is not feasible, such as buildings where central natural gas or oil heating systems are used, it will generally be the landlord or condo association who pays the corresponding energy bill. Otherwise, there is an option of making the occupant directly responsible for energy costs. As expected, Table 3 shows marked differences in the patterns of fuels used according to the agent who pays the utility bills. Buildings where the occupant pays are primarily heated by means of electricity. This is especially predominant in LRAs, where electricity is used for heating in 97% of rental dwellings where the tenant pays all bills directly, but in only 43% of dwellings where the landlord pays at least one bill. In cases where the landlord pays for the heat, the fuel used is more likely to be natural gas or oil. This observation is similar for owner-occupied LRAs where natural gas is more often used to supply heat to condominiums where occupants do not pay for their energy directly compared to units where occupants do pay directly.

Table 3: Summary Statistics for Major Household and Dwelling Characteristics

PANEL A: DDRT-style units								
	Owned				Rented			
	Occupant pays utility bills*		Utilities included in condo fees **		Tenant pays utility bills*		Utilities included in rent**	
Variable	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Household characteristics								
Income is more than $60000 (in %)	0.46	0.50	1.00.	.	0.24	0.43	0.06	0.25
Household size	2.85	1.46	3.00	.	2.80	1.38	2.37	1.46
Proportion of household under 18 years of age	0.18	0.23	0.00	.	0.22	0.26	0.17	0.26
Dwelling characteristics								
Year of construction	1975	18.56	1994	.	1974	16.54	1969	12.89
Space heating uses electricity (in %)	0.38	0.49	1.00	.	0.65	0.48	0.40	0.49
Space heating uses natural gas (in %)	0.54	0.50	0.00	.	0.35	0.48	0.44	0.50
N	326		1		133		63	
PANEL B: LRA-style units								
	Owned				Rented			
	Occupant pays utility bills*		Utilities included in condo fees**		Tenant pays utility bills*		Utilities included in rent**	
Variable	Mean	Standard Deviatio n	Mean	Standard Deviatio n	Mean	Standard Deviatio n	Mean	Standard Deviatio n
Household characteristics								
Income is more than $60000 (in %)	0.36	0.48	0.21	0.42	0.16	0.37	0.09	0.29
Household size	2.16	1.08	1.68	0.91	1.99	1.06	1.57	0.91
Proportion of household under 18 years of age	0.09	0.18	0.07	0.19	0.10	0.19	0.05	0.16
Dwelling characteristics								
Year of construction	1973	20.98	1986	11.26	1973	17.41	1971	14.60
Space heating uses electricity (in %)	0.76	0.43	0.57	0.50	0.97	0.18	0.43	0.50
Space heating uses natural gas (in %)	0.13	0.34	0.46	0.51	0.01	0.12	0.37	0.48
N	63		37		204		230	

* occupant pays all utility bills; ** occupant not responsible for at least one utility bill;

Effects of split incentives

The determination of which agent is responsible for paying for utilities is expected to have an impact on energy usage and technology choices due to 'split-incentive' agency and asymmetric information problems (outlined in Section 2). Below we examine the intensity of energy usage, the prevalence of energy-efficient appliances, and a variety of energy saving steps and practices that can be undertaken by occupants and owners. Summary statistics are presented in Tables 4 and 5, where shaded cells indicate potential instances of agency-related problems.

Intensity of Energy Use

Note that actual data on energy consumption for many observations were not available due to either (i) the fact that the unit was not individually metered; or (ii) the information was not provided by the occupant or owner. In these cases, values were imputed by Statistics Canada based on observed dwelling and household characteristics.[v] Therefore, although we provide information on the intensity of energy use, these statistics should be interpreted with caution. To the extent that imputed values are accurate, there is evidence of potential instances of usage effects in the SHEU 2003 data. In LRA buildings, the data suggest that tenants whose landlords pay at least one of the energy bills have an intensity of total energy use that is more than twice that of their counterparts who pay all of their own bills. This impact is larger than for rental DDRTs where the energy intensity in landlord-pay dwellings is approximately 1.5 times that in occupant-pay dwellings. As far as owner-occupants are concerned, the inclusion of utilities in 'condo fees' in LRAs is associated with an energy intensity that is almost twice of that found for owner-occupants who pay all of their energy bills.[vi]

When the intensity of electricity use, instead of total energy, is considered, there are no cases where those who do not directly pay all of their energy bills exhibit an increased intensity of use.   If however, the samples are split based on whether electricity is paid by the occupant or is included in rent or condo fees, the expected pattern of higher electricity intensity is found for households who do not pay directly for electricity (see footnote 4).

Table 4 Summary Stats for DDRT-style Dwellings

	Owned				Rented			
	Occupant pays utility bills*		Utilities included in condo fees **		Tenant pays utility bills*		Utilities included in rent**	
Variable	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Energy use (Gigajoules per square foot)								
Energy intensity***	0.07	0.04	0.03	.	0.06	0.04	0.09	0.06
Electricity intensity***	0.03	0.03	0.01	.	0.04	0.03	0.04	0.05
Temperature Settings during Heating Season (°C)								
Daytime Temperature	19.94	2.10	21.00	.	19.55	2.27	20.67	2.14
Evening Temperature	20.54	1.84	21.00	.	20.21	2.15	20.65	2.12
Night Temperature	19.30	2.23	21.00	.	18.85	2.44	19.83	2.43
Temperature varies across time of day	0.58	0.49	0.00	.	0.56	0.50	0.40	0.49
Equipment								
Age of main refrigerator	9.38	7.23	10.00	.	8.77	6.14	8.65	5.18
Age of stove	9.91	7.51	10.00	.	10.73	6.56	11.54	7.95
Age of heating equipment	16.17	11.93	10.00	.	16.15	8.99	21.37	12.24
Age of hot water tank	8.06	6.35	.	.	9.18	6.82	9.06	9.88
Energy Star® Ratio - major appliances	0.17	0.22	0.00	.	0.11	0.17	0.06	0.14
Energy Star® Ratio - small appliances	0.17	0.27	0.00	.	0.18	0.29	0.14	0.26
Number of small appliances per adult	3.59	1.82	1.33	.	3.68	2.07	3.72	2.56
Non-environmentally friendly behavior								
Use only incandescent lights	0.15	0.35	0.00	.	0.41	0.49	0.38	0.49
Use warm or hot water for the washing machine	0.65	0.48	0.00	.	0.46	0.50	0.64	0.49
Rinse dishes before using dishwasher	0.66	0.48	0.00	.	0.51	0.51	0.57	0.53
Do not use water saving showerhead	0.40	0.49	1.00	.	0.51	0.50	0.55	0.50
Dry dishes in dishwasher with heat on	0.54	0.50	0.00	.	0.47	0.50	0.86	0.38
Renovations								
At least one improvement	0.12	0.32	0.00	.	0.11	0.31	0.08	0.27
N	326		1		133		63	

* Occupant pays all utility bills; ** occupant not responsible for at least one utility bill; *** many values imputed.
Note: shaded cells indicate instances that are consistent with agency-related efficiency or usage problems.

Table 5: Summary Stats for Low Rise Apartments (LRAs)

	Owned				Rented			
	Occupant pays utility bills*		Utilities included in condo fees **		Tenant pays utility bills*		Utilities included in rent**	
Variable	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Energy use (Gigajoules per square foot)								
Energy intensity***	0.07	0.06	0.12	0.13	0.06	0.05	0.15	0.15
Electricity intensity***	0.05	0.04	0.03	0.02	0.06	0.04	0.05	0.08
Temperature Settings during Heating Season (°C)								
Daytime Temperature	19.79	2.22	19.24	2.54	19.13	2.13	20.26	2.18
Evening Temperature	20.10	2.22	19.97	2.22	19.82	1.98	20.62	2.00
Night Temperature	18.70	2.37	18.54	2.57	18.69	2.21	19.39	2.43
Temperature varies across time of day	0.49	0.50	0.49	0.51	0.47	0.50	0.47	0.50
Equipment								
Age of main refrigerator	9.63	6.83	9.29	6.08	9.88	6.36	10.40	7.04
Age of stove	11.84	8.64	10.54	7.61	10.90	6.90	13.46	7.94
Age of heating equipment	18.88	13.51	12.94	8.42	17.53	8.96	18.46	11.57
Age of hot water tank	7.93	6.72	6.82	3.84	6.77	5.47	8.18	7.43
Energy Star® Ratio - major appliances	0.14	0.22	0.08	0.17	0.10	0.19	0.03	0.12
Energy Star® Ratio - small appliances	0.11	0.23	0.09	0.23	0.14	0.25	0.11	0.23
Number of small appliances per adult	3.06	1.51	3.81	1.89	3.37	1.77	3.26	1.75
Non-environmentally friendly behavior								
Use only incandescent lights	0.19	0.40	0.03	0.16	0.37	0.48	0.44	0.50
Use warm or hot water for the washing machine	0.51	0.50	0.69	0.47	0.34	0.48	0.59	0.50
Rinse dishes before using dishwasher	0.68	0.47	0.67	0.48	0.75	0.44	0.75	0.44
Do not use water saving showerhead	0.46	0.50	0.49	0.51	0.59	0.49	0.62	0.49
Dry dishes in dishwasher with heat on	0.59	0.50	0.52	0.51	0.50	0.50	0.44	0.50
Renovations								
At least one improvement	0.17	0.38	0.11	0.31	0.14	0.35	0.15	0.36
N	63		37		204		230	

* Occupant pays all utility bills; ** occupant not responsible for at least one utility bill; *** many values imputed.
Note: shaded cells indicate instances that are consistent with agency-related efficiency or usage problems.

Temperature Settings and Other Energy-Saving Practices

Unlike energy use data, which are not always available for individual dwelling units, information on temperature settings can be gathered regardless of who pays the utility bills[vii]. In both LRA and DDRT rental accommodations, there is a clear pattern of tenants opting for higher temperatures (increased thermal comfort) at all times of day during the heating season if they are not responsible for the direct payment of all of their utility bills. And in rental DDRT units, those who pay all of their energy bills are more likely to vary the temperature during the day. This likely reflects behaviour whereby occupants turn down the temperatures when nobody is at home and/or at night in order to save on energy use. These patterns are not observed in owner-occupied LRA dwellings.

Aside from temperature setting habits, the SHEU survey also gathered information on a variety of other aspects of 'eco-friendly' behaviour for both occupants and owners. For owners, 'eco-friendly' energy-saving steps can be made by renovating the basic building 'envelope ' or updating major technologies such as the heating, ventilation and air conditioning (HVAC) infrastructure. Given the large number of categories pertaining to renovations in the SHEU survey, detailed information on these are not reported in our tables, except to the extent that some of these will be reflected in the average ages of heating equipment and hot water tanks (discussed below). In general, when looking at the percentages of multi-family rental dwellings where various types of renovations were undertaken in 2003, no consistent patterns emerge. In many cases, the share of dwellings that have undergone renovations is higher when a tenant pays the utility bills than when the landlord pays. There are however some pronounced differences across owned and rented dwellings. The share of dwellings that have undergone renovations is much higher for owned dwellings than for those in the rental market. These results suggest that the determinants of home improvements may be complex. Barriers such as difficulties in renovating when tenants are occupying the dwelling, access to investment loans for small landlords, and access to government incentive programs may play roles in the relatively low rate of renovations in rental dwellings.

The extent of ‘eco-friendly’ behaviour on the part of occupants is captured through a series of questions related to lighting and showerhead choices and washing machine and dishwasher settings. From Tables 4 and 5 we see that for each of the categories reported, there is a higher instance of occupants undertaking the less energy-efficient option when they do not directly pay all of their utility bills in at least one of the dwelling types. And for the use of warm/hot water for the washing machine and the use of a water saving showerhead, a consistent pattern is seen for both owner-occupants and tenants in all dwelling types: those who do not pay their own utility bills are less likely to choose the more environmentally friendly option.

Choice of equipment

In rental dwellings, bulky ‘major equipment’ such as HVAC systems, water heaters, and major household appliances are generally chosen by the landlord and will remain attached to the dwelling as tenants move in and out. Smaller items such as entertainment appliances (TVs, DVD players, VCRs, satellite dishes and stereo systems) are purchased by the tenant, who will keep them when moving from one dwelling to another.[viii] In owned dwellings, occupants are more likely to be the ones making the decisions regarding most items, with the exception of centrally provided heating and hot water systems. The SHEU survey data regarding the choice of equipment, including appliances and HVAC systems, reveal some instances that are consistent with what is expected in the presence of agency issues.

Purchasers of major equipment are expected to select more efficient (newer and/or Energy Star®) models if they are also the agent responsible for the payment of the associated energy bills. Under the assumption that heating and hot water technologies are not purchased by the occupants in LRAs, results for these technologies that are consistent with these expectations are only seen in buildings with owner-occupants. When utilities are covered in 'condo fees' heating equipment is on average almost 6 years newer, and hot water tanks a year newer. In rental units, however, the results are the opposite (although the difference in average ages is quite small for heating systems).

As with heating and hot water equipment, results pertaining to the presence of Energy Star® major appliances are consistent with expectations only in owner-occupied LRAs. Under the assumption that owner-occupants can select their own appliances, we would expect to (and do) see a higher proportion of Energy Star ® appliances when these owners also pay their own utilities. In LRA and DDRT rental units, where it is likely that the landlord has purchased the major appliances, there is on average a lower percentage of Energy Star® appliances when utilities are included in the rent. As far as the ages of refrigerators and stoves are concerned, results are also generally opposite to what would be expected in the presence of agency problems. Refrigerators and stoves are almost always older on average when selected by the agent who pays the bills (that is, owner-occupants who pay their own utilities and landlords who include utilities in the rent). One exception is the case of refrigerators in rented DDRTS, but the difference in ages is very small. Another possible exception occurs for stoves in owned buildings, if it is the case that these are supplied along with the unit at the time of purchase.

Finally, we consider small household appliances, which are assumed to be purchased by the occupant regardless of whether the household is an owner or tenant. In all cases we see that the ratio of the number of Energy Star® products to the total is higher when the occupant pays the utility bills. That is, occupants have a greater tendency to purchase energy-efficient models when they are responsible for the energy costs associated with their operation. Further evidence of potential instances of usage problems can be seen by that fact that in rented DDRTs, there is on average a slightly larger number of small appliances per adult in the household when the occupant is not responsible for all utility bills. This same pattern occurs in owner-occupied LRAs, but in these units the bills paid by the condo association are more likely to be natural gas than electricity, so it may not be reasonable to attribute this behaviour to agency problems.

In summary, there is mixed evidence regarding whether or not agency effects are important in the energy-use and technology decisions made by occupants and owners of multi-family dwellings in Canada. To investigate the issue further we next consider a set of formal econometric models.

4. Econometric Models

In this section we present our results from a series of econometric models that examine the determinants of temperature settings and 'eco-friendly' behaviour in Canadian multi-family dwellings. Temperature settings for the day, evening and night-time hours are modeled in two ways. First, we use a standard regression model that includes dummy variables for whether or not the occupant pays all of the utility bills and for whether or not the dwelling is occupied by an owner or a tenant while controlling for other factors. Second, we consider a model where the determinants of temperature setting are allowed to vary across groups, while taking into account sample selectivity issues. Aspects of 'eco-friendly' behaviour are modeled using a series of Probit regressions.

Temperature Setting

Since a substantial number of the energy use observations are imputed, as in Levinson and Nieman (2004), we instead focus on the temperature setting habits of households. Separate regressions are considered for daytime, evening and night-time settings. For each time of day, two approaches are considered. In the first, we consider a least squares regression on the pooled data for all households living in multi-family dwellings, using a specification that allows temperature settings to vary as a function of whether or not the household pays directly for its heat. Except for price effects, which are allowed to vary depending on whether or not the household pays directly for a specific fuel, all slopes are constrained to be constant across both groups. In the second approach we split the sample based on whether or not the occupant pays directly for heat. For these regressions, Heckman's two-step selectivity estimation approach is used (Heckman, 1976).

In both approaches, a wide set of control variables are used. These include a variety of building / dwelling unit, household, and location characteristics. The full set of controls can be seen in Table 6. The building / dwelling unit characteristics include building age, dwelling type (LRA or DDRT), dwelling size, and information pertaining to major appliances and the type of fuel used for the heating system. It is expected that older buildings will in general be less well insulated, and may therefore be more difficult to heat, resulting in higher thermostat settings. The type of building will have an impact on the number of outside walls and the presence of heated common areas. The choice of heating technology may affect ambient comfort and/or humidity levels in a home. The types of major appliances installed will have an impact on the amount of waste heat provided. The Energy Star ® ratio for major appliances, in addition to capturing differences in waste heat may also act as a proxy for the overall energy efficiency attitudes of the purchasing agent. Household characteristics include family size, family composition, income, and information on small portable appliances. The family size and composition variables are likely to affect the demand for heat at various times of the day. For example, a family with young children may wish to ensure that the younger members are warm at night. Income levels may influence how often there is somebody at home at various times of the day as well as the level of thermal comfort that a household can afford. The appliance and programmable thermostat variables may proxy for the general energy 'attitudes' of the household. In addition, the location variables capture the severity of weather during the heating season through the heating degree days variable and whether or not the family lives in an urban area. Finally, we control for average local electricity, natural gas and heating oil prices. [ix]

Table 6: Temperature Setting Regressions - Pooled and Selection Models (standard errors in parentheses)

	Day			Evening			Night		
	Pooled	Occupant Pays	Other Pays	Pooled	Occupant Pays	Other Pays	Pooled	Occupant Pays	Other Pays
Responsibility for Utility Bills									
Heat not paid by occupant	0.814*	n.a.	n.a.	0.621	n.a.	n.a.	0.438	n.a.	n.a.
	(0.416)			(0.411)			(0.480)		
Electricity not paid by occupant	0.989	-8.267	4.426	2.750	-15.242	6.841*	-3.959	-14.049	0.128
	(2.834)	(28.809)	(3.740)	(2.888)	(27.347)	(3.444)	(3.162)	(29.855)	(4.069)
Building Characteristics									
Decade of construction (omitted category: 1920 to 1929)									
2000 or later	-1.196*	-1.003	-1.212	-0.655	-0.482	-0.667	-0.168	-0.362	4.358
	(0.679)	(0.690)	(2.619)	(0.737)	(0.652)	(2.469)	(0.820)	(0.717)	(2.882)
1990 to 1999	-1.177**	-0.804	-3.877**	-0.905	-0.581	-3.153**	-0.720	-0.663	0.022
	(0.549)	(0.583)	(1.674)	(0.581)	(0.551)	(1.557)	(0.672)	(0.606)	(1.832)
1980 to 1989	-0.964*	-0.646	-3.562**	-0.758	-0.488	-3.097**	-0.522	-0.487	-0.042
	(0.545)	(0.573)	(1.591)	(0.576)	(0.542)	(1.488)	(0.664)	(0.596)	(1.748)
1970 to 1979	-0.914*	-0.684	-3.310**	-0.572	-0.234	-3.221**	-0.306	-0.382	0.348
	(0.545)	(0.576)	(1.577)	(0.576)	(0.544)	(1.476)	(0.668)	(0.598)	(1.734)
1960 to 1969	-0.647	-0.241	-3.652**	-0.300	-0.023	-2.753*	-0.159	-0.190	0.438
	(0.547)	(0.589)	(1.598)	(0.581)	(0.557)	(1.497)	(0.674)	(0.612)	(1.757)
1950 to 1959	-0.804	-0.524	-3.526**	-0.570	-0.192	-3.349**	0.040	0.158	0.156
	(0.559)	(0.592)	(1.630)	(0.584)	(0.560)	(1.528)	(0.677)	(0.615)	(1.793)
1940 to 1949	-1.363**	-0.957	-4.530**	-0.834	-0.518	-3.423**	-0.649	-0.437	-1.051
	(0.597)	(0.655)	(1.759)	(0.627)	(0.617)	(1.651)	(0.733)	(0.678)	(1.938)
1930 to 1939	-0.707	-0.145	-4.307**	0.077	0.662	-3.281*	0.250	0.810	-1.085
	(0.724)	(0.777)	(1.801)	(0.699)	(0.734)	(1.690)	(0.820)	(0.807)	(1.986)
Main heating fuel (omitted group: other)									
Electricity	-0.524*	-0.605**	3.105**	-0.219	-0.215	2.101*	-0.166	-0.134	2.231
	(0.268)	(0.299)	(1.306)	(0.267)	(0.283)	(1.228)	(0.293)	(0.311)	(1.435)
Natural Gas	-0.468	-0.449	2.489	0.021	0.190	1.823	0.270	0.139	2.899*
	(0.453)	(0.450)	(1.535)	(0.450)	(0.426)	(1.438)	(0.513)	(0.468)	(1.683)
Oil	-10.955	-31.017	21.483	-18.709	-33.209	18.154	-11.836	-3.782	-12.454
	(20.733)	(28.480)	(26.291)	(17.048)	(26.746)	(24.054)	(22.568)	(29.756)	(28.847)
Other									
Low Rise Apartment	-0.169	-0.084	0.050	-0.191	-0.268	0.143	-0.230	-0.178	-0.125
	(0.199)	(0.216)	(0.451)	(0.193)	(0.204)	(0.423)	(0.215)	(0.224)	(0.496)
ln(Heated Area)	0.088	0.074	-0.076	0.047	0.008	-0.004	-0.145	-0.161	-0.503
	(0.154)	(0.193)	(0.302)	(0.148)	(0.182)	(0.284)	(0.164)	(0.200)	(0.333)
Energy Star ®Ratio – Major Appliances	-0.869**	-0.743*	-1.674	-0.289	-0.132	-1.030	-0.546	-0.093	-3.163**
	(0.359)	(0.408)	(1.141)	(0.361)	(0.386)	(1.074)	(0.406)	(0.424)	(1.258)
Dishwasher	0.232	0.314*	0.275	0.313**	0.392**	0.0988	0.107	0.200	-0.021
	(0.166)	(0.179)	(0.469)	(0.159)	(0.169)	(0.441)	(0.179)	(0.186)	(0.517)
Air Conditioning	0.238	0.175	1.365	0.392**	0.359	1.393*	0.866***	0.754***	2.181**
	(0.230)	(0.260)	(0.867)	(0.198)	(0.246)	(0.811)	(0.246)	(0.270)	(0.950)
Freezer	0.010	0.119	-0.691**	-0.048	0.039	-0.524	-0.209	-0.059	-1.137***
	(0.144)	(0.164)	(0.344)	(0.134)	(0.155)	(0.321)	(0.154)	(0.171)	(0.376)
Large Refrigerator	0.103	0.075	0.183	0.050	0.122	-0.326	0.029	0.078	-0.109
	(0.149)	(0.163)	(0.351)	(0.141)	(0.154)	(0.330)	(0.157)	(0.170)	(0.387)
Location Characteristics									
ln(Heating Degree Days)	1.016***	1.036**	0.267	0.067	0.021	-0.215	1.470***	1.676***	-0.077
	(0.347)	(0.402)	(0.731)	(0.318)	(0.380)	(0.668)	(0.369)	(0.418)	(0.814)
Urban	0.235	0.136	0.391	0.153	0.101	0.466	0.735*	0.692	1.277
	(0.383)	(0.440)	(0.824)	(0.329)	(0.415)	(0.775)	(0.420)	(0.456)	(0.909)

Energy Prices									
ln(electricity price)	0.170 (0.456)	0.351 (0.546)	-1.134 (1.079)	-0.382 (0.417)	-0.137 (0.516)	-1.986** (0.993)	0.248 (0.490)	0.554 (0.567)	-0.852 (1.181)
Other pay*ln(electricity price)	0.473 (1.088)	-3.344 (10.745)	1.734 (1.457)	1.129 (1.100)	-6.141 (10.200)	2.733** (1.346)	-1.474 (1.220)	-6.285 (11.135)	0.128 (1.591)
ln(natural gas price)	0.091 (0.163)	0.063 (0.137)	0.619** (0.292)	0.079 (0.156)	-0.017 (0.130)	0.296 (0.274)	-0.110 (0.181)	-0.018 (0.142)	-0.135 (0.323)
Other pay*ln(natural gas price)	0.106 (0.157)	n.a.	n.a.	-0.039 (0.153)	n.a.	n.a.	0.130 (0.175)	n.a.	n.a.
ln(oil price)	4.109 (7.644)	11.463 (10.448)	-6.598 (9.700)	7.032 (6.296)	12.316 (9.812)	-5.722 (8.864)	4.431 (8.302)	1.475 (10.916)	5.345 (10.633)
Other pay*ln(oil price)	-0.047 (0.230)	n.a.	n.a.	-0.009 (0.218)	n.a.	n.a.	0.071 (0.264)	n.a.	n.a.
Household Characteristics									
Owner-occupant	0.307 (0.195)	0.366* (0.200)	-1.932*** (0.767)	-0.016 (0.188)	-0.049 (0.189)	-1.090 (0.720)	0.336* (0.202)	0.362* (0.208)	-1.911** (0.843)
Household Size	0.102 (0.085)	0.101 (0.096)	0.032 (0.231)	0.082 (0.080)	0.063 (0.090)	0.180 (0.216)	0.192** (0.092)	0.142 (0.099)	0.425* (0.254)
Somebody at home during the day	0.736*** (0.156)	0.776*** (0.167)	0.499 (0.331)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Proportion of Household under 18 yrs of age	0.269 (0.491)	0.264 (0.557)	0.764 (1.364)	0.385 (0.446)	0.507 (0.525)	-0.290 (1.282)	0.792 (0.528)	0.979* (0.577)	-0.286 (1.504)
Uses programmable thermostat	-0.534** (0.228)	-0.481** (0.239)	-1.357* (0.726)	0.271 (0.210)	0.334 (0.226)	-0.551 (0.683)	-0.898*** (0.224)	-0.947*** (0.249)	-0.825 (0.801)
Energy Star Ratio ® - Small Appliances	0.020 (0.268)	0.006 (0.305)	0.250 (0.716)	-0.314 (0.267)	-0.236 (0.289)	-0.485 (0.674)	0.003 (0.292)	0.058 (0.317)	-0.095 (0.789)
Number of Small Appliances per adult	-0.072* (0.042)	-0.075 (0.050)	-0.063 (0.101)	-0.020 (0.041)	-0.045 (0.046)	0.067 (0.093)	-0.092** (0.046)	-0.128** (0.051)	0.078 (0.109)
Annual Income Range (omitted category: <$20,000)									
$20,000 to $40,000	-0.368* (0.214)	-0.349 (0.246)	-0.386 (0.360)	-0.182 (0.205)	0.049 (0.232)	-0.726** (0.331)	-0.064 (0.227)	0.004 (0.255)	-0.298 (0.389)
$40,000 to $60,000	-0.329 (0.247)	-0.361 (0.278)	-0.145 (0.520)	-0.193 (0.229)	-0.084 (0.256)	-0.384 (0.487)	-0.272 (0.248)	-0.383 (0.281)	0.221 (0.572)
$60,000 to $80,000	-0.208 (0.286)	-0.172 (0.314)	-1.323** (0.701)	-0.109 (0.269)	0.073 (0.290)	-0.884 (0.653)	0.182 (0.280)	0.116 (0.319)	0.447 (0.766)
$80,000 to $100,000	-0.084 (0.339)	-0.128 (0.373)	0.064 (1.006)	-0.156 (0.287)	-0.023 (0.348)	-0.343 (0.928)	-0.214 (0.354)	-0.291 (0.383)	0.069 (1.085)
> $100,000	-0.605 (0.376)	-0.741* (0.388)	2.107 (1.554)	-0.341 (0.345)	-0.261 (0.360)	1.771 (1.448)	-0.716* (0.380)	-0.849** (0.396)	1.801 (1.697)
Other									
Selection Parameter	n.a.	0.406 (0.478)	0.984 (0.621)	n.a.	-0.019 (0.455)	0.676 (0.584)	n.a.	0.561 (0.494)	1.183* (0.672)
Constant	11.698*** (3.709)	11.839*** (4.482)	15.258* (8.199)	18.701*** (3.452)	19.658*** (4.236)	17.612** (7.465)	7.950** (4.006)	7.158 (4.655)	17.095* (9.101)
R-square	0.14	0.14	0.23	0.07	0.08	0.17	0.14	0.16	0.22
Test for overall significance (p-value)†	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Number of observations	931	722	209	931	772	209	931	722	209
Mean of dependent variable	19.73	19.57	20.28	20.28	20.20	20.58	19.05	18.94	19.41

Notes: heteroskedasticity consistent standard errors used throughout; ***, **, *: significant at 1%, 5%, 10%; n.a. = not applicable; †F test for pooled sample, LR test for selection model.

The variables of major interest for the purposes of this study are those related to which agent pays for utilities and energy prices. In the pooled model, we therefore include a pair of dummy variables regarding whether or not the occupant pays for heat and whether or not the occupant pays for electricity (which is generally needed to distribute heat regardless of which fuel is used to generate the heat). Standard economic theory predicts that temperature settings will fall as the cost of heating increases, so long as those costs are borne by the agent who is making decisions regarding thermal comfort. The electricity dummy variable is interacted with the electricity price variable. Similarly, the natural gas and oil prices were interacted with dummy variables for whether the occupant pays directly for these fuels or they are covered in rent or condo fees. This allows price effects to vary across the group of occupants who bear a positive marginal cost of using a particular energy source and the group of occupants who do not.

When the sample is split according to whether or not the occupant pays directly for heat, there is no need to include dummy variable and interaction terms pertaining to who pays the heat, as separate coefficients are estimated for each group. There is however a possible selectivity issue, as building owners and occupants may 'self-select' into particular arrangements regarding responsibilities for the payment of utility bills. In order to deal with this issue, the regressions for the split sample adjust for sample selectivity through the inclusion of an Inverse Mills Ratio (IMR) term from a reduced form Probit regression for whether or not the occupant pays for heat.[x] As in Levinson and Niemann (2004), a set of provincial dummies to allow for regional differences in the general practices regarding lease arrangements is used in the Probit equation to allow for identification in the temperature setting regressions.[xi]

The results from both approaches are presented in Table 6. Many of the results are consistent with general expectations. For example, from the pooled daytime temperature setting regression, we find that settings tend to be higher in colder regions (more heating degree days) and in households where there is somebody home during the day.[xii] Furthermore, in terms of the main focus of our study, we find that those who do not pay directly for heat tend to keep their dwellings almost 1^{o} celsius warmer during daytime hours. The magnitude of this effect is basically the same as that associated with somebody being home during the day. None of the price variables (including interaction terms), though, are significant. Temperatures are set at lower levels in newer dwellings, possibly due to better insulation or other improved energy efficiency features included in more recently constructed buildings. Settings are also lower in dwellings with a higher percentage of major appliances with an Energy Star® designation. Since a higher percentage of energy efficiency equipment in a dwelling should lead to less waste heat, the results could be due to this variable acting as a proxy for the state of the dwelling in general, including the quality of its thermal envelope. Temperatures are set lower when the dwelling is heated by electricity, possibly due to the resulting differences in indoor humidity. There is very little evidence of income effects on temperature settings. Those in the second lowest income bracket seem to select the lowest temperature settings. Households with more small appliances also select lower temperatures. Finally, those who use a programmable thermostat tend to set lower temperatures during the day compared to those who make adjustments manually.

Continuing with the pooled model, factors affecting evening and night-time temperatures differ from those that influence daytime settings. Evening temperatures are the most difficult to explain in terms of available information. The only individually significant variables are the dishwasher and air-conditioning variables. In both cases, the impacts are positive. Given that dishwashers produce waste heat and would therefore tend to decrease the need for a higher temperature setting, a positive coefficient suggests that this variable is capturing some sort of attitudinal characteristic. Perhaps those with dishwashers have preferences geared towards comfort. Similarly, the positive coefficient on the air-conditioning dummy may reflect preferences that favour indoor thermal comfort throughout the year. Overnight temperatures are influenced primarily by household and location characteristics. Those in colder areas and in urban locations choose higher temperature settings, as do larger families. As with daytime settings, those who use programmable thermostats and those with more small appliances set lower temperatures. And, as is the case for evening temperatures, those with air-conditioning prefer to have higher night-time temperatures. Note that in the pooled specifications, it is only for the daytime temperature settings that there is evidence of an agency effect. Furthermore, fuel prices are not found to have an impact on temperature settings, even for those who pay directly for heat, at any time of day.

When the sample is split according to who is responsible for paying for heat with group-specific slopes for all variables allowing for more flexibility in terms of differences in behaviour, we gain additional insight. For the nighttime regressions with the split samples, the IMR variable is significant for the subset of households who do not directly pay for their heat, providing evidence of sample selectivity.[xiii] For all times of day, the sets of significant factors vary across the two groups. Some of these observed differences are consistent with general expectations, while others are not.

During the day, whether or not somebody is at home during the day only matters for those who pay for their own heat. A plausible interpretation is that those who don't pay for their own heat do not bother to turn down the thermostat if the dwelling is left vacant during the day. For both daytime and nighttime hours, those who pay for their heat directly choose higher temperatures in colder areas while those who do not pay do not. That is, those who do not pay for heat are less sensitive to outdoor temperatures when deciding on an indoor temperature setting. Households who do not pay directly for heat are also the ones who tend to set the temperature as much as 4° higher in buildings that are older than those in our control group (of buildings constructed before 1930) during both daytime and evening hours, likely to overcome poor insulation, whereas households that pay for their energy do not adopt such a habit, possibly because they are less willing or able to afford the added comfort or because insulation has already been improved. The patterns of the coefficients across included age groups, however, are not completely consistent with expectations given that there is no significant effect associated with the newest buildings in the sample for those who do not pay directly for heat.

To the extent that the presence of air-conditioning reflects an increased preference for thermal comfort, the finding that it leads to an approximately 1° increase in nighttime settings for those who pay for their own heat, but a 2° increase for those who do not pay directly further supports the presence of agency effects. Similarly, to the extent that the Energy Star® ratio for major appliances captures the general energy efficiency and thermal envelope qualities of a dwelling, the fact that only those who pay for heat react to this in terms of daytime temperature settings may reflect an increased sensitivity of these agents to factors that can save on heating bills. The opposite pattern, however, is found for nighttime temperatures, with those who do not pay directly for heat setting lower temperatures in dwellings with a larger Energy Star® ratio.

There are two significant price effects in the split sample temperature regressions. During the day, natural gas prices have a positive impact on temperature settings for the group who do not pay for heat directly. Perhaps there is a psychological impact where these occupants take advantage of this seemingly 'free' gas that would be more difficult to afford if they had to pay for it directly.[xiv] During the evening hours, those who do not pay for electricity (in addition to not paying for heat), select higher temperatures, even more so if their heat is fueled by electricity. It is only for this group of occupants that electricity prices matter and have effects that are consistent with expectations. If a household does not pay for heat but does pay for the electricity required to distribute heat throughout the dwelling area, temperatures are lower. If, however, the household does not pay for electricity, this does not occur. In fact, similar to the natural gas price effect for daytime temperatures, there is a positive price impact (from the sum of the two electricity price coefficients) whereby agents take 'advantage' of a 'free' good that they might otherwise not be able to afford.

Overall, many of the results are consistent with the expectations. The first approach, using the pooled sample, suggests that not paying for heat affects daytime temperature settings. A variety of other household and dwelling characteristics also influence daytime and nighttime temperature settings, while evening temperatures prove difficult to model. This suggests that the thermal adjustments that households make occur mostly during the day and the night. The analysis of the split samples, the second approach, leads to similar general conclusions, as the variables that affect temperature settings vary across the two groups in ways that are consistent with the predictions related to agency effects. Furthermore, evening temperatures can be better explained when this approach is used, at least for the group that does not pay directly for heat. Regarding price sensitivity, only those households who do not pay for their heat are influenced by fuel costs. Somewhat surprisingly, those who do pay for energy, and hence bear a positive marginal cost, do not appear to respond directly to energy prices.

Environmentally (Un)friendly Behaviour of Occupants and Owners

A variety of aspects of behaviour related to energy and the environment can, in theory, be affected by which agent is responsible for paying utility bills in multi-family dwellings. In this section we examine some of these through the use of a series of Probit regressions. Five of these relate to the behaviour of dwelling occupants, and two with the behaviour of owners. In terms of occupant behaviour, the SHEU 2003 data include information on whether or not occupants:

(i) do not use a water-saving showerhead;

(ii) do not use cold water for laundry;

(iii) use only incandescent light bulbs;

(iv) rinse dishes before using dishwasher (for subset of dwellings with a dishwasher);

(v) dry dishes using 'heat' as compared to drying dishes by leaving the door open and the heat off (for subset of dwellings with a dishwasher).

The SHEU survey also includes a series questions regarding a wide variety of building upgrades that either were undertaken during the survey period or were planned for the following year. Given the large number of categories for possible renovations or retrofits, it is not feasible to report on all possible configurations. Here, we restrict our attention to the most general case of whether or not any upgrades were undertaken or planned.

All Probit models were run using the full sample with the inclusion of dummy variables to account for bill paying responsibilities. While it is reasonable to assume that occupants and owners self-select into bill-paying arrangements due to strong preferences related to thermal comfort and its affordability, it is less obvious that households would self-select into bill-paying arrangements in order to engage in the types of behaviour studied in this section. Two versions of each Probit model were run. The first included separate dummies for whether another agent (landlord or condo association) paid for electricity and heat. The second used a single dummy for whether or not another agent paid for any of the utilities.

The explanatory variables used in the Probit regressions are the same as those used in the temperature regressions (including the dummy variable for whether or not somebody is at home during the day and excluding the dishwasher variable for the two dishwasher-related regressions) with the addition of a set of provincial dummies. The results are summarized in Table 7 where we report which variables were significant in each regression and the direction of the impact. Note that while the regressions regarding owner behaviour have a few individually significant variables, and according to an LR test for overall significance are able to explain some of the variation in upgrade behaviour, the Probit model barely outperforms a naïve mode for the 2003 upgrades and is outperformed by a naïve model for the 2004 upgrade regression.[xv] Therefore, it can be concluded that little if anything can be learned from these regressions. Therefore, we focus on the regressions related to occupant behaviour which all outperform the corresponding naïve models.

Table 7: Probit Regressions for Occupant and Owner Behaviour

	Occupant Behaviour					Owner Behaviour	
	Do not use water-saving showerhead	*Do not use cold water for laundry*	*Use only incandescent bulbs*	*Rinse dishes before using dishwasher*	*Use heat to dry dishes in dishwasher*	*Upgrades undertaken in 2003*	*Planned upgrades for 2004*
positive impacts	[Urban*]; Low Rise Apartment*; [Heating fuel is natural gas*];	Owner-occupant***;	[Another agent pays heating bill*]	Proportion of household under 18**;	Urban*; Household size**	LRA**, PT used***, income*	income**, esr_ldl**, PT used***
negative impacts	Household size*; [Electricity price x other pays dummy*]; Energy Star® Ratio – Major Appliances*; Number of small appliances*; Dishwasher*; Uses programmable thermostat**	Income***; Number of small appliances*; Uses programmable thermostat**	Owner-occupant***; Income(*)[**]; [Heating fuel is natural gas*]; Dishwasher***	Income**; Number of small appliances**;	Energy Star® Ratio – Small Appliances*; Freezer**		large fridge**; (oil price*)
Regional effects (relative to BC)	Yes	No	Yes	Yes	No	No	No
Agency effects	[Yes]	No	[Yes]	No	No	No	No
N	954	728	971	390	387	971	971
% of 1's	51.3	54.7	29.8	65.9	53.2	13.0	12.2
Overall significance test: p-value	0.00	0.00	0.00	[0.02] (0.01)	[0.22](0.16)	0.03	0.02
McFadden Pseudo-R^2	[0.08] (0.07)	0.13	0.17	0.14	0.10	0.09	0.10
% of correct predictions	[61.9] (61.6)	[67.6] (67.9)	[74.2] (73.3)	[71.0] (72.1)	[62.2] (65.1)	87.1	[87.5] (87.7)

*significant at 10%; **significant at 5%; ***significant at 1%; []applies only to model with separate 'other pays for heat and electricity' dummies;
() applies only to model with single 'other pays for any utility' dummy

In the ‘occupant behaviour’ models, many results are robust to whether separate heat and electricity bill dummy variables are used or a single dummy variable for whether or not any bills are paid by another agent is used.[xvi] Note that in all cases, a positive (negative) impact indicates that the household is more likely to engage in the less (more) environmentally friendly option. Higher incomes, for example, whenever significant, lead to a higher probability of undertaking the more eco-friendly option. This income effect applies to the choice of water temperature when doing laundry, rinsing dishes before using the dishwasher, and lighting choices. The latter may reflect ‘first cost considerations’, as compact fluorescent bulbs are considerably more expensive. Larger households are more likely to choose a water-saving showerhead, but are also more likely to use a dishwasher’s heat option when drying dishes. Both of these make intuitive sense as larger households will use shower water more intensively (and are more likely to realize noticeable savings related to hot water conservation) and they are more likely to need a quick turnaround in terms of the re-use of dishes. Families with children are more likely to rinse dishes before using the dishwasher, possibly due to the types of food consumed and/or the state of cleanliness of dishes used by children.

There is also evidence that those who use more energy-efficient appliances or a programmable thermostat opt for additional eco-friendly behaviours, as they are more likely to use cold water for laundry and use water-saving showerheads, while they are less likely to use heat to dry dishes.[xvii] On the other hand, households with more small appliances or extra appliances such as dishwashers and freezers, who would presumably use more electricity, also tend to opt for the more environmentally friendly option in terms of the behaviours considered.

In terms of the main focus of this study, we find limited evidence of eco-friendly behaviour being directly influenced by agency factors. The only two instances relate to the use of a water-saving showerhead and the use of energy-efficient lighting. If another agent pays for heating, occupants are more likely to opt for less energy-efficient lighting. This could perhaps be due to a sort of rebound effect whereby money saved on heat is used towards the extra electricity costs associated with incandescent lighting. For water-saving showerheads, the results are counter-intuitive with only those who do not pay for electricity opting for the more energy-efficient option as electricity prices rise.

5. Conclusion

Based on recent household-level Canadian data, we examine problems of asymmetric information and agency issues in terms of their effects on energy-related decisions of residents and owners of multifamily dwellings. Such situations occur when, through the inclusion of utilities in rental payments or condominium fees, the occupant of a dwelling is not responsible for direct payment of some or all of the energy bills associated with the dwelling unit and/or does not choose the major appliances to be used in the dwelling. Descriptive statistics suggest that although there are many instances in which the differences across the sub-samples of those who do and do not pay directly for utilities are consistent with agency or asymmetric information effects, behaviour is not always in line with what might be expected from economic theory.

An econometric analysis of (i) temperature settings, and (ii) a variety of 'eco-friendly' behaviours allows us to further investigate the ways in which agency effects or split incentives manifest themselves in the multi-family dwelling sector. The strongest evidence of agency effects appears in the temperature setting behaviour of households who do not pay directly for heat. These households tend to select higher temperature settings, by about 1° Celsius, during the day. They are also less likely to turn down their thermostats if the dwelling is unoccupied during the day or when cold weather is less severe. Furthermore, unlike their counterparts who pay for their own heat, those in the oldest buildings set higher temperatures during day and evening hours by as much as 3° to 4°, possibly to overcome worse insulation. At night, among those with the strongest preferences for year-round thermal comfort, as evidenced by the presence of air-conditioning, occupants who do not pay directly for their heat increase their temperature settings by about 1° more than those who do pay directly. There is no evidence of detrimental agency effects in terms of the behaviour of dwelling owners, but this is likely at least partially due to data limitations, including a lack of information regarding the characteristics of building owners.

Possibly because heat is considered as a necessity by Canadian households, there is little in terms of price or income effects found in the temperature setting regressions. In the rare instances where prices were significant, occurring only for the subsample of those who do not pay for heat directly, higher prices were associated with higher temperature settings. This is perhaps due to an attitude whereby occupants take advantage of what seems to be an unusually good ‘bargain’ in terms of not paying for the use of an expensive energy source. Income, while not mattering for temperature setting, does matter for other types of household behaviour, with higher income households being more likely to engage in environmentally friendly actions.

From a policy perspective, the results point towards possible benefits from improving the energy-efficiency of multi-family dwellings. Dwellings where occupants do not pay directly for heat might be especially targeted for improvements related to the energy-efficiency of heating technologies and the building’s thermal envelope in order to counter-act the temperature-setting behaviour of households in these units. Given that the majority of these households live in rental accommodations, expansion of existing programs or the institution of new programs that explicitly target owners of rental buildings should be considered. Another approach could be to promote arrangements whereby all occupants pay directly for energy use. However, efforts to provide separate billing for energy costs across tenants of utility-included multifamily dwellings may be limited by the technologies in place in existing buildings and could result in constraints on fuel choice and overall energy efficiency in new buildings as not all technologies readily allow for individual metering. An additional tack might include educational efforts aimed at occupants, indicating perhaps the impact of higher temperature settings and other energy-related behaviour on energy use and the environment.

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Footnotes

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[i] **Source**: Office of the Energy Efficiency, Natural Resources Canada, EnerGuide for Houses database.

[ii] Apartment buildings with more than four floors were excluded from the survey.

[iii] Some utility companies, such as Georgia Power in the U.S., offer home energy use calculators, based on local climate conditions, that households can use to roughly determine how much various appliances and technologies affect their energy use. See http://c01.apogee.net/calcs/appcalc/?utilityid=gapower (last accessed November 30, 2010)

[iv] Given the diversity in the sample regarding specific utilities that are included in rents or condo fees, the sample can be split in many ways. Summary statistics calculated according to other possible splits are available from the authors upon request.

[v] 29% of electricity values, 54% of natural gas values, and 62% of oil values for the 1057 observations used in Tables 4 and 5 were imputed.

[vi] Given that only 1 of 327 owned DDRT units corresponds to a case where the occupant does not pay all utility bills, we do not make any comparisons for this particular subset of the data.

[vii] For dwellings in which the occupant does not have control over heat settings (approximately 4% of the multi-family dwelling subsample), temperature settings are not recorded in SHEU.

[viii] While a tenant would not be likely to take an incandescent light bulb when moving, a tenant might consider moving more expensive CFL bulbs to a new residence.

[ix] Average electricity, natural gas, and heating oil prices by city of residence were provided to the authors by the Canadian Building Energy End-use Data and Analysis Centre (CBEEDAC) (www.cbeedac.com) .

[x] An alternative model where the selection term was based on whether or not the occupant pays for all of the utilities was also considered. Also, more complicated double selection models were considered, but the bivariate Probit required for the first stage did not converge.

[xixi] To conserve space, the full Probit results are not reported. The provincial dummy variables used for identification indicate significant differences across regions. Other factors that are significant at the 5% level are ownership, the unit being in an LRA, building age, household size, the fuel used for heating,

local electricity and oil prices, the types of major appliances in the dwelling, and the use of a programmable thermostat.

[xii] The dummy variable for whether or not somebody is at home during the day is excluded from the reported evening and night temperature setting regressions, as it would not be expected to influence behaviour at other times of day. If included, the term is always statistically insignificant at other times of the day.

[xiii] For regressions using the 'occupant pays' subsample, the IMR is calculated as $-\phi(a_i)/\Phi(a_i)$ and for regressions involving the 'occupant does not pay' subsample, the IMR is calculated as $\phi(a_i)/[1-\Phi(a_i)]$ where ϕ is the normal pdf, Φ is the normal cdf, and a_i is the value of the estimated Probit index for the corresponding observation.

[xiv] While a long-term occupant may expect rents or condo fees to rise in response to a more intensive use of heating when prices or high, short-term tenants would be less likely to take future rent / fees into consideration.

[xv] A naïve model predicts that 0s (1s) for all observations if the majority of actual values in the sample are 0 (1). Therefore, for the 2003 upgrade regression a naïve model would predict 0s correctly for 87% of the sample and for the 2004 upgrade regression a naïve model would predict 0s correctly for 87.8 of the observations. These results are likely affected by the lack of information on owner characteristics for rental properties in the data set.

[xvi] Results that only apply to the former are enclosed in square brackets, while results that only apply to the latter are enclosed in round brackets.

[xvii] To the extent that the full set of environmentally friendly behaviours are jointly determined, endogeneity problems may exist in the Probit and temperature regressions. Unfortunately, the data set does not offer much in terms of possible instruments to test for or address these problems.

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